MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2025, 21(9), em2693
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/16771

Principals as STEM leaders: Insights from Qatar's government schools using Q methodology research

Mohammed Emad Osman Omer [1,2*], Youmen Chaaban [1]

[1] Qatar University, Doha, QATAR
[2] Ministry of Education and Higher Education, Doha, QATAR

Received 07 April 2025 ▪ Accepted 28 July 2025

Abstract
This study aimed to explore the key dimensions of school principals' science, technology, engineering, and mathematics (STEM) leadership capabilities in Qatari government schools. The study employed Q methodology research guided by a theoretical framework that identifies five critical dimensions of STEM leadership, namely STEM knowledge and practices, contexts, dispositions, tools and critical orientation. A purposive sampling technique was used to select 26 principals. Data collection was conducted between November 2024 and February 2025 from principals in government schools across Qatar. Ensuring diversity in terms of school level, experience, gender and geographic location. Data was collected through Q sorting activities, where participants rank-ordered a set of 40 statements representing STEM leadership capabilities, followed by post-sorting interviews to gather qualitative insights. Q factor analysis identified 3 viewpoints among participants, namely assessment innovation through collaborative learning, contextually grounded student-centered leadership, and resource-enabled STEM implementation. This study is limited to government schools in Qatar and reflects principals' self-reported perspectives at one point in time. The study contributes to existing knowledge on effective STEM education leadership and provides valuable insights, with implications for future research, policy development and leadership preparation programs.

Keywords: STEM education, principals' capabilities, Q methodology, Qatar

INTRODUCTION

Science, technology, engineering, and mathematics (STEM) education has garnered considerable global interest in recent years (Bryan & Guzey, 2020; Freeman et al., 2019). Due to the swift progress of technology and the growing need for proficient manpower in STEM disciplines, it is imperative for nations to provide resources and give priority to STEM education (Marginson, 2013). Qatar, like many other nations, has recognized the need to develop a strong STEM workforce to support its transition towards a knowledge-based economy (Qatar National Vision 2030, 2008). Strong leadership in STEM education, especially at the school level, is important to accomplish this objective. Principals have a significant role in shaping the learning environment and fostering student achievement (Geiger et al., 2023).

To move away from a resource-based economy and toward a knowledge-driven one, Qatar has set out on a bold path, as outlined in Qatar National Vision 2030 (2008). To achieve this goal, the country has invested heavily in education, with a particular focus on STEM fields. Qatar National Vision 2030 (2008) emphasizes the importance of developing a skilled and innovative workforce that can contribute to the country's economic diversification and sustainable development. Aligned with this aim, the Qatari government has launched various initiatives to promote STEM education, such as the establishment of specialized STEM-based schools, the integration of STEM programs in conventional schools and the provision of professional development opportunities for teachers (Said, 2016).

Notwithstanding these attempts, education in STEM fields in Qatar still faces obstacles that need to be addressed. These include the need for more qualified

✉ mo2303812@qu.edu.qa **(*Correspondence)** ✉ ychaaban@qu.edu.qa

Contribution to the literature

- This study identifies three distinct STEM leadership approaches among Qatari principals, revealing how assessment innovation, cultural relevance, and resource provision represent different pathways to effective STEM implementation.
- It demonstrates that principals' equity orientations vary significantly across leadership approaches, with implications for ensuring inclusive STEM education in Middle Eastern contexts.
- It provides practical insights for designing professional development programs that address diverse leadership strengths.

STEM teachers, the limited integration of STEM subjects in the curriculum and the lack of student interest and engagement in STEM learning (Said, 2016). To overcome these challenges, effective leadership at the school level is essential. Principals who possess strong STEM leadership capabilities can help to create a supportive learning environment, motivate teachers and students and ensure the successful implementation of STEM education initiatives (Geiger et al., 2023).

Despite the importance of STEM education and the role of school leadership in its implementation, there is little research that examines STEM leadership capabilities in extant literature (Geiger et al., 2023; Talib et al., 2025), and no previous research in this area in the specific context of Qatar. By addressing these research gaps, educators, policymakers and researchers can work together to develop contextually relevant strategies for supporting principals in their efforts to lead successful STEM initiatives in schools. Accordingly, the current study aims to explore school principals' STEM leadership capabilities in Qatari government schools. By focusing on this component of school leadership, the study intends to enhance existing understandings on effective STEM education implementation and influence policy and practice in educational systems.

Using the model proposed by Geiger et al. (2023), which identifies five critical competencies for STEM leadership, this study seeks to establish a nuanced illustration for developing and enhancing principals' STEM leadership capabilities in educational settings. The study is guided by the following research question: What are the most important key dimensions of STEM leadership skills as perceived by school principals in Qatari government schools? By addressing this question, the study aims to provide a comprehensive understanding of what principals need to successfully lead STEM initiatives in their schools, thus contributing to the broader discourse on STEM leadership and facilitating meaningful comparisons with other research in this domain.

STEM Education

There is an expanding body of research that attempts to define and characterize the STEM field as a result of the rising emphasis on STEM education. Many people use the term "STEM education" yet there is little consensus on its definitions and scope (Breiner et al., 2012). This ambiguity has led to diverse interpretations and approaches to STEM education, spanning from combining STEM fields to tackling real-world problems using STEM-related knowledge and abilities (Bybee, 2010).

Vasquez et al. (2013) propose a continuum of STEM education, which spans from disciplinary to transdisciplinary approaches. Disciplinary approaches focus on teaching STEM subjects separately, while transdisciplinary approaches integrate multiple STEM disciplines to address authentic, real-world problems. Between these extremes lie multidisciplinary and interdisciplinary approaches, which involve varying degrees of integration and connection between STEM subjects. Furthermore, Kelley and Knowles (2016) offer a comprehensive conceptual framework grounded in situated cognition theory, which emphasizes the importance of contextualized, authentic learning experiences. Engineering design challenges, a motivating context, scientific inquiry, mathematical thinking and technological literacy are the four essential elements identified by their framework for inclusive STEM learning. By situating learning within real-world problems and engaging students in iterative design processes, this framework aims to develop students' ability to apply STEM concepts and practices in meaningful ways. The authors argue that the integration of these elements into learning creates experiences that deepen students' understanding of STEM disciplines and promotes their critical thinking, creativity and problem-solving skills.

While these frameworks are helpful in guiding the effective implementation and study of integrated STEM education, nonetheless, the lack of a clear, universally accepted definition of STEM education has implications for both research and practice. It can hinder the development of a coherent body of knowledge, as well as the planning and execution of effective STEM learning initiatives (English, 2016). Consequently, there is a need for ongoing dialogue and research to refine and clarify the conceptualization of STEM education, while also acknowledging the value of diverse approaches tailored to specific educational contexts and goals.

Leadership in STEM education

There are several different ways that leadership has been conceptualized and defined. In their description of leadership, Hallinger and Kovačević (2021) highlight the importance of leaders in inspiring and directing others to work together towards a common objective. Similarly, leadership is defined by (Gumus et al., 2018) as an influence process grounded in professional and personal values that provide an organization's stakeholders with a shared vision for the future and motivate them to work together to make that vision a reality. In recent years, collaboration and decentralization have replaced more conventional, hierarchical forms of leadership (Spillane et al., 2001). Leadership can be shared amongst members of an organization, not just those in formal positions of power, according to conceptualizations of distributed leadership (Gronn, 2002). As Natarajan et al. (2021) argue, STEM learning is most successful when it is a group effort involving many people; educators, students, parents and community members. The role of principals is important in building a shared vision and identity around STEM learning, as well as enabling teachers to assume positions of leadership while participating in collaborative inquiry and coming up with new ideas.

Next to teaching, leadership plays a role in ensuring that students have access to high-quality instruction in STEM fields. Several empirical studies reveal that STEM leadership is complex and multidimensional, requiring principals to possess various knowledge, abilities and attitudes that foster an innovative and supportive learning environment for STEM learners (Likourezos et al., 2020; Talib et al., 2025) For instance, STEM leadership integrates comprehensive knowledge and capabilities enhancing learning environments. Natarajan et al. (2021) outline three such components, including teacher agency, professional identity and community engagement. This framework promotes teacher empowerment and collaborative networks supporting STEM implementation. Without teachers, STEM education cannot materialize, yet school principals are considered the drivers of innovation through establishing shared vision, enabling teacher leadership through inquiry-based practices (Park et al., 2024). This facilitates adaptive curriculum development addressing the various educational needs of students (Kennedy & Odell, 2014).

To support principals in developing these critical leadership capabilities, Thibaut et al. (2018) emphasize the importance of targeted professional learning opportunities that are grounded in research and context-sensitive practices. This includes not only building content knowledge and pedagogical skills but also cultivating the dispositions and mindsets necessary for effective STEM leadership, such as a willingness to take risks and learn from failure, and a commitment to equity and inclusion. Because modifying established practices often encounters resistance, principals need to be better prepared in change management and establishing collaborative communities, while ensuring equitable access to quality STEM education (Kelley & Knowles, 2016). In sum, STEM education's increasing importance necessitates systematic leadership development through structured professional learning (Falloon et al., 2024).

THEORETICAL FRAMEWORK

The theoretical framework that guided this study is the model for principals' STEM leadership capability, which was developed by Geiger et al. (2023). This comprehensive model encompasses five critical dimensions: STEM discipline-specific and integrated knowledge and practices, contexts, dispositions, tools and critical orientation. By grounding the current research in this framework, we aimed to contribute to a deeper understanding of how principals' knowledge, skills and dispositions interact with contextual factors to shape their effectiveness in promoting STEM teaching and learning.

The first dimension, STEM discipline-specific and integrated knowledge and practices, highlights the need for principals to possess a strong foundational understanding of key concepts, skills and practices within each STEM discipline, as well as the ability to identify and foster connections between these disciplines (Geiger et al., 2023). Principals who possess this knowledge and understanding are better equipped to support teachers in developing and implementing integrated STEM curricula that are rigorous, coherent and relevant to students' lives and future careers (Kelley & Knowles, 2016). Moreover, principals' awareness of diverse STEM careers and their role in promoting economic growth and individual well-being enables them to create a school culture that values and encourages STEM education as a means of preparing students for success in the 21st century (Natarajan et al., 2021). By actively leading initiatives to support STEM teaching and learning, principals can foster a school environment that promotes innovation, creativity and excellence in STEM education (Geiger et al., 2023).

The second dimension emphasizes the importance of context in shaping effective STEM leadership practices. This dimension recognizes that principals must be attuned to the unique needs, opportunities and constraints of their school settings and adapt their leadership strategies accordingly. Effective STEM leaders develop a contextually relevant vision for STEM education, align resources and structures to support that vision and navigate the complex social and political dynamics of their school communities (Natarajan et al., 2021). This requires a deep understanding of factors such as student demographics, teacher expertise, community partnerships and policy environments (Geiger et al., 2023). By attending to context, principals can create the conditions necessary for meaningful and sustainable STEM integration, such as fostering a supportive school culture, providing targeted professional development and establishing collaborative structures for teacher leadership (Thibaut et al., 2018). Ultimately, a context-sensitive approach to STEM leadership enables principals to tailor their efforts to the specific needs and goals of their schools, thereby increasing the likelihood of successful STEM implementation (Holmlund et al., 2018).

In relation to the third dimension, dispositions, effective STEM leadership heavily relies on the positive dispositions of principals, as they significantly impact problem-solving, innovation and change promotion within schools (Geiger et al., 2023; Natarajan et al., 2021). To successfully implement STEM programs and support student learning outcomes, leaders must nurture a disposition that encourages intellectual risk-taking, creativity and critical thinking (Han, 2017). Moreover, aligning the beliefs of teachers and leaders with the principles of STEM education is crucial for achieving desired outcomes, highlighting the importance of embracing innovation and change (Marginson, 2013). Effective STEM leaders also demonstrate an understanding of the emotional aspects of stakeholders and actively promote readiness for STEM initiatives within their school communities (López et al., 2022). Ultimately, fostering positive dispositions towards STEM education and cultivating a culture of continuous learning and adaptation is essential for principals to effectively lead STEM education efforts in their schools (Geiger et al., 2023).

The fourth dimension, tools, focuses on the role of resources in supporting effective STEM education. This dimension recognizes that principals must have a strong understanding of the various physical, representational and digital tools that are essential for STEM teaching and learning. Physical tools such as scientific equipment, representational tools like graphs and diagrams, and digital tools including computers and software are all critical components of STEM education (Thibaut et al., 2018). Effective STEM leaders must be knowledgeable about these tools and their potential to enhance student learning, as well as be able to provide the necessary resources and support for their integration into the curriculum (Geiger et al., 2023). Moreover, principals must ensure that teachers have access to professional development opportunities that enable them to effectively use these tools in their instruction (Natarajan et al., 2021). By prioritizing the strategic use of STEM-specific tools and technologies, principals can create a learning environment that supports student engagement, inquiry and problem-solving, ultimately leading to improved outcomes in STEM education (Geiger et al., 2023)

The final dimension emphasizes the importance of a critical orientation in effective STEM leadership. This orientation involves the ability to use evidence and data to make informed decisions and judgments related to STEM teaching, learning program and educational change (Geiger et al., 2023; Nasir & Vakil, 2017). Principals with a critical orientation possess the capacity to analyze data, challenge arguments and make evidence-based decisions that support the growth and success of STEM initiatives in their schools (Geiger et al., 2023). Moreover, fostering a critical orientation among students is crucial in mathematics education, as it empowers them to engage with the world, recognize the persuasive power of mathematics and make informed decisions based on mathematical reasoning (York-Barr & Duke, 2004). In today's data-driven world, developing quantitative literacy is essential for individuals to confidently confront authority and understand societal issues. By adopting and promoting a critical orientation, principals can create a school culture that values evidence-based decision-making, encourages students to challenge existing perspectives and prepares them to navigate complex educational and real-world contexts (Geiger et al., 2023).

By aligning this study with the constructs and language of the Geiger et al. (2023) model and other relevant literature, we seek to situate our findings within the broader discourse on STEM leadership and facilitate meaningful comparisons with other research in this domain. This framework guided our exploration of how principals in Qatari government schools navigate the complexities of STEM leadership, providing a structured approach to understanding the multifaceted nature of their roles in promoting effective STEM education.

This study contributes uniquely to STEM leadership literature by examining how principals in a specific Middle Eastern context operationalize Geiger et al.'s (2023) five dimensions. Unlike previous studies that propose theoretical frameworks or examine single aspects of STEM leadership, this research reveals how multiple leadership approaches coexist within one educational system, each emphasizing different dimensions while facing distinct challenges in balancing innovation, cultural relevance and equity.

METHODOLOGY

Overview

This study takes place in Qatar, where pedagogical advancement towards STEM education has been highlighted as an important part of the country's overall strategy. The study focuses on principals from Qatari government schools across different educational levels (primary, preparatory, and secondary). Q methodology was employed for data collection and analysis (Brown, 1993; Watts & Stenner, 2012) to explore school principals' perspectives on their STEM leadership capabilities. Q methodology allows researchers to uncover the subjective and collective perspectives of participants in a systematic and structured way. A distinguishing technique of Q is its clustering of participants based on the similarities and differences of their perspectives (Watts & Stenner, 2012). Rather than quantifying predefined variables, Q supports the exploration of complex, nuanced perceptions that emerge from participants' experiences and intrapersonal characteristics (McKeown & Thomas, 2013). This approach is suitable for understanding school principals' subjectivities toward STEM leadership capabilities, including their experiences with STEM, actions and behaviors in leading STEM initiatives in their schools, and perceptions of their leadership roles.

In his address to nature in 1935 (cited in Stenner et al., 2008), Stephenson proposed a reversed method to Spearman's conventional factor analysis. In contrast to a by-variable factor analysis commonly employed in R methodology, Q factor analysis follows a by-person approach that considers participants as variables (Watts & Stenner, 2012). The research design followed four steps, as recommended in previous educational research using Q methodology (Watts & Stenner, 2012).

Step 1. Q sample development

The first step in Q entails generating a comprehensive list of statements, commonly called a concourse. For this study, a concourse was developed through an intensive examination of previous studies and initial interviews with participating principals. These two sources of concourse development; that is the informational and conversational sources, ensured that the list of statements represented all conceivable and interrelated statements about the problem under investigation. The theoretical framework proposed by Geiger et al. (2023) constituted a starting point for generating statements. As the number of statements generated for the concourse was too large, we engaged in a process of reduction by eliminating repetitions and grouping the statements into categories and subcategories, corroborating with the theoretical framework adopted in this study. To ensure clarity, the statements were piloted before use. Three experts familiar with STEM education and school leadership in Qatar reviewed the Q sample and provided comments on the relevance and wording of the statements. This was followed by two rounds of piloting for feedback to assess statement formulation and translation. The final Q sample consisted of 40 statements presented in both Arabic and English to participants.

Step 2. P set selection

A total of 26 principals from Qatari government schools were selected to participate in this research using a stratified purposive sampling technique. This sample size is considered sufficient to capture a range of perspectives while remaining manageable for data collection and analysis (Watts & Stenner, 2012). To ensure a diverse sample, we considered school level, experience, gender and geographic location when selecting participants. After obtaining ethical approval from Qatar University's IRB committee, the first author contacted potential participants through a mailing list obtained from the Ministry of Education and Higher Education (MOEHE) in Qatar. Participants received an approval letter from the MOEHE, consent form and instructions on responding to the email. A total of 26 principals from government schools across Qatar responded to the invitation and participated in this study between November 2024 and February 2025. Demographic data included 19 males and 7 females. The age range of all participants was 40-60, and their years of experience as school principals was 2-35 years. The type of school included 9 primary, 8 preparatory and 19 secondary government schools.

Step 3. Q sorting activities

For Q-sorting activity, an online resource (Lutfallah & Buchanan, 2019) (https://app.qmethodsoftware.com) was used to collect participants' ranking activities. On the front page, participants read instructions for the data collection procedure. These included sorting the statements into three categories, depending on whether they strongly agreed, strongly disagreed or were neutral about the condition of instruction. Next, participants rank ordered the statements on a quasi-normal and symmetrical grid, which they could see on the screen. Once completed, a single and holistic configuration called a Q sort was obtained from each participant. Following this sorting activity, participants were instructed to elaborate on the statements they had sorted at the extreme ends of the grid. These elaborations were useful for the interpretation of results and offering participants' reasoning in their own words.

Step 4. Q factor analysis and interpretation

Data analysis was conducted using Q method software (see https://app.qmethodsoftware.com). Centroid factor extraction was employed instead of principal component analysis, allowing for exploratory and theoretically-informed factor rotation rather than a mathematically determined single solution. This approach preserves researchers' ability to explore data patterns through abductive analysis while maintaining methodological rigor (Watts & Stenner, 2012). Following extraction, Varimax rotation was performed to optimize factor structure. This orthogonal rotation method maintains a 90-degree relationship between factor axes and ensures statistical independence and zero-correlation between factors. The rotation procedure positions factors to maximize explained study variance while achieving a simple structure by ensuring Q sorts primarily load on single factors. Factor arrays were generated using normalized factor scores (z-scores) calculated as follows: z score = (item total - mean of all item totals) / standard deviation of all item totals.

These standardized scores enabled systematic cross-factor comparisons and the creation of factor arrays representing idealized Q sorts for each factor. The process employed weighted averaging where higher loading exemplars received greater weight in determining factor scores, as they better exemplify factor viewpoints. Factor retention decisions followed multiple criteria, including

(1) Kaiser-Guttman criterion (eigenvalues > 1.00),

(2) minimum two significantly loading Q sorts per factor,

(3) Humphrey's rule where cross-product of two highest loadings exceeds twice the standard error,

(4) clear factor distinction post-rotation, and

(5) satisfactory explained study variance.

The final solution prioritized both statistical criteria and theoretical considerations to ensure interpretable factors representing distinct viewpoints emerging from the data. The results of these analytical procedures are presented in **Table 1**.

Table 1. Quantitative summary of emerging factors

Emerging factor	F 1	F 2	F 3	N
Number of defining variables	8	6	9	3
Average relative coefficient	0.8	0.8	0.8	
Composite reliability	0.97	0.96	0.973	
Standard error of factor z-scores	0.173	0.2	0.164	
Eigenvalues	4.2354	1.9150	1.2638	
Explained variance	8	6	9	

Note. F: Factor & N: Null

Validity and Reliability

The validity of the Q-sample was ensured through expert review by three specialists in STEM education and school leadership in Qatar, followed by two rounds of piloting to verify statement clarity and translation accuracy. The high composite reliability scores for all three factors (0.97, 0.96, and 0.973) demonstrate strong internal consistency of the identified viewpoints.

F-1. Assessment innovation through collaborative learning

Eight participants loaded significantly on F-1, accounting for 8% of the opinion variance (see **Figure 1**). The viewpoint expressed through F-1 demonstrated a

Figure 1. F-1 idealized Q sort (Source: Authors' own elaboration, using Q-sort data)

leadership approach that prioritized assessment innovation and collaborative learning environments. F-1 participants' leadership approach centered on allowing teachers to experiment with new and innovative assessment methods suitable for STEM education (33; +5) and ensuring that students' work in STEM projects is collaborative for exchanging ideas and problem-solving (3; +5). These two equally emphasized perspectives revealed their commitment to both teacher-led assessment innovation and student-centered collaborative learning.

A main distinction with F-1 participants' viewpoint was their focus on facilitating innovation through recognition and strategic planning. They strongly encouraged students to present innovative ideas for STEM projects (28; +4), directly building upon their commitment to collaborative learning environments (3; +5). This student-focused approach was balanced with appreciating teachers' efforts in implementing STEM projects and providing rewards (36; +4), thus creating a recognition system that reinforced their highest-ranked priority of assessment innovation (33; +5). Regarding strategic planning, they ensured the school's vision encompasses STEM education (19; +4) and developed plans that integrated national standards with STEM objectives (20; +3). Most significantly, they acknowledged the tension between innovative practices and systemic requirements, recognizing that Ministry assessments conflict with STEM project assessment methods (34; +3). Nonetheless, they encouraged teachers to experiment with new and innovative assessment methods that are suitable for STEM education (33; +5). They showed moderate interest in conducting periodic assessments of STEM programs to ensure their alignment with national curricula (21; -1), thus suggesting that they valued innovation over strict curriculum alignment.

Another distinctive characteristic was their targeted capacity building approach that enabled innovation. These leaders organized workshops for teachers (15; +2) that directly supported teacher experimentation with assessment methods (33; +5), while consistently encouraging innovative teaching methods (32; +2). Unlike F-2 participants, they showed slight acceptance of participating in specialized training courses to increase knowledge of STEM disciplines and their integration (6; 0). Similarly, while they had a negative view of participating in conferences and seminars related to STEM disciplines (5; -2), this was still less negative than F-2's strong rejection (5; -4). This pattern suggests a more receptive, though still limited, approach to formal professional development. Interestingly, despite their innovation focus, they admitted having some limitations in their expertise, specifically in developing curricula that integrate STEM disciplines (11; +1). This honest self-assessment contrasts sharply with F-3 participants who strongly rejected this statement. Their commitment to collaborative student work (3; +5) was philosophically grounded in their belief that STEM education effectively develops critical thinking and problem-solving skills (29; +3). This pedagogical commitment was reinforced through their explicit rejection of direct instruction methods that limit student initiatives (35; -4), creating a coherent instructional approach centered on collaboration.

A further distinctive feature was the equity and engagement tensions within their implementation approach. Despite their strong emphasis on collaborative learning (3; +5), they expressed only moderate belief that all students can succeed in STEM regardless of their background (27; +1). This four-point ranking difference reveals a significant equity tension within their approach, suggesting their collaborative learning environments might not be designed with universal student success in mind. Similarly, they showed only moderate support for ensuring all students participate in STEM programs regardless of their backgrounds and abilities (26; +1), further highlighting this equity gap. A similar disconnect appeared between their strong encouragement of student innovative ideas (28; +4) and limited emphasis on organizing exhibitions for student projects (17; -2), indicating they valued the innovation process more than showcasing outcomes to broader audiences. Their implementation approach was characterized by limited external engagement, consistently rejecting both corporate partnerships (25; -4) and school exchange programs (13; -3), with the latter showing a significant difference from F-2 participants who were neutral about exchange programs (13; 0). They also showed little interest in working with curriculum experts and educational consultants to ensure STEM programs align with sustainable development goals (22; -3), further emphasizing their internally focused approach. Unlike F-2 participants who valued organizing meeting schedules for teachers to discuss ideas and plan STEM projects, F-1 participants showed little interest in this collaborative planning time (9; -1), suggesting they prioritized individual teacher experimentation over structured collaborative planning.

The pattern revealed participants as confident innovators who created protected spaces for assessment experimentation and collaborative learning while maintaining limited external connections. Their approach demonstrated a notable consistency between their two highest priorities: innovative assessment and collaborative learning and their strategic, capacity-building and resource management approaches. However, tensions emerged in the equity dimension, where their strong emphasis on collaborative learning was not matched by equally strong belief in universal student success. Similarly, their focus on idea generation without corresponding emphasis on showcasing students' work suggested an internally focused innovation approach that might limit broader impact.

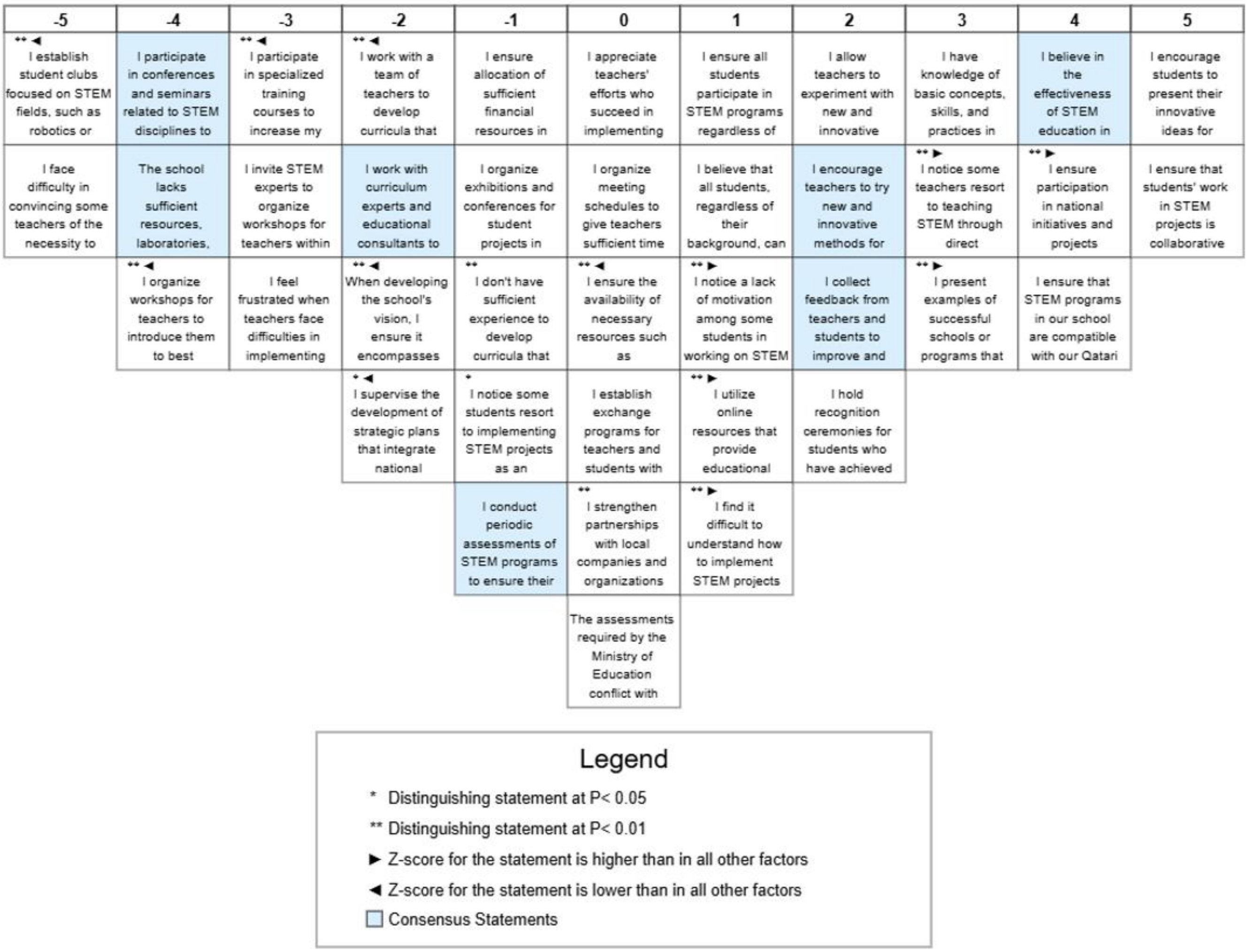

Figure 2. F-2 idealized Q sort (Source: Authors' own elaboration, using Q-sort data)

These specific tensions raise important questions about whether their innovative assessment practices were designed to benefit all students equally, and whether their limited external engagement might constrain the sustainability and system-wide influence of their otherwise innovative approach to STEM leadership.

F-2. Contextually grounded, student-centered STEM leadership

Six participants loaded significantly on F-2, accounting for 9% of the opinion variance (see **Figure 2**). The viewpoint expressed through F-2 demonstrated a leadership approach that prioritized student agency within culturally relevant STEM education. F-2 participants emphasized encouraging students to present their innovative ideas for participating in STEM projects, no matter how simple (28; +5) and ensuring students' work in STEM projects is collaborative for exchanging ideas and problem-solving (3; +5).

A main distinction with F-2 participants' viewpoint was their emphasis on contextual relevance in STEM implementation. This was manifested through their commitment to ensuring STEM programs are compatible with Qatari culture and relevant to students' backgrounds (23; +4) while also participating in national initiatives related to STEM (24; +4). This contextual approach aligned with their belief in STEM's effectiveness for developing critical thinking, problem-solving, and decision-making skills (29; +4), suggesting they valued STEM for its educational benefits within their specific cultural context. Unlike F-1 participants, they placed much less emphasis on ensuring that the school's vision encompasses STEM education (19; -2) and supervising strategic plans that integrate national curriculum standards with STEM objectives (20; -2), indicating a preference for contextual relevance over formal strategic processes. They showed a slight negative stance toward conducting periodic assessments of STEM programs to ensure their alignment with national curricula (21; -1), similar to F-1 participants.

Another distinctive characteristic was their approach to teacher support. F-2 participants demonstrated knowledge of basic concepts, skills, and practices in STEM disciplines (1; +3) while encouraging teachers to try innovative methods for teaching (32; +2) and assessment (33; +2). They supported improvement through collecting feedback from teachers and students

(40; +2) and recognizing student achievements (18; +2). Notably, they rejected facing difficulty in convincing teachers to implement changes in STEM projects (10; -5), suggesting an approach that avoided confrontation. Unlike F-1 participants, F-2 participants valued organizing meeting schedules to give teachers sufficient time to discuss ideas, exchange experiences, and plan STEM projects (9; 0) (diff = -0.755), indicating a more collaborative approach to planning despite their rejection of formal structures. They also utilized online resources that provide educational materials and training courses in STEM fields (4; +1), a statement that distinguished them from F-1 participants who rated this statement negatively. This resourcefulness in finding accessible materials aligned with their preference for practical solutions over formal structures.

A further distinctive feature was their stance toward implementation challenges and professional learning. F-2 participants acknowledged teachers' use of direct instruction methods (35; +3) and responded by presenting examples of successful STEM integration (14; +3). The latter statement showed a significant distinction from F-1 participants who rated this statement negatively, highlighting their preference for learning through examples rather than formal structures. This pragmatic recognition of classroom realities, rather than simply rejecting traditional methods, revealed a nuanced understanding of implementation challenges. They also acknowledged noticing a lack of motivation among some students in working on STEM projects (30; +1), a perspective that strongly contrasted with both F-1 and F-3 participants who rejected this observation. Despite acknowledging difficulties in understanding integrated STEM implementation (2; +1), they rejected specialized training courses (6; -3), conferences and seminars (5; -4), and organizing teacher workshops (15; -4). This pattern suggests a preference for approaches other than formal professional development. They also strongly rejected establishing student clubs focused on STEM fields (16; -5), further emphasizing their preference for integrated rather than specialized approaches to STEM education.

F-2 participants showed a distinctive approach to external engagement. While F-1 participants strongly rejected establishing exchange programs for teachers and students with other schools, F-2 participants were neutral about this practice (13; 0), suggesting greater openness to external connections. Similarly, they were neutral about strengthening partnerships with local companies and organizations (25; 0), a position that contrasted significantly with both F-1 participants who rejected partnerships and F-3 participants who strongly embraced them. This balanced stance on external engagement reflected their contextually grounded approach, selectively engaging with external entities that aligned with their cultural and educational priorities.

The pattern revealed F-2 participants as leaders who prioritized student agency within culturally relevant STEM implementation, while rejecting formal professional development and directive approaches to teacher change. Their leadership philosophy is centered on creating authentic, culturally relevant learning experiences where students can innovate and collaborate, supported by teachers who are encouraged to experiment rather than follow prescribed methods. Their pragmatic acknowledgment of implementation challenges, combined with their rejection of formal structures, suggested a leadership approach grounded in practical wisdom and contextual understanding rather than standardized processes or strategic planning.

F-3. Resource-enabled STEM implementation

Nine participants loaded significantly on F-3, accounting for 11% of the opinion variance (see **Figure 3**). The viewpoint expressed through F-3 demonstrated a leadership approach centered on ensuring the availability of necessary resources such as laboratories, technological tools, and educational materials to support practical implementation of STEM curricula (37; +5) and believing in the effectiveness of STEM education in developing students' critical thinking, problem-solving, and decision-making skills (29; +5). These two perspectives showed their commitment to well-resourced, outcome-focused implementation.

A main distinction with F-3 participants' viewpoint was their strong emphasis on resource provision and external partnerships. This was manifested through their prioritization of strengthening partnerships with local companies and organizations to provide opportunities for practical and realistic application of STEM curricula (25; +4). The emphasis on partnerships showed a remarkable contrast with F-2 and even more so with F-1, revealing a fundamentally different approach to external engagement. Their infrastructure focus enabled them to ensure allocation of sufficient financial resources in the school budget to support STEM education (38; +2), demonstrating a comprehensive approach to resource mobilization that addressed physical, external, and financial dimensions. This financial emphasis significantly distinguished them from both F-1 and F-2 participants, who placed less importance on budgetary allocations. Their resource-rich perspective was accompanied by a striking rejection of finding it difficult to understand how to implement STEM projects in an integrated way (2; -5). While a direct causal relationship cannot be established from the data alone, this pattern suggests F-3 participants may associate adequate resource provision with implementation confidence.

Another distinctive characteristic was their commitment to showcasing and recognizing students' projects within their cultural context. F-3 participants strongly valued organizing exhibitions and conferences for student projects in STEM fields, providing

Figure 3. F-3 idealized Q sort (Source: Authors' own elaboration, using Q-sort data)

opportunities to showcase work and creativity to an audience (17; +4). This emphasis created a dramatic contrast with F-1 and F-2 participants, highlighting a fundamentally different approach to public demonstrations of student work. This focus on public demonstration was reinforced through encouraging students to present innovative ideas for participating in STEM projects, no matter how simple (28; +3) and holding recognition ceremonies for students who achieved outstanding accomplishments in STEM fields (18; +2). Unlike F-2 participants who strongly rejected student clubs, F-3 participants supported establishing student clubs focused on STEM fields, such as robotics or programming clubs, to enhance student engagement in these areas (16; +1). This student-centered orientation was deliberately situated within cultural relevance by ensuring STEM programs are compatible with Qatari culture and relevant to students' backgrounds and experiences (23; +3). They found students to welcome these initiatives with high levels of motivation for STEM projects (30; -4) and implement innovative projects that are not only applications of what they learned in class (31; -3), indicating their belief that students were engaging innovatively rather than merely applying classroom learning.

A further distinctive feature was their professional development approach and instructional philosophy. F-3 participants emphasized organizing workshops for teachers to introduce best practices and modern methods for teaching STEM subjects (15; +4) as a key professional development strategy. This emphasis on workshops as a professional development strategy created a stark contrast with F-2 participants who strongly rejected this approach, revealing fundamentally different professional development philosophies. They showed slightly positive interest in inviting STEM experts to organize workshops for teachers within the school (12; 0), distinguishing them from F-2 participants who rejected this practice. They complemented these formal approaches by allowing teachers to experiment with innovative assessment methods suitable for STEM education (33; +2) and encouraging teachers to try innovative methods for teaching STEM subjects (32; +2). Together, these approaches to teacher development focused on methodological innovation. Their instructional philosophy was defined by rejecting teachers' use of direct instruction methods that prevented students from taking initiative (35; -5). This rejection of direct instruction created a dramatic contrast with F-2 participants who acknowledged this practice, highlighting fundamentally different views of current classroom practices.

This professional development orientation was supported by having knowledge of basic concepts, skills, and practices in STEM disciplines (1; +3) and confidence in curriculum development (11; -4). F-3 participants showed moderate interest in working with a team of teachers to develop curricula that integrate STEM disciplines (7; +1), distinguishing them from F-2 participants who rejected this collaborative curriculum approach. The coherence of their approach was further reflected in their rejection of feeling frustrated when teachers face difficulties implementing STEM curricula (8; -4), suggesting confidence in their professional development strategy. Regarding curriculum alignment, they showed a neutral stance toward conducting periodic assessments of STEM programs to ensure their alignment with national curricula (21; 0), slightly more positive than both F-1 and F-2 participants.

In contrast to both F-1 and F-2 participants, F-3 participants showed limited commitment to ensuring all students participated in STEM programs regardless of their backgrounds and abilities (26; -3) and believing all students can succeed in STEM fields (27; -2). This notable difference suggests that while F-3 participants excelled at creating resource-rich environments for STEM implementation, they may have had more limited expectations about universal student success, raising important equity considerations within their otherwise proactive implementation approach.

This pattern revealed participants as excelling in creating resource rich environments that enable effective STEM implementation centered on showcasing and recognizing students' work. Their approach combines infrastructure development, external partnerships and cultural relevance to create implementation contexts where student achievement can be publicly celebrated and teachers are supported through professional development focused on innovative methodologies. This raises important questions about the relationship between resource provision and implementation confidence, suggesting a leadership perspective that views adequate physical and financial resources as foundational to successful STEM education.

Consensus across factors

An analysis of consensus statements reveals areas of strong agreement among the three factors. Seven consensus statements provide insight into shared values across different leadership approaches. All participants agreed on the value of STEM education in developing students' critical thinking, problem-solving, and decision-making skills (29; +3/+4/+5). They also agreed on encouraging teachers to try new and innovative methods for teaching STEM subjects (32; +2/+2/+2), showing consistent support for teaching innovation across all approaches. All three factors showed similar views on collecting feedback from teachers and students to improve and develop curricula and practices related to STEM education (40; +1/+2/+1), demonstrating a shared commitment to continuous improvement. There was also agreement on the limited value of working with curriculum experts and educational consultants to ensure STEM programs align with sustainable development goals (22; -3/-2/-2), suggesting this was not seen as a priority across leadership practices. Additionally, all factors showed negative views toward participating in conferences and seminars related to STEM disciplines (5; -2/-4/-2), indicating limited interest in this form of professional development.

DISCUSSION

This study identified three distinct leadership approaches to STEM implementation in Qatari schools: (F-1) assessment innovation through collaborative learning, (F-2) contextually grounded student-centered leadership, and (F-3) resource-enabled implementation. We analyze these findings through the themes identified below. This structure allows us to examine the three leadership approaches and develop integrated implications for practice and policy.

Knowledge and Contexts: Navigating Cultural Relevance and Strategic Planning in STEM Implementation

The findings reveal distinct approaches to knowledge integration and contextual adaptation among Qatari principals. F-1 principals demonstrated a strong commitment to strategic planning and curriculum alignment, ensuring their school's vision encompasses STEM education while developing plans that integrate national standards with STEM objectives. Their focus on assessment innovation reflects a sophisticated understanding of STEM discipline knowledge and how it can be evaluated, aligning with Talib et al.'s (2025) emphasis on the principal's role in refining assessment methods to evaluate student learning in STEM subjects.

In contrast, F-2 principals approached knowledge and contexts through a cultural lens, as they prioritized the compatibility of STEM programs with Qatari culture and participation in national initiatives. This contextually grounded approach resonates with EL-Deghaidy et al.'s (2017) findings that culturally responsive STEM education significantly increases student engagement and achievement in Middle Eastern contexts. Their pragmatic recognition of implementation challenges demonstrates what Treagust et al. (2020) identified as a key factor in successful STEM implementation in Qatar through thoughtful adaptation to local contexts rather than wholesale adoption of international models.

F-3 principals approached contexts primarily through resource provision and external partnerships, demonstrating a keen understanding of the environmental dimensions of STEM implementation. Their emphasis on establishing partnerships with local companies and organizations shows a clear focus on creating supportive external environments for STEM education. This approach aligns with research by Fahy (2022), who found that transformational leadership significantly influences principals' commitment to STEM initiatives and enhances their schools' participation and implementation of STEM programs through strategic partnerships.

Across all factors, principals showed skepticism toward aligning STEM programs with sustainable development goals. This stands in contrast to Maass et al.'s (2019) emphasis on the growing importance of sustainability in international STEM education. Additionally, all principals rejected the notion that resource limitations hinder STEM implementation, reflecting Qatar's substantial investments in educational infrastructure.

The varying approaches to knowledge integration and contextual adaptation suggest several important implications for STEM leadership development. Professional development programs should help principals integrate strategic planning (F-1) with cultural relevance (F-2) and resource mobilization (F-3). This integrated approach would address what Said (2016) identified as a persistent challenge in Qatari STEM education; that is, connecting classroom innovation to broader national development priorities while maintaining cultural authenticity.

Policy initiatives should focus on building networks that connect internally focused principals (F-1) with those who excel at external partnerships (F-3) to create communities of practice that bridge these complementary approaches. Kayan-Fadlelmula et al. (2022) identified such connections as critical for addressing persistent gaps in STEM implementation in GCC countries. Falloon et al. (2024) further emphasize that successful STEM ecosystems require principals to engage with external stakeholders, fostering trust and collaboration that enhances educational outcomes.

Dispositions and Tools: Balancing Innovation, Collaboration, and Resource Provision

The findings reveal significant variations in how principals approach the dispositions and tools dimensions of STEM leadership (Geiger et al., 2023). F-1 principals demonstrated strong dispositions toward innovation and collaboration, allowing teachers to experiment with new assessment methods and ensuring that students' work in STEM projects is collaborative. This aligns with Hudson et al.'s (2012) research on the importance of distributed leadership and self-activation in successful STEM projects. However, their tool utilization was primarily internally focused, with limited engagement with external resources or partnerships.

F-2 principals exhibited strong dispositions toward student-centeredness and cultural responsiveness, encouraging students to present innovative ideas for STEM projects while ensuring alignment with Qatari cultural contexts. Their tool utilization was distinctive in its rejection of formal professional development structures, including workshops, conferences, and specialized training courses. This tension, which Surahman and Wang (2023) identified as a conflict between constructivist learning ideals and operational realities, represents a significant challenge in their implementation approach.

F-3 principals excelled in the tools dimension, ensuring the availability of necessary resources such as laboratories, technological tools, and educational materials. Their disposition toward resource mobilization and celebratory events shows a clear focus on creating supportive infrastructures for STEM education. This approach aligns with Nawaz et al.'s (2024) findings on the importance of purpose-built STEM labs for enhancing practical skills and fostering creativity and problem-solving in resource-constrained environments.

Consensus across factors emerged in principals' positive dispositions toward innovative teaching methods and critical thinking development. All principals valued encouraging teachers to try new approaches and believed in the effectiveness of STEM in developing higher-order thinking skills, which reflects a shared commitment to pedagogical innovation that transcends specific implementation approaches.

The diverse approaches to dispositions and tools suggest important implications for STEM leadership development. Professional learning should address the tension between innovation and equity concerns evident in F-1 principals, helping them recognize how assessment innovation must be explicitly designed with equity considerations to avoid reinforcing existing disparities. As McKay (2025) argues, principals can help teachers understand how project-based learning can address the needs of underrepresented students in STEM.

Educational policy should support F-2 principals in developing more structured approaches to teacher capacity building that maintain cultural authenticity while providing necessary professional development. As Geiger et al. (2023) note, effective STEM leadership requires ongoing professional learning for teachers to cultivate a robust STEM culture within schools. Park et al. (2024) further emphasize that teacher leadership plays a crucial role in STEM education by facilitating professional development, mentoring peers, and engaging in collaborative practices.

Resource allocation strategies should address the disconnect between resource provision and equity commitments evident in F-3 principals, ensuring that infrastructure investments are coupled with explicit attention to inclusive access. This disconnect can lead to well-resourced STEM programs primarily benefiting already-advantaged student populations (Calabrese Barton & Tan, 2020).

System-wide initiatives should build on the shared disposition toward innovative teaching methods and leverage this common ground to create professional learning communities that span different leadership approaches. Hilton et al. (2015) demonstrate that when school principals actively participate in professional development alongside teachers, it fosters a collaborative environment that enhances both teacher and principal growth.

Critical Orientation: Addressing Equity, Implementation, and Evidence-Based Decision Making

The critical orientation dimension encompasses evidence-based decision making, equity considerations, and reflective practice areas where all three leadership approaches showed both strengths and limitations. This dimension is particularly crucial as it represents the foundation for transformative leadership in STEM education, determining whether innovations, resources, and cultural adaptations benefit all students.

F-1 principals demonstrated strengths in strategic planning and curriculum alignment, suggesting a data-informed approach to STEM leadership. However, a notable disconnect emerged between their collaborative values and equity beliefs, as they expressed only moderate belief that all students can succeed in STEM regardless of background. This tension between innovation and equity has been identified by Nixon et al. (2024) as a significant challenge in STEM leadership, requiring what they term "generative inclusion" approaches that explicitly connect innovative practices to equity outcomes.

F-1 principals also balanced innovation with an acknowledgment of systemic tensions, recognizing that Ministry assessments often conflict with STEM project assessment methods. This awareness aligns with what Rose et al. (2019) identified as a critical skill for school principals to navigate competing demands while maintaining focus on student learning outcomes.

F-2 principals showed strengths in their pragmatic acknowledgment of implementation challenges, as evidenced by their willingness to recognize current teaching realities including direct instruction methods. This transparent assessment of implementation barriers represents a valuable form of critical reflection. They also demonstrated contextual sensitivity in their strong emphasis on cultural relevance and national initiatives. However, their moderate position on equity combined with limited strategic planning suggests challenges in systematically addressing equity considerations within their culturally responsive approach. Sellami et al. (2023) identified similar tensions in their study of STEM education in Middle Eastern contexts, where cultural authenticity and equity concerns sometimes create competing priorities for educational leaders. As Treagust et al. (2020) argue, successfully balancing these priorities requires culturally relevant pedagogy which includes critical consciousness, courageous leadership, student engagement, and community involvement.

F-3 principals exhibited strengths in their comprehensive resource strategy, including infrastructure, financial resources, and partnerships. However, a significant limitation emerged in their approach to equity, with their exceptional emphasis on resource provision standing in stark contrast to their limited belief in universal student participation and success. This disconnect suggests an approach that focuses more on providing resources than ensuring equitable access and outcomes. Kayan-Fadlelmula et al. (2022) identified this tendency as a persistent challenge in Gulf STEM education, noting that despite substantial investments, GCC countries continue to face challenges such as low student interest and enrollment in STEM fields. Almoosa (2023) similarly found that curriculum limitations and instructional strategies remain significant barriers to effective STEM education, suggesting that resource provision alone is insufficient.

The differences in critical orientation were further illuminated through principals' responses to implementation difficulties. F-2 principals acknowledged challenges in understanding integrated STEM implementation, while F-1 and F-3 strongly rejected such difficulties, suggesting either higher implementation confidence or less willingness to acknowledge challenges.

Principal preparation programs must address equity considerations in STEM education, helping principals develop culturally responsive approaches that combine critical consciousness with practical strategies for inclusion. These programs should engage principals in examining their implicit beliefs about student capability, particularly for students from traditionally underrepresented groups in STEM. Toolo (2023) argues that such belief examination is a prerequisite for genuine equity-focused leadership, as unexamined assumptions often constrain principals' ability to envision and implement truly inclusive STEM environments.

Professional development should help principals develop more sophisticated data literacy and evidence-based decision-making capabilities, enabling them to identify equity gaps and track the impact of interventions. Sellami et al. (2023) emphasize the importance of such capabilities for ensuring that STEM education initiatives reach all students, particularly those from historically underrepresented groups.

Educational policy should establish clearer accountability frameworks for equity outcomes in STEM education. Martinović and Milner-Bolotin (2024) identify this as a critical gap in many STEM implementation efforts, arguing that effective professional learning communities must place teacher leadership in STEM contexts at the center of improvement efforts.

CONCLUSION AND FUTURE DIRECTIONS

The study findings reveals both distinctive strengths and areas for development across the dimensions of leadership capabilities. Each leadership approach contributes valuable elements to a comprehensive STEM leadership model: F-1 principals excel in assessment innovation and strategic planning; F-2 principals demonstrate strength in cultural relevance and student-centeredness; and F-3 principals show expertise in resource mobilization and external partnerships. All three approaches show areas for growth in the critical orientation dimension, particularly regarding the integration of equity considerations with their respective leadership strengths. This finding suggests that effective STEM leadership development in Qatar requires an integrated approach that combines the strengths of each leadership profile while explicitly addressing equity and inclusion.

Based on our findings, we offer three key recommendations. First, principal preparation programs should acknowledge these three distinct approaches and help leaders integrate strengths from each while addressing their respective limitations particularly regarding equity. Second, policymakers should design professional development that brings together principals from different approaches to foster mutual learning. Third, future researchers should investigate whether these leadership profiles exist in other socio-cultural contexts and examine their correlation with student STEM outcomes. The main lesson from this study is that effective STEM leadership requires conscious integration of multiple approaches rather than adherence to a single model.

Future research should explore how principals develop across these dimensions over time, how leadership approaches correlate with student outcomes, and how targeted interventions might address specific limitations in each dimension. Comparative studies between Qatar and other Gulf states could further illuminate how cultural, economic, and policy contexts influence STEM leadership development, while participatory research involving multiple stakeholders could support the co-design of contextually relevant, equity-focused leadership practices.

By developing principals' capabilities across all dimensions of STEM leadership, with particular emphasis on strengthening critical orientation, Qatar can build a corps of school principals equipped to design STEM learning environments that benefit all students and support the country's vision of a knowledge-based economy that combines innovation with equity and cultural authenticity.

Limitations

This study has several limitations that should be acknowledged. First, the sample included 26 principals from government schools in Qatar, excluding private and international school contexts. Second, Q-methodology captures principals' subjective viewpoints rather than observed practices, and these perspectives were collected at one point in time (November 2024-February 2025). Third, the three factors identified explain 28% of the total variance, suggesting additional leadership perspectives may exist. As with all Q-methodology studies, the findings identify distinct viewpoints rather than their prevalence in the population and are not intended for statistical generalization.

Author contributions: MEOO: conceptualization, methodology, investigation, formal analysis, writing – original draft; **YC:** conceptualization, methodology, supervision, funding acquisition, writing – review & editing. Both authors agreed with the results and conclusions.

Funding: This research received a student grant from Qatar University [QUST-1-CED-2025-192].

Ethical statement: The authors stated that the study was approved by the Qatar University Institutional Review Board on 11 November 2024 with approval number QU-IRB 264/2024-EA. Written informed consents were obtained from the participants.

AI statement: The authors stated that AI-based grammar checking software (Grammarly) was used for proofreading the manuscript. No content generation was performed by AI. All content, analysis, and interpretations are the original work of the authors, who take full responsibility for the accuracy and integrity of the research.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

Almoosa, A. (2023). Teachers' perceptions towards the implementation of STEM education in the state of Kuwait. In F. Alhashem, H. Pacheco-Guffrey, & J. A. Boivin (Eds.), *Advances in educational technologies and instructional design* (pp. 209-221). IGI Global. https://doi.org/10.4018/978-1-6684-6883-8.ch009

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics, 112*(1), 3-11. https://doi.org/10.1111/j.1949-8594.2011.00109.x

Brown, S. R. (1993). A primer on Q methodology. *Operant Subjectivity, 16*(3/4), 91-138. https://doi.org/10.22488/okstate.93.100504

Bryan, L., & Guzey, S. S. (2020). K-12 STEM education: An overview of perspectives and considerations. *Hellenic Journal of STEM Education, 1*(1), 5-15. https://doi.org/10.51724/hjstemed.v1i1.5

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher, 70*(1), 30-35.

Calabrese Barton, A., & Tan, E. (2020). Beyond equity as inclusion: A framework of "rightful presence" for guiding justice-oriented studies in teaching and learning. *Educational Researcher, 49*(6), 433-440. https://doi.org/10.3102/0013189X20927363

EL-Deghaidy, H., Mansour, N., Alzaghibi, M., & Alhammad, K. (2017). Context of STEM integration in dchools: Views from in-service science teachers. *Eurasia Journal of Mathematics, Science and Technology Education, 13*(6), 2459-2484. https://doi.org/10.12973/eurasia.2017.01235a

English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education, 3*(1), Article 3. https://doi.org/10.1186/s40594-016-0036-1

Fahy, A. (2022). A national study of Irish leadership in STEM education. *Academy of Management Proceedings, 2022*(1), Article 17923. https://doi.org/10.5465/AMBPP.2022.17923abstract

Falloon, G., Stevenson, M., Hatisaru, V., Hurrell, D., & Boden, M. (2024). Principal leadership and proximal processes in creating STEM ecosystems: An Australian case study. *Leadership and Policy in Schools, 23*(2), 180-202. https://doi.org/10.1080/15700763.2022.2094810

Freeman, B., Marginson, S., & Tytler, R. (2019). An international view of STEM education. In A. Sahin, & M. J. Mohr-Schroeder (Eds.), *STEM education 2.0* (pp. 350-363). BRILL. https://doi.org/10.1163/9789004405400_019

Geiger, V., Beswick, K., Fraser, S., & Holland-Twining, B. (2023). A model for principals' STEM leadership capability. *British Educational Research Journal, 49*(5), 900-924. https://doi.org/10.1002/berj.3873

Gronn, P. (2002). Distributed leadership as a unit of analysis. *The Leadership Quarterly, 13*(4), 423-451. https://doi.org/10.1016/S1048-9843(02)00120-0

Gumus, S., Bellibas, M. S., Esen, M., & Gumus, E. (2018). A systematic review of studies on leadership models in educational research from 1980 to 2014. *Educational Management Administration & Leadership, 46*(1), 25-48. https://doi.org/10.1177/1741143216659296

Hallinger, P., & Kovačević, J. (2021). Science mapping the knowledge base in educational leadership and management: A longitudinal bibliometric analysis, 1960 to 2018. *Educational Management Administration & Leadership, 49*(1), 5-30. https://doi.org/10.1177/1741143219859002

Han, S. W. (2017). What motivates high-school students to pursue STEM careers? The influence of public attitudes towards science and technology in comparative perspective. *Journal of Education and Work, 30*(6), 632-652. https://doi.org/10.1080/13639080.2017.1329584

Hilton, A., Hilton, G., Dole, S., & Goos, M. (2015). School leaders as participants in teachers' professional development: The impact on teachers' and school leaders' professional growth. *Australian Journal of Teacher Education, 40*(12). https://doi.org/10.14221/ajte.2015v40n12.8

Holmlund, T. D., Lesseig, K., & Slavit, D. (2018). Making sense of "STEM education" in K-12 contexts. *International Journal of STEM Education, 5*(1), Article 32. https://doi.org/10.1186/s40594-018-0127-2

Hudson, P., English, L. D., Dawes, L., & Macri, J. (2012). Contextualizing a university-school STEM education collaboration: Distributed and self-activated leadership for project outcomes. *Educational Management Administration & Leadership, 40*(6), 772-785. https://doi.org/10.1177/1741143212456915

Kayan-Fadlelmula, F., Sellami, A., Abdelkader, N., & Umer, S. (2022). A systematic review of STEM education research in the GCC countries: Trends, gaps and barriers. *International Journal of STEM Education, 9*(1), Article 2. https://doi.org/10.1186/s40594-021-00319-7

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(1), Article 11. https://doi.org/10.1186/s40594-016-0046-z

Kennedy, T. J., & Odell, M. R. L. (2014). Engaging students in STEM education. *Science Education International, 25*(3), Article 246.

Likourezos, V., Beswick, K., Geiger, V., & Fraser, S. (2020). How principals can make a difference in STEM education. *The Australian Educational Leader, 42*(2), 33-36.

López, N., Morgan, D. L., Hutchings, Q. R., & Davis, K. (2022). Revisiting critical STEM interventions: A literature review of STEM organizational learning. *International Journal of STEM Education, 9*(1), Article 39. https://doi.org/10.1186/s40594-022-00357-9

Lutfallah, S., & Buchanan, L. (2019). Quantifying subjective data using online Q-methodology software. *The Mental Lexicon, 14*(3), 415-423. https://doi.org/10.1075/ml.20002.lut

Maass, K., Geiger, V., Ariza, M. R., & Goos, M. (2019). The role of mathematics in interdisciplinary STEM education. *ZDM, 51*(6), 869-884. https://doi.org/10.1007/s11858-019-01100-5

Marginson, S. (2013). *STEM: Country comparisons: international comparisons of science, technology, engineering and mathematics (STEM) education*. Australian Council of Learned Academies.

Martinović, D., & Milner-Bolotin, M. (2024). Re-imagining professional learning communities in education: Placing teacher leadership in STEM context. *School Science and Mathematics*. https://doi.org/10.1111/ssm.18315

McKay, H. F. (2025). Empowering principals to lead project-based learning with students historically underrepresented in STEM. *Interdisciplinary Journal of Problem-Based Learning, 18*(1). https://doi.org/10.14434/ijpbl.v18i1.36896

McKeown, B., & Thomas, D. (2013). *Q methodology*. SAGE. https://doi.org/10.4135/9781483384412

Nasir, N. S., & Vakil, S. (2017). STEM-focused academies in urban schools: Tensions and possibilities. *Journal of the Learning Sciences, 26*(3), 376-406. https://doi.org/10.1080/10508406.2017.1314215

Natarajan, U., Tan, A. L., & Teo, T. W. (2021). Theorizing STEM leadership: Agency, identity and community. *Asia-Pacific Science Education, 7*(1), 173-196. https://doi.org/10.1163/23641177-bja10021

Nawaz, M., Ahmed Khan, I., & Imran Ahmad, M. (2024). STEM integration in resource constrained environments. In M. Azeem Ashraf, & S. Maekele Tsegay (Eds.), *Education and human development* (vol. 14). IntechOpen. https://doi.org/10.5772/intechopen.113066

Nixon, N., Lin, Y., & Snow, L. (2024). Catalyzing equity in STEM teams: Harnessing generative AI for inclusion and diversity. *Policy Insights from the Behavioral and Brain Sciences, 11*(1), 85-92. https://doi.org/10.1177/23727322231220356

Park, B.-Y., Campbell, T., Hanrahan, J., Dolma, T., Murray, E., Russell, J., Lisy, E., & Bai, Y. (2024). Teacher leadership within a districtwide STEM teacher professional network. *International Journal of Leadership in Education*. https://doi.org/10.1080/13603124.2024.2330553

Qatar National Vision 2030. (2008). Qatar national vision 2030. *GCO*. https://www.gco.gov.qa/en/about-qatar/national-vision2030/

Rose, M. A., Geesa, R. L., & Stith, K. (2019). STEM leader excellence: A modified Delphi study of critical skills, competencies, and qualities. *Journal of Technology Education, 31*(1), 42-62. https://doi.org/10.21061/jte.v31i1.a.3

Said, Z. (2016). Science education reform in Qatar: Progress and challenges. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(8), 2253-2265. https://doi.org/10.12973/eurasia.2016.1301a

Sellami, A., Santhosh, M. E., Siby, N., Bhadra, J., & Ahmad, Z. (2023). High school students' perceptions of the role of social support in cultivating their interests in and aspirations to STEM degrees and careers–A Middle Eastern case study. *Sustainability, 15*(17), Article 12960. https://doi.org/10.3390/su151712960

Spillane, J. P., Halverson, R., & Diamond, J. B. (2001). Investigating school leadership practice: A distributed perspective. *Educational Researcher, 30*(3), 23-28. https://doi.org/10.3102/0013189X030003023

Surahman, E., & Wang, T.-H. (2023). In-service STEM teachers professional development programmes: A systematic literature review 2018-2022. *Teaching and Teacher Education, 135*, Article 104326. https://doi.org/10.1016/j.tate.2023.104326

Talib, S., Alias, B. S., Matore, M. E. E. M., & Abdullah, A. H. (2025). Empowering STEM education through the role of principals: A systematic literature review. *Journal of Education and Learning, 19*(1), 570-578. https://doi.org/10.11591/edulearn.v19i1.21889

Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., Boeve-de Pauw, J., Dehaene, W., Deprez, J., De Cock, M., Hellinckx, L., Knipprath, H., Langie, G., Struyven, K., Van De Velde, D., Van Petegem, P., & Depaepe, F. (2018). Integrated STEM education: A systematic review of instructional practices in secondary education. *European Journal of STEM Education, 3*(1), Article 02. https://doi.org/10.20897/ejsteme/85525

Toolo, L. (2023). Integrating technological and educational collaborations: Enhancing leadership and participation in STEM fields. *International Journal of Research in STEM Education, 5*(2), 19-33. https://doi.org/10.33830/ijrse.v5i2.1595

Treagust, D. F., Qureshi, S. S., Vishnumolakala, V. R., Ojeil, J., Mocerino, M., & Southam, D. C. (2020). Process-oriented guided inquiry learning (POGIL) as a culturally relevant pedagogy (CRP) in Qatar: A perspective from grade 10 chemistry classes. *Research in Science Education, 50*(3), 813-831. https://doi.org/10.1007/s11165-018-9712-0

Vasquez, J. A. (2013). *STEM lesson essentials, grades 3-8: Integrating science, technology, engineering, and mathematics*. Heinemann.

Watts, S., & Stenner, P. (2012). *Doing Q methodological research: Theory, method and interpretation*. SAGE.

York-Barr, J., & Duke, K. (2004). What do we know about teacher leadership? Findings from two decades of scholarship. *Review of Educational Research, 74*(3), 255-316. https://doi.org/10.3102/00346543074003255