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Instructional Interaction Barriers of Mathematics Teachers in Saudi Arabia

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Abstract

Background/purpose. Instructional interaction barriers—including physical, psycho-emotional, perceptual, semantic, and management-related factors—can impede learning and diminish the overall effectiveness of classroom practice. This study examines the barriers faced by mathematics teachers in Saudi Arabia and their differences across gender, school type, school level, and teaching experience.

Materials/methods. A descriptive research design was employed using a purposive sample of 270 mathematics teachers from Al-Ahsa schools during the 2023–2024 academic year. Data were collected using a structured questionnaire and analyzed in SPSS 25.0 with independent-samples $t(268)$ tests, one-way ANOVA, and Tukey post hoc comparisons.

Results. Male teachers reported significantly higher levels of instructional interaction barriers than female teachers ($t(268) = 2.81$, $p = .005$, Cohen's $d = 0.35$). Public school teachers experienced greater challenges than those in private schools ($p < .05$). Secondary school teachers reported higher psycho-emotional, management, and perceptual barriers than primary and intermediate teachers ($p < .01$). Teaching experience was associated with differences in physical and perceptual barriers, with less experienced teachers reporting higher levels of barriers.

Conclusion. Demographic and institutional factors meaningfully shape classroom interaction for mathematics teachers. Targeted professional development and structured mentoring—particularly pairing expert teachers with novice ones—are recommended to strengthen teacher–student interaction across educational settings in Al-Ahsa and comparable contexts.

Limitations and implications. The study is limited to a single educational region and relies on self-reported data, which may affect generalizability. Future research should employ broader sampling and mixed data sources.

1. Introduction

In classrooms around the world, the quality of interaction between teacher and student often defines whether a lesson becomes a lasting memory—or a forgotten routine. Instructional interaction is not merely the exchange of information; it is the core of meaningful learning. It shapes students' sense of belonging, confidence, and motivation to engage with ideas. In Saudi Arabia, where classrooms are undergoing rapid transformation through digital initiatives and evolving pedagogical expectations, understanding the barriers to effective instructional interaction has never been more urgent.

This study emerges from that urgency. It seeks to listen deeply to the voices of mathematics teachers—those navigating the daily realities of classrooms in Al-Ahsa—and to uncover the hidden frictions that prevent effective instruction from becoming connection. By examining how these barriers vary across gender, school type, teaching experience, and grade level, the research offers insights that go beyond numbers: it offers a comprehensive and human-centered understanding of what truly limits, and potentially liberates, the act of teaching.

In every mathematics classroom, meaningful learning is not only about delivering content—it's about connection. When teachers pause to check for understanding, adjust their explanations, or encourage a hesitant student, they are engaging in what scholars call instructional interaction—a dynamic, reciprocal process that lies at the heart of effective teaching (Mercer & Howe, 2012; Hofkens, Pianta, & Hamre, 2023; Emslander et al., 2025), with reviews confirming its consistent link to student outcomes across contexts (Roorda, Koomen, Spilt, & Oort, 2011). Through this interaction, students become more than passive receivers of information; they participate, question, reflect, and grow (Martin & Collie, 2019; Vargas Madriz, Konishi, & Wong, 2024).

Recent research shows that high-quality teacher–student interaction improves not only cognitive outcomes but also emotional well-being, engagement, and motivation (Mercer, Hennessy, & Warwick, 2019; van de Pol, Volman, & Beishuizen, 2010). For instance, Aldrup, Carstensen, and Klusmann (2021) emphasized the long-term impact of teacher responsiveness on classroom interaction quality. In mathematics education, where abstract concepts often feel distant or intimidating to students, the teacher's ability to scaffold learning and foster a safe, responsive environment can make the difference between success and disconnection (Pianta, Hamre, & Allen, 2020; Wang, Chen, Hwang, Guan, & Wang, 2022; Abed, Abed, & Shackelford, 2024). Interactive teaching strategies—questioning, dialogic feedback, small-group tasks—are increasingly recognized as essential for building mathematical confidence and conceptual understanding (Çelik & Alpan, 2023; Thompson & Pascal, 2012). A recent meta-analysis by Wang et al. (2022) confirmed that strong teacher–student interaction significantly improves student achievement, especially in technology-enhanced learning environments.

However, many teachers face persistent barriers that limit their ability to build such interaction. These may include perceptual biases ("students don't care"), emotional fatigue, overcrowded classrooms, unclear policies, or even rigid curricula (Bakar, Shah, & Xu, 2020; Kakepoto, Laghari, & Laghari, 2022). These challenges are often invisible in policy discussions, yet they quietly erode the foundation of classroom learning. Wang, Degol, and Amemiya (2020) stressed that negative classroom climate—often stemming from disrupted interaction—can undermine students' academic and psychological functioning. When teachers struggle to engage with students—not because they lack will or skill, but because systemic and psychological obstacles stand in the way—students pay the price in lost understanding and disengagement (Zheng, 2021).

In the Kingdom of Saudi Arabia, mathematics education has become a national priority, with growing emphasis on interactive pedagogy aligned with Vision 2030 educational reforms. Teachers are being encouraged to move beyond traditional lecture-based instruction toward more dialogic,

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participatory approaches (Susanto, Agustina, & Rozali, 2020; Alrabai, 2022). Yet, implementation on the ground remains challenging and uneven. Teachers—especially those working in public schools, high-enrollment settings, or with limited professional support—continue to report difficulties in sustaining meaningful interaction with students (Hussain, Muhammad, & Yasin, 2021). Despite these realities, little empirical research has systematically examined how these barriers manifest within Saudi mathematics classrooms, particularly in relation to demographic and contextual variables such as gender, school level, and teaching experience.

This study was designed to fill that gap. By investigating mathematics teachers' perceptions of instructional interaction barriers in the Al-Ahsa region, the research aims to identify patterns across professional and institutional contexts. In doing so, it not only amplifies teachers' voices but also contributes to improving classroom culture and instructional quality. More importantly, it offers a step toward classrooms where every student is seen, every question is heard, and interaction becomes a bridge—not a barrier—to learning. Therefore, based on the stated problem and the contextual importance of improving instructional interaction in Saudi mathematics classrooms, the research aim and questions are presented as follows:

1.1. Research Aim and Questions

Building upon the theoretical and empirical insights discussed in the literature—particularly the lack of empirical studies on instructional interaction in Saudi mathematics classrooms—this study aims to identify and analyze the instructional interaction barriers perceived by mathematics teachers in Saudi Arabia, with a focus on how these barriers differ by gender, school type, school level, and teaching experience. The study also seeks to inform future teacher training and policy development aimed at strengthening interactive pedagogical practices in mathematics classrooms. Accordingly, the following research questions guide the investigation:

1. Is there a significant difference between mathematics teachers' perceptions of instructional interaction barriers based on their gender (male and female)?

2. Is there a significant difference in perceived instructional interaction barriers according to the type of school (public vs. private)?

3. Is there a significant difference in perceptions based on the school level taught (primary, intermediate, secondary)?

4. Is there a significant difference in reported instructional interaction barriers according to years of teaching experience?

2. Literature Review

2.1. Instructional Interaction: A Foundational Concept

Instructional interaction lies at the heart of effective teaching and learning, especially in mathematics classrooms where abstract reasoning and symbolic representations often hinder comprehension. Without sustained engagement between teachers and students, such challenges can lead to disengagement and learning difficulties. Instructional interaction is defined as a dynamic, reciprocal process in which knowledge is co-constructed during instructional activities. It encompasses verbal exchanges, non-verbal cues, questioning, scaffolding, and real-time feedback (Mercer & Howe, 2012; Hofkens et al., 2023), thereby transforming the classroom from a space of knowledge transmission into one of shared meaning-making. Research has consistently highlighted the critical role of high-quality teacher–student interaction in shaping learning outcomes across diverse classroom settings (Pianta & Hofkens, 2023).

A meta-analysis by Wang et al. (2022) confirms the powerful role of teacher–student interaction in enhancing student achievement in both traditional and technology-enhanced environments, underscoring its relevance in varied instructional contexts. Moreover, strong instructional interaction supports not only academic growth but also emotional engagement and student motivation. Martin and Collie (2019) emphasize that positive teacher–student relationships foster emotional security, which is essential for academic engagement—particularly in mathematics, where anxiety and confusion are common (Mercer et al., 2019; Vargas Madriz et al., 2024).

In mathematics education specifically, well-structured interaction improves conceptual understanding and mathematical confidence. Roorda et al. (2011) found strong associations between teacher–student relationships and students' school engagement and academic success in a multilevel meta-analysis. Similarly, Pianta et al. (2020) and Çelik & Alpan (2023) demonstrate that relational and dialogic teaching approaches enhance learning outcomes in mathematics classrooms. Chang (2022) further shows that engagement is strongly linked to teacher clarity and responsiveness, while Aldrup et al. (2021) highlight the predictive value of sustained teacher responsiveness for high-quality instructional interaction and long-term student success.

For this study, instructional interaction barriers are defined as any internal or external factors that hinder meaningful, reciprocal engagement between teachers and students during classroom instruction. These barriers are conceptualized across six key dimensions:

- **Physical barriers** refer to environmental limitations such as overcrowded classrooms, poor acoustics, or inadequate lighting that restrict teacher mobility and student monitoring. For example, a teacher managing 35 students in a cramped classroom may struggle to facilitate group work or circulate effectively.

- **Psycho-emotional barriers** involve emotional or psychological conditions that negatively impact interaction, such as teacher burnout, student anxiety, or lack of mutual trust. A fatigued teacher, for instance, may find it difficult to respond empathetically to student needs.

- **Perceptual barriers** stem from implicit biases or assumptions held by teachers about students, such as believing some are unmotivated or incapable, which can unconsciously reduce interaction.

- **Semantic barriers** involve breakdowns in understanding due to unclear language, jargon, or lack of scaffolding. A mathematics teacher who uses terms like "asymptote" or "vector space" without explanation may alienate students unfamiliar with these concepts.

- **Organizational/management barriers** include institutional constraints such as rigid curricula, administrative demands, and limited instructional time, which reduce opportunities for dialogic teaching.

- **Pedagogical and technological barriers** arise when teachers lack training in interactive strategies or digital tools, leading them to rely on lecture-based instruction with limited engagement.

These dimensions often overlap and interact. A single barrier can trigger or reinforce others—for example, organizational pressures may exacerbate emotional fatigue, which in turn lowers perceptual sensitivity to student needs. If left unaddressed, such barriers can collectively undermine classroom engagement and learning outcomes.

2.2. Reinforcing the Dimensions of Instructional Interaction Barriers

Although instructional interaction is essential for effective learning, it is not always accessible or consistent. Teachers across educational systems frequently encounter obstacles that inhibit meaningful engagement with students. Based on an extensive synthesis of contemporary literature, these barriers continue to be classified along the six dimensions outlined above:

• **Physical barriers** include structural challenges such as overcrowded classrooms, restricted mobility, and inadequate lighting or acoustics. These conditions impair a teacher's ability to move, interpret student cues, and implement group-based strategies (Kakepoto, Laghari, & Laghari, 2022).

• **Psycho-emotional** barriers refer to teacher exhaustion, student stress, and the absence of rapport or trust. Studies confirm that classroom climate significantly influences students' academic and emotional functioning (Wang, Degol, & Amemiya, 2020). Emotional burnout, in particular, leads to teacher withdrawal from interactive practices, while emotionally unprepared students may avoid participation (Pianta et al., 2020; Hofkens et al., 2023).

• **Perceptual barriers** arise when teachers develop fixed negative expectations about students, such as assuming some are less capable or motivated. These assumptions can limit interaction and reduce inclusion (Bakar, Shah, & Xu, 2020).

• **Semantic barriers** occur when teachers use overly technical or ambiguous language without scaffolding, especially in mathematics instruction. Complex or unscaffolded terminology may hinder students' ability to engage meaningfully (Çelik & Alpan, 2023; Vargas Madriz et al., 2024).

• **Organizational barriers** include time constraints, curricular pressures, and a lack of professional development in interactive teaching. Under pressure to deliver content, teachers may sacrifice dialogue and responsiveness (Mercer et al., 2019; Bratchuk & Smith, 2023; Aldrup, Carstensen, & Klusmann, 2021).

• **Pedagogical and technological barriers** reflect limited training in learner-centered approaches or digital tools, which may result in over-reliance on unidirectional lecturing (Susanto et al., 2020; Alrabai, 2022).

These categories are not mutually exclusive; in practice, they often overlap and reinforce one another. Organizational demands may heighten emotional strain, diminishing perceptual awareness and responsiveness. Consequently, interventions targeting interaction barriers must account for their interrelated and compounded nature.

2.3. Instructional Interaction in Mathematics Education

Mathematics instruction introduces distinct interactional demands. Students may hesitate to participate due to fear of errors or social embarrassment. Simultaneously, teachers are expected to manage instructional clarity, pacing, and real-time responsiveness in conceptually dense subject matter (Pianta et al., 2020). Research shows that interactive practices such as guided questioning, formative feedback, and collaborative problem-solving foster deeper learning and student confidence.

Wang et al. (2023) found that teacher scaffolding during synchronous online mathematics sessions significantly boosted middle school students' engagement, particularly when instructors actively monitored understanding (Çelik & Alpan, 2023; van de Pol et al., 2010; Li & Xue, 2023). Nevertheless, mathematics teachers often report more severe psycho-emotional and organizational barriers than colleagues in other subjects, largely due to curriculum demands and content complexity (Bakar et al., 2020). These constraints can limit opportunities for dialogic engagement and responsive teaching, reinforcing the importance of examining instructional interaction within the unique context of mathematics education.

2.4. Saudi Context: Challenges and Gaps

Saudi Arabia has made notable efforts to reform instructional practice under Vision 2030, promoting student-centered learning and interactive pedagogy. Yet, implementation challenges persist. Teachers in public schools, in particular, report difficulties in interacting due to overcrowded classrooms, limited training, and bureaucratic constraints (Hussain, Muhammad, & Yasin, 2021;

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Agustina & Rozali, 2020; Alsaeed & Aladil, 2024). This aligns with recent findings demonstrating variation in mathematics teachers' instructional interaction practices across Saudi Arabia and neighboring Gulf contexts, particularly due to differences in institutional support for interactive pedagogy (Mohamed, Khalil, & Awaji, 2023).

While some studies have explored general instructional communication challenges in Saudi schools, few have addressed instructional interaction as a distinct construct—particularly in mathematics education. The actual implementation of interactive teaching strategies remains challenging and uneven in practice. Similar instructional communication barriers have also been documented in Qatar's governmental schools, particularly those related to student motivation, classroom climate, and teachers' limited autonomy in shaping interaction (Abu-Shawish, 2024).

Moreover, the literature is notably lacking in investigations that consider how these barriers vary across teacher demographics (e.g., gender, years of experience) or institutional types (e.g., public vs. private schools). This gap limits our understanding of how instructional interaction can be improved across contexts.

2.5. Rationale for the Current Study

While previous studies have addressed general instructional challenges in mathematics education, few have examined these issues through a comprehensive, multidimensional framework that considers emotional, perceptual, and institutional barriers—particularly within the Saudi context. Moreover, the existing literature rarely examines how these barriers vary across teacher demographics, such as gender, teaching experience, school level, or school type. These limitations highlight a pressing need for context-sensitive, empirically grounded research that captures teachers' lived experiences and instructional realities. Addressing these gaps is essential not only for advancing theoretical understanding but also for supporting culturally responsive professional development initiatives.

Given the growing recognition of instructional interaction as a driver of student success and the range of barriers that hinder it, this study aims to explore the types and intensity of instructional interaction barriers as perceived by mathematics teachers in the Al-Ahsa region of Saudi Arabia. The region's diversity in school types, teacher demographics, and educational stages provides valuable context for understanding the complexity of these barriers. This investigation examines how such barriers manifest across professional and demographic variables—including gender, school level, teaching experience, and school type—to inform targeted interventions, teacher preparation programs, and policy development aimed at strengthening mathematics instruction.

3. Methodology

This study employed a predominantly descriptive, quantitative design, supported by supplementary qualitative data, to gain a comprehensive understanding of the barriers to instructional interaction faced by mathematics teachers. Specifically, a mixed-methods approach was adopted, with qualitative insights complementing and contextualizing the quantitative findings. This triangulation strengthens methodological validity and provides a more comprehensive understanding of the instructional challenges.

3.1. Research Design

A convergent mixed-methods design was implemented, wherein quantitative and qualitative data were collected concurrently, analyzed separately, and integrated during the interpretation phase. This design was chosen because it allows the strengths of both methods to be combined—statistical generalizability through quantitative data and contextual richness through qualitative data. Together, these strengths provide a more holistic understanding of the research problem.

3.2. Participants and Sampling

The study was conducted in the Al-Ahsa Governorate, Saudi Arabia, during the 2023–2024 academic year. The target population consisted of mathematics teachers from primary, intermediate, and secondary public and private schools. A purposive sampling strategy was applied to ensure representation across gender, school type, and years of teaching experience. Based on Cochran's (1962) formula, a total of 350 participants were targeted. Of these, 310 questionnaires were distributed, yielding 270 valid responses, ensuring adequate statistical power.

To allow meaningful group comparisons, teaching experience was classified into three levels: novice (0–10 years), competent (11–20 years), and expert (more than 20 years). This classification was grounded in previous research on teacher development, which aligns with Dreyfus and Dreyfus's (1980) skill acquisition framework, emphasizing developmental transitions in pedagogical expertise. Furthermore, the selection of Al-Ahsa was informed by its educational diversity and accessibility, which supported both sampling feasibility and the study's contextual relevance to the study's aims. Although geographically restricted to Al-Ahsa, the region's demographic and institutional diversity enhances the relevance and transferability of the study's findings to comparable Saudi educational contexts.

3.3. Research Instrument

The primary data collection tool was a researcher-developed questionnaire, conceptually informed by an extensive review of relevant literature. Existing tools were examined; however, none were fully aligned with the study's conceptual framework. Therefore, the instrument was developed and tailored to fit the current educational context.

The questionnaire consisted of two sections. The first gathered demographic information—including gender, school type, school level, and teaching experience—while the second contained 28 statements assessing perceived barriers to instructional interaction. These barriers were conceptualized across five dimensions: physical, psycho-emotional, semantic, management, and perceptual.

Physical barriers are external environmental factors, such as overcrowded classrooms and inadequate lighting. Psycho-emotional barriers involve psychological states like stress, fatigue, and low student engagement. Semantic barriers capture issues related to language, such as unclear terminology or student misunderstandings. Management barriers relate to curricular overload, time constraints, and difficulties integrating technology. Perceptual barriers reflect assumptions held by teachers regarding students' willingness or ability to participate.

Example items included statements such as "Overcrowded classrooms reduce my ability to interact effectively with students" (physical barrier) and "Administrative tasks take time away from meaningful student interaction" (management barrier). Participants responded on a 3-point Likert scale (1 = True, 2 = Partially True, 3 = Not True at All) to indicate the extent to which each item represented a classroom barrier in their experience.

3.4. Validity and Reliability

To ensure content validity, the instrument was reviewed by five experts in educational measurement and mathematics pedagogy, and revisions were made accordingly. Based on their feedback, four items were removed and three new items were added to better align the instrument with the study's objectives. A pilot test involving 25 teachers not included in the final sample further validated the tool.

Reliability was established through both test–retest procedures and internal consistency analysis. Pearson correlation coefficients ($r = .80$ and $r = .78$) indicated temporal stability over a two-

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week interval. Cronbach's alpha coefficient demonstrated strong internal consistency (overall α = .86), with subscale reliability values ranging from .80 to .89, indicating robust coherence among the instrument's items.

3.5. Interviews

To supplement the quantitative data and deepen understanding of teachers' experiences, semi-structured interviews were conducted with eight participants drawn from the main sample. Maximum variation sampling within the main sample was used to ensure representation of different years of experience and school levels.

The interviews were guided by a single open-ended question: "What is the most significant barrier that prevents you from engaging in meaningful instructional interaction with your students during math lessons?"

Interviews were conducted in Arabic, recorded with informed consent, and transcribed verbatim. Following transcription, a systematic thematic analysis was conducted using Braun and Clarke's (2006) six-step framework: familiarization, coding, theme generation, theme review, definition/naming, and reporting. Two independent reviewers coded the transcripts, and any discrepancies were resolved through discussion, enhancing the credibility and dependability of the qualitative findings.

The integrated analysis allowed the qualitative data to contextualize and enrich the quantitative results, thereby strengthening the explanatory power of the study.

3.6. Data Collection and Analysis

Data collection was facilitated through both online and paper-based questionnaires distributed via school administrative channels to maximize accessibility and response rates. Participation was voluntary and confidential, with prior ethical approval granted by the regional educational authority, and all procedures complied with ethical standards consistent with the Declaration of Helsinki. Prior to analysis, data screening was conducted to identify missing values and outliers, ensuring data quality for subsequent statistical testing.

Quantitative data were analyzed in SPSS version 25.0 using both descriptive (means, standard deviations) and inferential statistics, including independent-samples t-tests, one-way ANOVA, and Tukey's post hoc comparisons. Assumptions for each statistical test—normality and homogeneity of variances—were examined using the Shapiro–Wilk and Levene's tests, respectively. These analyses enabled examination of differences in teachers' perceptions according to gender, school type, school level, and teaching experience.

Qualitative interview data were analyzed thematically following Braun and Clarke's (2006) framework and then integrated with the quantitative results through a side-by-side comparison, enabling convergence, expansion, and explanation of the statistical findings. This triangulation provided a more nuanced interpretation of the barriers to instructional interaction and strengthened the overall validity of the study.

3.7. Ethical Considerations

This study was reviewed and approved by the Research Ethics Committee at King Faisal University (Approval No: KFU-2025-ETHICS3702). The researchers or participants declared no conflict of interest. It was funded by the Deanship of Scientific Research at King Faisal University (Grant No: KFU252536). Participation was entirely voluntary, and informed consent was obtained from all participants prior to data collection. Confidentiality and anonymity were strictly maintained by assigning pseudonyms, removing all identifying information, and securely storing and deleting audio recordings after transcription. Survey responses were also anonymized and stored in encrypted digital files accessible only to the research team. The study involved no physical or professional risks, and participants retained the right to withdraw at any time without consequence or impact on their employment status.

4. Results

The results are presented in alignment with the study's central questions regarding the effects of gender, school type, school level, and teaching experience on perceived barriers to instructional interaction. Each subsection corresponds to one of these variables to illustrate how contextual factors shape teachers' instructional experiences.

4.1. Demographic Information

The demographic profile of the participating mathematics teachers revealed a balanced gender distribution, with 52.6% identifying as female (n = 142) and 47.4% as male (n = 128). Regarding workplace affiliation, 60% of participants (n = 162) were employed in public schools, while the remaining 40% (n = 108) worked in private schools.

In terms of teaching level, 35.5% of teachers (n = 96) taught at the primary level, 32.9% (n = 89) at the intermediate level, and 31.4% (n = 85) at the secondary level, indicating a relatively even distribution across educational stages.

Teachers' professional experience was categorized into three levels: novice (0–10 years), competent (11–20 years), and expert (more than 20 years). Novice teachers comprised 33.7% of the sample (n = 91), competent teachers constituted 36.6% (n = 99), and expert teachers accounted for 29.6% (n = 80).

Overall, this balanced demographic distribution ensured adequate representation across gender, school type, teaching stage, and experience level, thereby enhancing the interpretive rigor and validity of the subsequent comparative analyses.

4.2. Barriers by gender

An independent-samples t-test was conducted to examine whether statistically significant differences existed in instructional interaction barriers between male and female mathematics teachers. Results showed that male teachers (n = 128) reported significantly higher levels of instructional interaction barriers across several dimensions compared to female teachers (n = 142), particularly in the physical, psycho-emotional, and perceptual components of interaction, as well as on the overall scale.

For the overall scale, male teachers scored M = 1.68 (SD = 0.39), compared to M = 1.55 (SD = 0.37) for female teachers, $t(268) = 2.81$, $p = .005$, with a small-to-medium effect size ($d = 0.34$). Subscale effect sizes indicated that the largest difference was observed in physical barriers ($d = 0.64$, medium-to-large), followed by psycho-emotional barriers ($d = 0.42$, medium), and perceptual barriers ($d = 0.28$, small). These values demonstrate that the gender differences were not only statistically significant but also practically meaningful in educational contexts, particularly regarding physical and psycho-emotional challenges.

As summarized in Table 1 and illustrated in Figure 1, male teachers consistently reported higher barrier scores across most subscales.

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Table1. T-Test Analysis of Instructional Interaction Barriers Based on Gender

Subscale	Gender	*n*	*M*	*SD*	*t* value
Physical barriers	Male	128	1.70	0.43	5.27***
	Female	142	1.43	0.41	
Psycho-emotional barriers	Male	128	1.55	0.32	3.44**
	Female	142	1.42	0.30	
Semantic barrier	Male	128	1.80	0.45	1.13
	Female	142	1.74	0.42	
Management barrier	Male	128	1.70	0.31	1.79
	Female	142	1.63	0.33	
Perceptual barrier	Male	128	1.66	0.43	2.25*
	Female	142	1.55	0.37	
Overall barrier	Male	128	1.68	0.39	2.81*
	Female	142	1.55	0.37	

**p<0.05, **p<0.01, ***p<0.001*

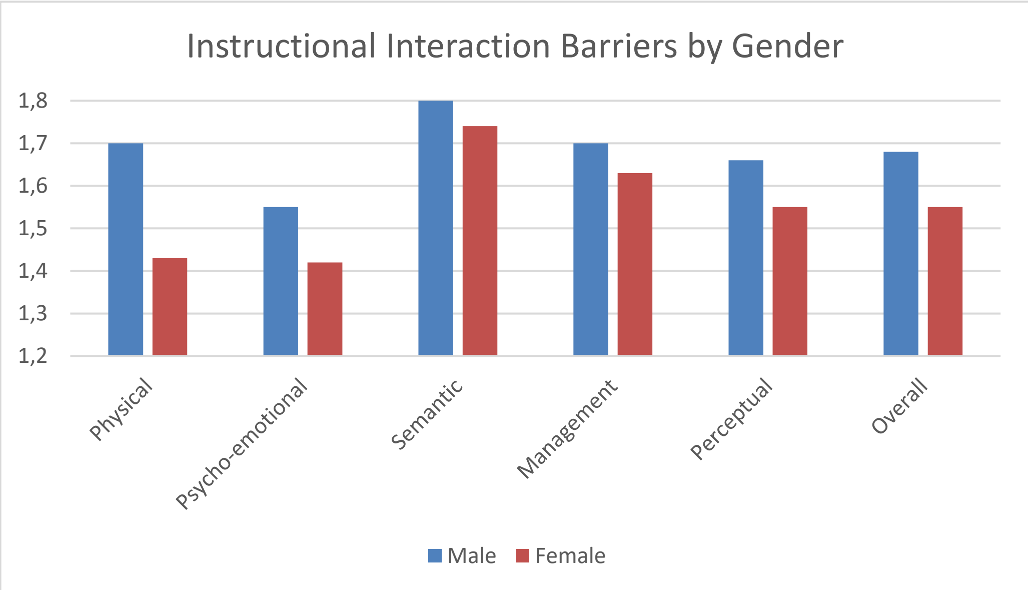

Figure1. Distribution of instructional interaction barrier scores by gender

4.3. Barriers by school type

An independent-samples t-test was conducted to examine whether school type influenced mathematics teachers' perceptions of instructional interaction barriers. Results revealed that public school teachers (n = 162) reported higher overall barriers (M = 1.58, SD = 0.41) than private school teachers (n = 108, M = 1.48, SD = 0.40), t(268) = 1.98, p = .049, indicating a small effect size (d = 0.26). Public school teachers also reported significantly higher levels of physical barriers (t = 4.04, p < .001, d = 0.47, small-to-medium), psycho-emotional barriers (t = 2.50, p < .05, d = 0.31, small-to-medium), and semantic barriers (t = 2.44, p < .05, d = 0.32, small-to-medium).

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As summarized in Table 2 and illustrated in Figure 2, teachers in public schools consistently reported greater instructional interaction barriers than their private school counterparts. Although the differences were statistically significant in several dimensions, effect sizes were generally small, suggesting that practical differences in instructional interaction experiences remain modest across school types.

Table2. T-Test Analysis of Instructional Interaction Barriers Based on School Type

Subscale	School type	*n*	*M*	*SD*	*t value*
Physical barriers	Public	162	1.55	0.43	4.04***
	Private	108	1.33	0.45	
Psycho-emotional barriers	Public	162	1.57	0.41	2.50*
	Private	108	1.44	0.43	
Semantic barriers	Public	162	1.61	0.40	2.44*
	Private	108	1.49	0.35	
Management barrier	Public	162	1.55	0.36	0.23
	Private	108	1.54	0.35	
Perceptual barrier	Public	162	1.64	0.43	1.14
	Private	108	1.58	0.41	
Overall barrier	Public	162	1.58	0.41	1.98*
	Private	108	1.48	0.40	

*$p<0.05$, **$p<0.01$, ***$p<0.001$

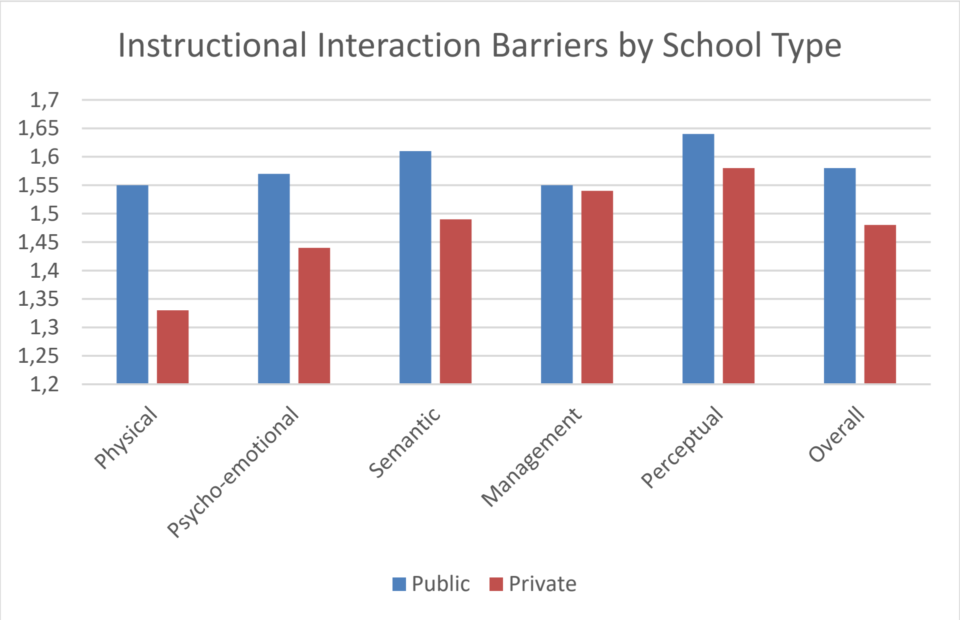

Figure 2. Comparison of barriers across public and private schools

4.4. Barriers by School Level

A one-way analysis of variance (ANOVA) was conducted to examine whether mathematics teachers' experiences with instructional interaction barriers differed across school levels. The findings revealed statistically significant differences in three dimensions: psycho-emotional barriers, management barriers, and perceptual barriers (see Table 3). These results suggest that instructional challenges are shaped by the increasing cognitive, emotional, and administrative demands associated with higher-grade mathematics instruction.

Table3. ANOVA Results of Instructional Interaction Barriers across School Levels

Subscale	School levels	*n*	*M*	*SD*	*F*	*P*
	primary	96	1.40	0.39	0.91	0.41
Physical barriers	intermediate	89	1.45	0.41		
	secondary	85	1.48	0.38		
	primary	96	1.39	0.38	5.52	.005 ($p < .01$)
Psycho-emotional barriers	intermediate	89	1.40	0.36		
	secondary	85	1.56	0.4		
	primary	96	1.56	0.4	0.32	0.73
Semantic barrier	intermediate	89	1.58	0.45		
	secondary	85	1.61	0.42		
	primary	96	1.56	.35	5.31	.005 ($p < .01$)
Management barrier	intermediate	89	1.58	.33		
	secondary	85	1.71	.31		
	primary	96	1.45	.42	8.22	< .001 ***
Perceptual barrier	intermediate	89	1.60	.39		
	secondary	85	1.68	.35		
	primary	96	1.47	.38	2.6	0.07
Overall barrier	intermediate	89	1.52	.39		
	secondary	85	1.60	.37		

**p<0.05, **p<0.01, ***p<0.001*

Post hoc comparisons using Tukey's test showed that secondary school teachers experienced significantly higher psycho-emotional barriers (M = 1.56, SD = 0.40) compared to primary (M = 1.39, SD = 0.38) and intermediate teachers (M = 1.40, SD = 0.36), p = .005, $\eta^2 = 0.04$. Similarly, secondary teachers reported elevated management barriers (M = 1.71, SD = 0.31) relative to primary (M = 1.56, SD = 0.35) and intermediate teachers (M = 1.58, SD = 0.33), p = .005, $\eta^2 = 0.038$.

Perceptual barriers also increased significantly at higher school levels, with intermediate (M = 1.60, SD = 0.39) and secondary teachers (M = 1.68, SD = 0.35) showing higher scores than primary teachers (M = 1.45, SD = 0.42), p < .001, $\eta^2 = 0.058$. These effect sizes—ranging from small to moderate—indicate that while differences are statistically significant, their practical magnitudes are more pronounced in perceptual barriers.

The distribution of psycho-emotional and management barriers across school levels is further illustrated in Figure 3, reinforcing that instructional interaction challenges become more pronounced as teachers progress to upper-grade mathematics classrooms.

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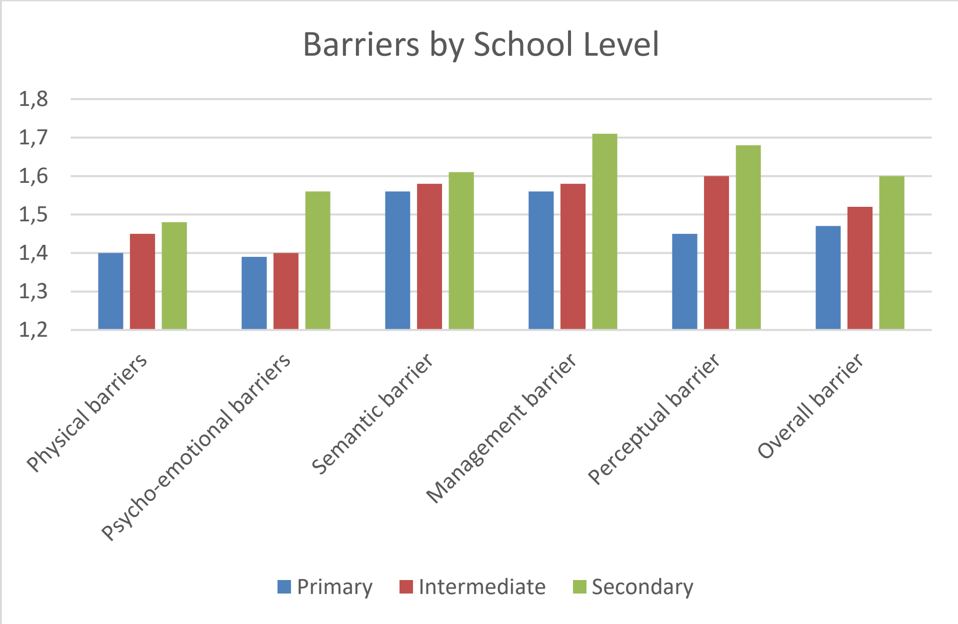

Figure 3. Psycho-emotional and management barriers by school level

The effect sizes across significant dimensions suggested small to moderate practical differences, reflecting a gradual increase in instructional challenges as teaching progresses to higher grade levels.

4.5. Barriers by teaching experience

A one-way analysis of variance (ANOVA) was conducted to examine whether teaching experience influenced mathematics teachers' perceptions of instructional interaction barriers. Statistically significant differences were found in physical barriers, perceptual barriers, and the overall barrier score (see Table 4). These findings suggest that novice teachers tend to perceive more instructional challenges than their more experienced peers.

Table 4. ANOVA results of instructional interaction barriers by teaching experience

Subscale	Experience years	*N*	*M*	*SD*	*F*	*P*
	novice	91	1.62	.42	10.0	0.001***
Physical barriers	competent	99	1.41	.35		
	expert	80	1.39	.37		
	novice	91	1.60	.44	1.43	.24
Psycho-emotional barriers	competent	99	1.53	.37		
	expert	80	1.50	.39		
	novice	91	1.40	.31	2.38	.09
Semantic barrier	competent	99	1.32	.37		
	expert	80	1.29	.35		
	novice	91	1.68	.42	1.07	.34
Management barrier	competent	99	1.62	.37		
	expert	80	1.59	.45		

	novice	91	1.70	.37	7.82	0.005**
Perceptual barrier	competent	99	1.50	.44		
	expert	80	1.48	.42		
	novice	91	1.60	.40	3.55	0.03*
Ooverall barriers	competent	99	1.48	.38		
	expert	80	1.45	.41		

*p<0.05, **p<0.01, ***p<0.001

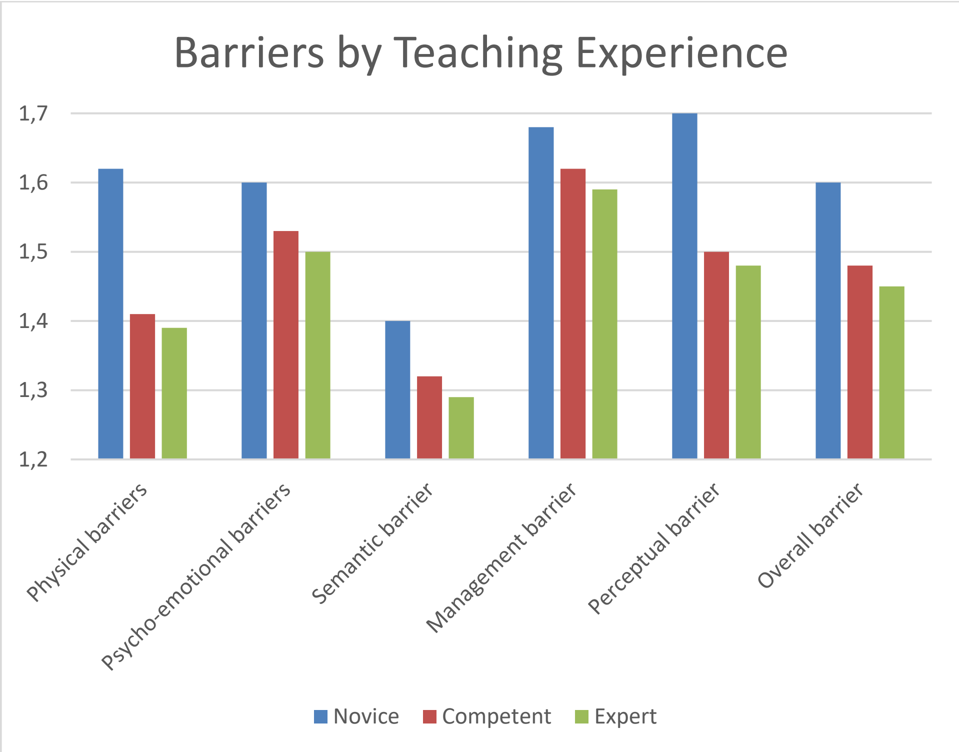

Figure 4. Physical and perceptual barriers by teaching experience

Post hoc comparisons using Tukey's test showed that novice teachers (0–10 years) reported significantly higher physical barriers (M = 1.62, SD = 0.42) than both competent teachers (11–20 years; M = 1.41, SD = 0.35) and expert teachers (>20 years; M = 1.39, SD = 0.37), p = .001, $\eta^2 = 0.07$. Perceptual barriers followed a similar pattern (F = 7.82, p = .005, $\eta^2 = 0.055$). A significant difference was also observed in the overall barrier score (F = 3.55, p = .03, $\eta^2 = 0.026$).

These patterns, illustrated in Figure 4, demonstrate that novice teachers consistently perceived greater challenges than their more experienced peers. Although the effect sizes ranged from small to moderate, they indicate that teaching experience accounts for a meaningful—albeit limited—portion of the variance in perceived instructional interaction barriers.

4.6. Qualitative Insights: Teachers' Voices

To complement the quantitative analyses, semi-structured interviews were conducted with eight mathematics teachers representing different school levels and years of experience. The aim was to explore deeper, context-based interpretations of the instructional interaction barriers identified in the statistical results.

A thematic analysis was performed following Braun and Clarke's (2006) six-phase approach, including familiarization, coding, theme development, reviewing, defining, and reporting. Codes were

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compared and refined to ensure credibility and analytical consistency. These qualitative insights were further used to contextualize quantitative variations across gender, school level, and teaching experience—thereby strengthening triangulation and interpretive rigor.

All interview excerpts were translated into English for reporting while preserving their original meaning. Each participant was assigned a coded identifier (e.g., T.36) to ensure confidentiality. Teachers expressed emotional fatigue, classroom-management pressures, and perceptual ambiguity toward student behavior—concerns that aligned with the identified quantitative dimensions.

One teacher highlighted student disengagement as a major challenge, stating: “Sometimes the students are physically present but mentally absent. You ask questions and get no reactions. It makes you feel like you’re teaching a wall.” (T.36, Secondary School, Male, 6 years of experience). This perception reflects the perceptual barriers more frequently reported by novice and secondary-level teachers in the quantitative results.

Another teacher emphasized the burden of class size and workload: “I have 35 students in a single classroom, and I’m expected to give attention to each of them. It’s not just exhausting—it’s impossible.” (T.230, Primary School, Female, 8 years of experience). This aligns with physical and management barriers, consistent with findings indicating higher structural challenges in primary and public-school settings.

Psycho-emotional challenges were also evident, as one teacher shared: “Sometimes I feel emotionally drained, like I’m pouring energy into a void. When students don’t respond or misbehave, I start questioning my own methods.” (T.116, Intermediate School, Female, 11 years of experience). This sentiment reinforces statistical results indicating emotional strain in mid-career teaching roles.

Another participant described curriculum and time constraints: “Even when I try interactive methods, the system doesn’t support me. There’s too much content to cover, and no room for creative strategies.” (T.145, Secondary School, Male, 17 years of experience). This corresponds with the management barriers that were significantly higher among teachers in upper-school levels.

Additionally, some teachers acknowledged their own limitations in sustaining student engagement: “We assume students are not motivated, but sometimes it’s us—we’re too tired to make the lesson engaging.” (T.203, Intermediate School, Female, 21 years of experience).

This quote highlights the reciprocal nature of emotional and perceptual barriers, confirming that student interaction depends on teacher well-being.

Overall, the qualitative findings provided a deeper understanding of the social and emotional dynamics that shape classroom interaction. They complemented and reinforced the quantitative results by illustrating how instructional constraints are experienced in daily teaching practices. These insights underscore the importance of targeted professional support, manageable curriculum expectations, and teacher well-being initiatives to enhance instructional-interaction effectiveness.

5. Discussion

The findings of this study provide empirical support for the theoretical concerns raised in the literature review—particularly regarding the influence of demographic, institutional, and technological factors on classroom interaction. These results highlight meaningful patterns of variation across gender, school type, school level, and teaching experience, confirming that instructional interaction is a socially and contextually shaped process rather than a uniform pedagogical practice. By integrating quantitative trends with qualitative narratives, the study offers a nuanced understanding of how teachers’ professional realities influence their capacity to sustain meaningful instructional engagement, particularly within Saudi Arabia’s evolving educational landscape.

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5.1. Gender Differences

The results revealed that male teachers reported significantly higher instructional interaction barriers than female teachers across physical, psycho-emotional, and perceptual domains. These findings align with Pal et al. (2016) but diverge from others such as Cengil (2016) and Ozmen et al. (2016), indicating that gender differences in interaction are highly context-dependent rather than universal.

One teacher expressed the emotional aspect of these challenges: “Female teachers tend to connect faster with students emotionally. I often struggle to get the same openness.” (T.116). This reinforces the role of relational sensitivity and emotional attunement, which are often more prevalent among female teachers, in facilitating effective interaction (Çelik & Alpan, 2023; Vargas Madriz et al., 2024).

Culturally embedded expectations in Saudi Arabia may further intensify these differences, with male teachers often positioned in more authoritative roles, accompanied by larger class sizes and stricter behavioral expectations (Alhazmi & Nyland, 2013; Elyas & Picard, 2013). These contextual pressures could contribute to the higher psycho-emotional and perceptual barriers reported by males. Meanwhile, female teachers may benefit from culturally reinforced emotional communication patterns that align more naturally with the interactive demands of teaching.

Moreover, emotional fatigue has been shown to disproportionately affect male teachers in similar contexts (Pianta et al., 2020), which may amplify their perception of instructional barriers.

Overall, these findings provide an original contribution by demonstrating that gender-related interactional barriers among mathematics teachers are shaped not only by pedagogical factors but also by cultural role expectations. Tailored professional development is therefore recommended to support male teachers in strengthening relational and emotional communication strategies.

5.2. School Type

Public school teachers reported higher levels of barriers than teachers in private schools, particularly in the physical and psycho-emotional dimensions. These differences likely reflect variations in classroom organization, resource availability, and institutional support. As one participant emphasized, “In private schools, we often have smaller classes, better lighting, and more freedom to innovate. Public schools are more rigid and crowded.” (T.230)

This finding aligns with existing literature (Pal et al., 2016; Martin & Collie, 2019), which demonstrates that school climate and infrastructure exert a significant influence on teachers’ instructional interaction. In the Saudi context, public schools typically serve larger student populations and face greater pressure regarding curriculum compliance, potentially intensifying the emotional and environmental demands placed on teachers.

Although the statistical differences observed were small, their practical implications suggest that improving school conditions—particularly by reducing overcrowding and enhancing institutional support—could mitigate barriers to interaction and foster more effective mathematics learning environments.

5.3. School Level

The level of schooling significantly influenced teachers’ perceptions of instructional interaction barriers. Secondary school teachers reported notably greater challenges in the psycho-emotional and management domains than primary and intermediate teachers, which may reflect the increasing academic demands, behavioral complexity, and intensified curriculum pressures associated with upper-grade mathematics instruction. Secondary-level teachers often deal with larger class sizes,

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high-stakes assessment environments, and more evident student disengagement, contributing to heightened stress and a perceived loss of instructional control—particularly in mathematics, where the cognitive load is already high.

Perceptual barriers also showed a clear upward trend from primary to intermediate and secondary levels, indicating that communication and interaction difficulties intensify as students' progress academically. One teacher reinforced this finding: "By high school, the gap becomes clear. Many students have developed negative beliefs about math, and that blocks any attempt at interaction." (T.36)

These findings indicate that secondary school teachers experience greater instructional interaction barriers than those in primary or intermediate stages. This can be attributed to increased curriculum pressures, high-stakes examinations, and students' heightened anxiety toward mathematics during adolescence. Similar challenges are also prevalent in STEM-focused secondary settings across the Gulf region, where teachers face additional constraints linked to content complexity and limited opportunities for interactive pedagogy (Sellami, Santhosh, Bhadra, & Ahmad, 2024).

This suggests a need for targeted professional training that enables mathematics teachers, particularly those teaching higher grade levels, to adopt responsive communication strategies tailored to adolescents' cognitive and affective needs. Overall, these results highlight the need for intervention programs specifically designed for upper school levels, where both instructional and emotional challenges appear more pronounced.

5.4. Teaching Experience

Findings revealed that novice teachers (0–10 years) perceived significantly more instructional interaction barriers—particularly in the physical and perceptual dimensions—than competent and expert teachers. This suggests that professional maturity plays a critical role in shaping how teachers interpret and respond to classroom challenges. Experienced teachers are typically more adept at managing classroom dynamics, maintaining emotional regulation, and adapting instructional strategies to student needs.

Perceptual barriers followed a similar pattern, as novice teachers often struggle to distinguish between student disengagement and misunderstanding, leading to heightened uncertainty about instructional effectiveness. One newly appointed teacher expressed this challenge: "I don't know if they're bored or confused. I keep explaining, but they just stare. I wish someone told me how hard this part would be." (T.2)

These results align with prior studies (Ozmen et al., 2016; Ahmed et al., 2020), which indicate that early-career teachers may initially rely on surface-level interpretations of student behavior, increasing their sensitivity to perceived interaction failures.

Overall, the findings emphasize the importance of targeted mentoring, peer coaching, and ongoing professional development—particularly during the transition from novice to competent teaching phases (Aldrup et al., 2021). Such support can help reduce stress, strengthen instructional confidence, and improve the quality of teacher–student interaction.

5.5. Comparison with Similar Context

When compared with findings from similar educational systems in the Gulf region, the present study reveals both convergences and divergences. For instance, Hussain and Alghamdi (2020) reported comparable psycho-emotional strain and limited institutional autonomy among teachers in Bahrain and Kuwait. Likewise, Al-Harthy (2018) identified perceptual barriers among early-career teachers in Oman. These consistencies suggest that many instructional interaction barriers across the

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region stem from shared systemic characteristics such as centralized curricula, heavy teaching loads, and exam-driven classroom cultures.

However, Emirati teachers were found to report fewer semantic barriers, likely due to stronger bilingual support within classrooms (Ahmed & Hassan, 2019). This contrast underscores the important role of language policy and differentiated instructional support in reducing barriers to student participation in mathematics.

Moreover, the current findings extend regional knowledge by illustrating how barriers differ not only between countries but also within the same national context across gender, school level, and teaching experience—an analytical dimension rarely explored in prior Gulf-based studies. By examining these micro-level variations, the present research provides a more nuanced and contextually grounded contribution to the regional literature.

Future research could benefit from broader cross-national investigations that incorporate cultural values, teacher preparation models, and school governance structures as explanatory variables for instructional interaction differences across GCC contexts. Such comparative work would support the development of regionally responsive professional development frameworks that address both shared and context-specific challenges.

5.6. The Role of Technology in Instructional Interaction

Although technological and pedagogical barriers were acknowledged in the literature review, interview data revealed a more nuanced relationship between digital tools and instructional interaction. While platforms like Madrasati and Microsoft Teams offered flexibility, many teachers described reduced student engagement and emotional distance. One participant (T.203) shared: "During online classes, it was hard to know if students were even there. There were fewer questions, less dialogue—it felt like I was talking to a void." These perceptions align with Alsaeed and Aladil (2024), who argue that Saudi Arabia's digital transformation under Vision 2030 has improved access but not necessarily interaction—especially in mathematics instruction, where real-time conceptual discussion is crucial.

As one teacher (T.145) reflected: "We were handed the tools, but not the methods." This reinforces the quantitative finding that psycho-emotional and perceptual constraints remain elevated, especially among teachers dealing with disengagement in virtual environments.

These results extend prior research by illustrating that technology does not automatically enhance communication—its success relies on teachers' preparedness to integrate digital pedagogy that supports interpersonal connection and active participation (Pianta et al., 2020). Therefore, professional development should include training on interaction design, not merely platform usage, to create emotionally attuned and cognitively stimulating digital learning spaces.

5.7. Toward Stronger Pedagogical Support

The integration of quantitative and qualitative findings in this study reinforces the understanding that instructional interaction barriers are multifaceted, dynamic, and context-dependent. Statistical analyses illuminated structural and demographic patterns, while interviews revealed the lived realities underlying those patterns. Together, these strands of evidence underscore the need for systemic interventions that equip teachers with the emotional, perceptual, and technological competencies essential for meaningful classroom engagement.

This study contributes uniquely by demonstrating how demographic variables intersect with institutional pressures to shape teachers' experiences—a dimension that has been insufficiently addressed in previous Saudi and regional research. In doing so, it highlights the complex ecology of teaching, where individual skill, institutional support, and cultural expectations collectively influence the quality of instructional interaction.

Ultimately, fostering effective instructional interaction requires more than technical expertise; it demands empathy, trust, and sustained institutional commitment. When teachers are empowered with professional voice, self-efficacy, and culturally responsive pedagogical training, classrooms can evolve into more engaging, equitable, and relationally supportive learning environments.

5.8. Practical Implications for Policy and Teacher Development

The findings of this study carry significant implications for educational policymakers and school leaders in Saudi Arabia. Given the clear variability in perceived instructional interaction barriers across gender, school type, school level, and teaching experience, professional development programs should be differentiated to address the distinct needs of each teacher group.

For example, novice teachers—who reported heightened perceptual and physical challenges—may benefit from structured mentoring, peer observation, and classroom management coaching. Male teachers—who experienced greater psycho-emotional strain—may require professional support focused on relationship-building and empathetic communication strategies. Public school teachers—who face more structural and environmental obstacles—would benefit from enhanced material resources, manageable workloads, and institutional flexibility.

Additionally, digital pedagogy training should be embedded within continuous professional development to ensure teachers are adequately prepared for blended and technology-enhanced learning environments aligned with the goals of Vision 2030.

By translating these findings into actionable professional standards, supervisory frameworks, and school-level reforms, the Ministry of Education can enhance instructional effectiveness, reduce teacher burnout, and foster more equitable, engaging, and sustainable mathematics learning environments across the Kingdom.

6. Conclusion

This study demonstrated that instructional interaction barriers vary significantly by gender, school type, school level, and teaching experience among mathematics teachers in Saudi Arabia. The integration of quantitative results with teachers' personal accounts provided a deeper understanding of how these barriers manifest in daily practice, particularly the emotional fatigue associated with student disengagement and the structural constraints of overcrowded classrooms and demanding curricula. These findings reinforce that effective instructional interaction requires supportive working environments, pedagogical adaptability, and attention to teacher well-being — alongside curriculum expectations.

Moreover, improving teachers' interactional capabilities aligns directly with the goals of Saudi Arabia's Vision 2030, as meaningful teacher–student communication is essential for developing motivated, resilient, and high-achieving learners in mathematics. To translate these findings into practice, several targeted actions are recommended:

Implications for schools and professional development:

• Strengthen mentoring and coaching programs for novice teachers to enhance classroom-management and student-engagement skills. Enhancing teacher–student interaction, which has shown positive influence on learning outcomes in Saudi educational contexts (Abed, Abed, & Shackelford, 2024), should remain a core focus of professional development initiatives aligned with Vision 2030 reforms.

• Provide structured well-being support — such as peer mentoring and stress-reduction initiatives — particularly for male and secondary-level teachers facing heightened psycho-emotional strain.

• Improve physical learning environments in public schools to reduce noise, overcrowding, and resource limitations.

• Offer training on dialogic and student-centered instructional communication that addresses both semantic and perceptual misunderstandings in mathematics.

• Enhance digital pedagogy preparation to ensure technology increases — rather than inhibits — student interaction.

Implications for policy planning:

• Align professional development with differentiated teacher needs based on experience level and school context.

• Incorporate interaction-focused standards into accreditation and supervision frameworks.

• Support initiatives that connect instructional interaction with well-being and workload reforms.

By prioritizing these actions, educational leaders can reduce persistent instructional barriers and foster more engaging, equitable, and interactive learning environments that empower both teachers and students to thrive.

7. Limitations and Future Research

Despite the strengths of its mixed-methods design, this study has several limitations. The sample was limited to mathematics teachers in the Al-Ahsa region, which may restrict the generalizability of findings to other Saudi regions with different school contexts and administrative policies. Additionally, the quantitative results were based on self-reported data, which may be subject to personal bias or social desirability effects. The qualitative component, while providing valuable contextual depth, included only eight participants, offering a focused yet limited range of perspectives.

To build upon these findings, future research should:

• Include broader regional samples across Saudi Arabia to enhance representativeness.

• Integrate classroom observations and student perspectives to triangulate and validate self-reported data.

• Expand qualitative sampling to capture a wider diversity of teaching experiences and school contexts.

• Employ longitudinal designs to examine how instructional interaction barriers evolve across different career stages.

• Evaluate the effectiveness of targeted professional development programs designed to reduce perceptual and psycho-emotional barriers.

Strengthening evidence-based research along these directions will support scalable improvements in instructional interaction and contribute to realizing the educational aspirations outlined in Saudi Arabia's Vision 2030.

Declarations

Author Contributions. Both authors contributed equally to the conception, design, data collection, analysis, and writing of this study. Both authors approved the final version of the manuscript.

Conflicts of Interest. The authors declare that they have no conflict of interest.

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Data Availability Statement. The data supporting the findings of this study are available from the corresponding author upon reasonable request; sensitive data are protected in accordance with institutional policies.

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Generative AI Usage. The authors used generative AI tools (e.g., ChatGPT) to improve the manuscript's language clarity. All interpretations and analyses remain the sole responsibility of the authors.

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