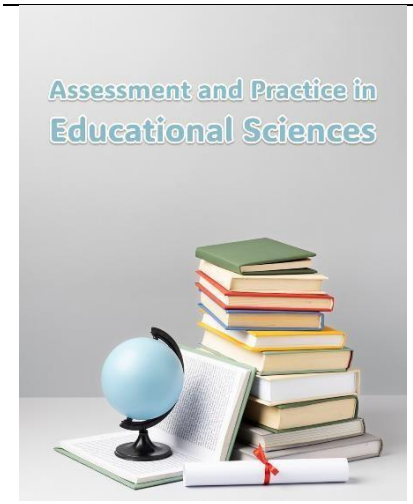
Assessment and Practice in Educational Sciences



Identifying Effective Metrics in Instructor–Student Interaction in Virtual Education

ABSTRACT

This study was conducted with the aim of designing and validating an indigenous and comprehensive model for virtual education, focusing on identifying and strengthening effective interaction between instructors and students in Iranian universities. The research was implemented using a sequential exploratory mixed-methods approach. In the qualitative phase, employing a phenomenological method and interviews with 12 experts, the dimensions and components of the initial model were extracted. In the quantitative phase, the proposed model was tested using a researcher-developed questionnaire (89 items) and a sample of 379 students from universities in Golestan Province. The data were analyzed using confirmatory factor analysis and structural equation modeling in PLS and SPSS software. The findings led to the design and validation of a six-dimensional model that explains effective interaction based on educational, communicative, emotional-psychological, and technological dimensions. The components of "active student participation" and "quality of instructor feedback" were identified as the strongest indicators of interaction. Confirmatory factor analysis confirmed good model fit and significant path coefficients (all above 0.79). The proposed model provides a systematic and indigenous framework for understanding and improving interaction in virtual education in Iran. This model indicates that achieving high-quality interaction requires moving beyond a one-way information transmission paradigm toward activating instructional design, sustained bidirectional communication, and simultaneous attention to emotional and technical dimensions. Application of this model can serve as a basis for developing practical strategies for instructors, instructional designers, and policymakers.

Keywords: Virtual education; instructor–student interaction; indigenous model; validation

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Introduction

The rapid expansion of virtual education has fundamentally transformed the landscape of higher education, reshaping traditional teaching–learning processes and redefining the nature of instructor–student interaction. Advances in digital technologies, learning management systems, and online communication tools have enabled universities to transcend temporal and spatial constraints, offering unprecedented access to educational opportunities. However, alongside these advantages, virtual education has raised critical pedagogical, psychological, ethical, and organizational challenges, particularly with regard to sustaining meaningful and effective interaction between instructors and students. Interaction is widely recognized as a cornerstone of educational quality, influencing learner engagement, motivation, satisfaction, and academic achievement. In

virtual environments, where physical co-presence is absent, the design and facilitation of interaction become even more crucial and complex (1, 2).

The global shift toward virtual education was dramatically accelerated during the COVID-19 pandemic, compelling higher education institutions worldwide to adopt online and blended learning models with limited preparation. This sudden transition highlighted both the potential and the limitations of virtual education systems. While online platforms enabled continuity of instruction, many studies reported weaknesses in interaction quality, feedback mechanisms, emotional support, and student engagement. These shortcomings underscored the need for systematic models that explicitly address instructor–student interaction as a multidimensional construct encompassing educational, communicative, emotional, technological, and organizational dimensions (3, 4). Consequently, interaction has emerged as a central criterion for evaluating the effectiveness and sustainability of virtual education.

From a pedagogical perspective, effective interaction is closely linked to instructional design quality and the alignment of learning activities with educational objectives. Research in virtual and blended learning environments indicates that well-structured content, active learning strategies, collaborative tasks, and timely formative assessment significantly enhance student participation and learning outcomes. Heutagogical and learner-centered approaches further emphasize autonomy, self-regulation, and co-construction of knowledge, positioning students as active agents rather than passive recipients of information (5, 6). In this context, instructor–student interaction extends beyond content delivery to include guidance, facilitation, scaffolding, and adaptive feedback tailored to learners' needs.

Communication constitutes another critical dimension of interaction in virtual education. Unlike face-to-face classrooms, online learning environments rely heavily on mediated communication through synchronous and asynchronous channels such as video conferencing, discussion forums, messaging systems, and emails. The clarity, frequency, and reciprocity of communication significantly influence students' perceptions of presence, accessibility, and support. Empirical studies demonstrate that continuous, transparent, and bidirectional communication fosters trust, reduces ambiguity, and enhances students' sense of connection with instructors and peers (7, 8). Conversely, delayed responses, unclear instructions, and limited opportunities for dialogue can weaken engagement and lead to dissatisfaction and disengagement.

Beyond instructional and communicative aspects, the emotional and psychological dimensions of interaction play a vital role in virtual education. Students' motivation, sense of belonging, self-efficacy, and emotional well-being are strongly shaped by the quality of their interactions with instructors. In virtual settings, where learners may experience isolation, anxiety, or cognitive overload, emotional support and empathy from instructors become essential. Studies have shown that instructor behaviors such as encouragement, recognition of individual differences, and respectful interaction contribute significantly to sustaining motivation and persistence in online courses (9, 10). At the same time, inadequate management of online interactions may expose students to cyber-related harms, including miscommunication, emotional distress, and inappropriate behaviors, highlighting the need for ethical and supportive interaction frameworks (11).

Technological infrastructure and digital competencies form another foundational layer influencing instructor–student interaction. The effectiveness of interaction in virtual education is contingent upon reliable platforms, user-friendly interfaces, and access to diverse communication and collaboration tools. Learning management systems, virtual classrooms, and emerging technologies such as virtual and augmented reality offer new possibilities for interactive and experiential learning, particularly in professional and skills-based education (12). However, technological barriers, limited digital literacy, and insufficient technical support can hinder interaction and exacerbate inequities among students and instructors. Therefore, interaction models must account for both enabling and constraining technological factors (13).

Institutional, legal, and ethical considerations further shape the context of virtual education and interaction. Universities are increasingly required to address issues related to academic integrity, data privacy, digital rights, and ethical conduct in online environments. Faculty members and students alike express concerns regarding the legal and ethical dimensions of virtual education, which can influence their willingness to engage openly and interactively (14). Effective interaction models must therefore be aligned with institutional policies, ethical standards, and support structures to ensure safe, equitable, and responsible learning environments.

Empirical evidence from diverse disciplinary and cultural contexts underscores that instructor–student interaction is not a unidimensional phenomenon but rather a complex system of interrelated components. Comparative and cross-cultural studies reveal variations in interaction patterns influenced by educational traditions, institutional cultures, and disciplinary norms. For example, analyses of interaction in different university systems highlight how pedagogical expectations and communication styles shape the dynamics of virtual classrooms (7). Similarly, studies conducted in medical and paramedical education contexts demonstrate that students' preferences, satisfaction, and learning experiences in virtual education are closely tied to interaction quality, feedback, and perceived instructor presence (1, 15).

Despite the growing body of research on virtual education, several gaps remain. Many existing studies focus on isolated aspects of interaction, such as communication tools or student satisfaction, without integrating educational, emotional, technological, and organizational dimensions into a coherent framework. Moreover, a significant portion of the literature relies on descriptive evaluations or short-term assessments conducted during emergency remote teaching periods, limiting their generalizability and theoretical depth (3, 4). There is a clear need for comprehensive, empirically validated models that conceptualize instructor–student interaction as a multidimensional construct and provide practical guidance for instructional design, faculty development, and policy-making in virtual education.

In response to this need, recent scholarship has begun to propose integrative models aimed at improving interaction quality in virtual university systems. These models emphasize the alignment of pedagogical strategies, communication practices, motivational support, and technological infrastructure to create interactive and learner-centered online environments (8, 9). Additionally, the integration of self-directed and heutagogical principles highlights the evolving role of instructors as facilitators of learning leadership rather than sole transmitters of knowledge (5, 6). However, many of these models remain context-specific or lack rigorous validation across diverse student populations.

Given the expanding role of virtual education in higher education systems and its strategic importance for academic continuity, quality assurance, and educational equity, developing a robust and validated model of instructor–student interaction is both a theoretical and practical imperative. Such a model should not only capture the multifaceted nature of interaction but also reflect the specific cultural, institutional, and technological context in which virtual education is implemented. By synthesizing insights from educational theory, empirical research, and contemporary technological developments, it becomes possible to design interaction frameworks that enhance learning effectiveness, student satisfaction, and instructional sustainability (2, 13).

Accordingly, the present study seeks to address these gaps by systematically designing and validating a comprehensive model of virtual education with an emphasis on instructor–student interaction, integrating educational, communicative, emotional–psychological, technological, and organizational dimensions, with the aim of providing an empirically grounded framework to improve the quality and sustainability of interaction in virtual higher education.

Methods and Materials

In this study, to achieve the main objective—designing and validating a virtual education model with an emphasis on instructor–student interaction—a sequential exploratory mixed-methods approach was employed. In the qualitative phase, in order to achieve in-depth exploration and description of the nature of the phenomenon, the lived-experience phenomenological method based on Edmund Husserl's approach was used. Participants in this phase consisted of 12 expert and experienced instructors in virtual education, who were selected through purposive snowball sampling until theoretical saturation was reached. Data were collected through in-depth semi-structured interviews and subsequently coded and analyzed using thematic analysis. This process led to the extraction of components, dimensions, and indicators of interaction and ultimately to the design of the initial conceptual model of the study. In the quantitative phase, aimed at validating the qualitative model, a descriptive–survey method was employed. The statistical population of this phase consisted of students from universities in Golestan Province, from whom 379 individuals were selected as the sample using the Krejcie and Morgan formula and stratified random sampling. The data collection instrument in this phase was a researcher-developed questionnaire based on the qualitative findings, comprising 89 items. Instrument validity was confirmed through content validity (by calculating CVI and CVR indices), face validity, and construct validity (convergent and discriminant). Reliability was also confirmed by calculating Cronbach's alpha and composite reliability coefficients (all above 0.70). Quantitative data were analyzed using descriptive and inferential statistics (including exploratory and confirmatory factor analysis and structural equation modeling) with SPSS and PLS software. Overall, this two-phase methodology enabled both an in-depth understanding of the phenomenon and comprehensive validation of the findings.

Findings and Results

Based on the concepts and content presented in the previous chapters—generalities, literature review, and research method—this section examines and analyzes the data obtained from the qualitative, descriptive, and inferential investigation of the target statistical sample. Through data analysis, information and results are discovered, identified, and categorized. Since the present study focuses on designing and validating a virtual education model with an emphasis on instructor–student interaction at the university level, the researcher analyzed the data obtained from interviews and questionnaires after extraction and categorization, conducting qualitative analysis and quantitative analysis using SPSS version 21 and PLS version 3.2, as well as the Kolmogorov–Smirnov test, one-sample t-test, exploratory factor analysis, confirmatory factor analysis, and structural equation modeling. What follows presents data analysis based on qualitative, quantitative, and inferential data. Prior to entering the main discussion, demographic information related to participants in the qualitative phase and the statistical sample in the quantitative phase is presented.

Table 1. Multidimensional and Integrated Indicators of Instructor–Student Interaction in Virtual Education

Organizing Theme	Initial Themes
Educational Interaction Indicators (Related to teaching–learning quality and instructional design)	Clarity and transparency of instructional objectives
	Coherent and logical course structure
	Effective and goal-oriented instructional content design
	Diversity of interactive instructional activities
	Quality of collaborative and group activities
	Design of group activities based on active learning
	Continuous and process-oriented assessment of learning
	Alignment of assessment methods with instructional objectives
	Continuous, regular, and practical instructor feedback
	Alignment of feedback with student performance and progress
	Completion of instructional activities and assignments by students

	Ability to apply learned content in activities and projects
Communicative Interaction Indicators (Related to the quality, continuity, and clarity of instructor–student communication)	Prompt and timely instructor responses to questions
	Clarity of messages, instructions, and instructional expectations
	Availability of diverse communication channels (chat, forum, email, online sessions)
	Regular opportunities for questions and answers
	Bidirectional and multidirectional dialogue in virtual classes
	Continuous and sustained interaction throughout the course
	Activation and facilitation of group discussions
	Level of student participation in discussions and forums
	Quality of communicative messages and interactions
	Timely and effective instructional notifications
	Ease of establishing formal and informal communication with the instructor
Emotional–Psychological Interaction Indicators (Related to students' emotional, psychological, and social experiences)	Student motivation for learning
	Instructor emotional and psychological support
	Development of mutual trust between instructor and students
	Strengthening a sense of belonging to the class and learning group
	Sense of psychological safety in expressing questions and viewpoints
	Student satisfaction with instructional interactions
	Instructor attention to students' individual needs
	Respectful and positive instructor–student interactions
	Enhancement of learning self-efficacy and self-confidence
	Interest in active participation in instructional activities
	Willingness to continue learning and interaction in the virtual environment
Technical–Technological Interaction Indicators (Related to infrastructures and tools facilitating interaction)	Ease of use of the educational platform (e.g., LMS)
	Easy and stable access to instructional content and resources
	Reliability and stability of the virtual education system
	Availability of diverse communication tools (chat, forum, videoconference)
	Instructor and student familiarity with the educational platform
	Quality of user experience in the virtual environment
	Speed and efficiency of the educational system
	Adequate and accessible technical support
	Possibility of synchronous and asynchronous interaction
	Absence of technical barriers in the instructional interaction process

The following table presents the results of confirmatory factor analysis (CFA) for assessing the model fit and measurement validity of the "Virtual Education with Emphasis on Instructor–Student Interaction" model. This model consists of six latent (unobserved) dimensions, each measured by observable components (items/questions). For each relationship between a component and its corresponding latent dimension, three key indices are reported.

Table 2. Results of Confirmatory Factor Analysis

Dimension / Component	t-value	Standardized Coefficient (β)	R^2
Continuous communication and information exchange	182.110	0.924	0.856
Student motivation and support	96.134	0.952	0.907
Educational	95.338	0.914	0.835
Communicative	128.739	0.933	0.871
Emotional / Psychological	30.268	0.790	0.625
Active student participation	213.862	0.966	0.932
Quality of instructor feedback and communication	169.970	0.952	0.907
Individual barriers	65.926	0.845	0.715
Organizational and technological barriers	88.345	0.905	0.819
Use of online tools and technologies	38.136	0.801	0.642

Design of collaborative and group activities	97.844	0.905	0.818
Continuous feedback and opportunities for direct interaction	48.089	0.816	0.666
Instructional and participatory activities	133.437	0.951	0.905
Communication, support, and access to technological tools	92.364	0.940	0.884

Standardized coefficient (β) indicates the strength of the relationship between each component and its higher-order latent dimension. All coefficients range from 0.790 to 0.966, exceeding the minimum acceptable threshold of 0.70. These results indicate excellent convergent validity of the model, meaning that each set of components strongly and appropriately measures its intended latent dimension. The highest coefficient belongs to the component "Active student participation" (β = 0.966), indicating that this component is the strongest indicator for measuring the level of effective interaction. The lowest coefficient is related to the "Emotional/Psychological" component (β = 0.790), which nevertheless remains within an acceptable range.

Coefficient of determination (R^2) specifies the extent to which each component explains the variance of its corresponding latent dimension. R^2 values range from 0.625 to 0.932. For example, the component "Student motivation and support" explains approximately 91% ($R^2 = 0.907$) of the variance in the quality and continuity of interaction dimension. The component "Active student participation", with $R^2 = 0.932$, demonstrates the highest explanatory power. Even the lowest value ($R^2 = 0.625$) remains acceptable, indicating adequate explanatory contribution of the component. Identifying quantitative and qualitative indicators, monitoring tools, and effective evaluation methods enables precise analysis of interaction levels and refinement of instructional approaches. These indicators play a vital role in improving the virtual education process and designing efficient interactive models. To further examine this issue, the study revisits the qualitative analyses conducted earlier, and the relevant sections are re-presented here.

Based on the results of structural equation modeling using PLS software, the relationships among dimensions, components, and the main variable—virtual education with emphasis on instructor–student interaction—demonstrate substantial explanatory power. The R^2 value of the main variable indicates that the set of dimensions included in the model explains a significant portion of the variance in instructor–student interaction in virtual education, reflecting the structural adequacy of the model. Among these, the dimensions "Instructor–Student Interaction in Virtual Education" and "Quality and Continuity of Instructor–Student Interaction", as key mediating constructs, play an important intermediary role in transmitting the effects of components to the main variable. Their R^2 values fall within the moderate-to-high range, indicating appropriate explanatory power at multiple levels of the model. Regarding path coefficients, the educational dimension, with a high path coefficient (approximately 0.91), is identified as one of the strongest predictors of instructor–student interaction, highlighting the central role of instructional design quality, continuous feedback, and learning-centered activities in strengthening interaction. Similarly, the communicative dimension, with a very strong path coefficient (approximately 0.93), indicates that continuous, transparent, and bidirectional communication between instructors and students accounts for the largest share in explaining effective interaction. The student motivation and support component within the quality and continuity dimension also shows a high path coefficient (approximately 0.95), confirming that motivation, support, and a sense of belonging are decisive factors in sustaining interaction. In contrast, the emotional–psychological component, with a moderate path coefficient (approximately 0.79), still exerts a significant effect on interaction, though its role is more facilitative and contextual rather than a primary determinant. Additionally, the components "Individual barriers," "Organizational and technological barriers," and the dimension "Interaction barriers and challenges", with notable path coefficients, indicate that the presence of such barriers can inversely or negatively affect interaction levels, making their management essential for the success of the model. For example, the level of effective instructor–student interaction, with an appropriate R^2 value (approximately 0.35), suggests that the dimensions and components of the model explain a meaningful portion of variance in this construct. Overall, the combination

of strong path coefficients and moderate-to-high R^2 values demonstrates the structural validity, theoretical coherence, and desirable explanatory power of the proposed model in explaining instructor–student interaction in virtual education.

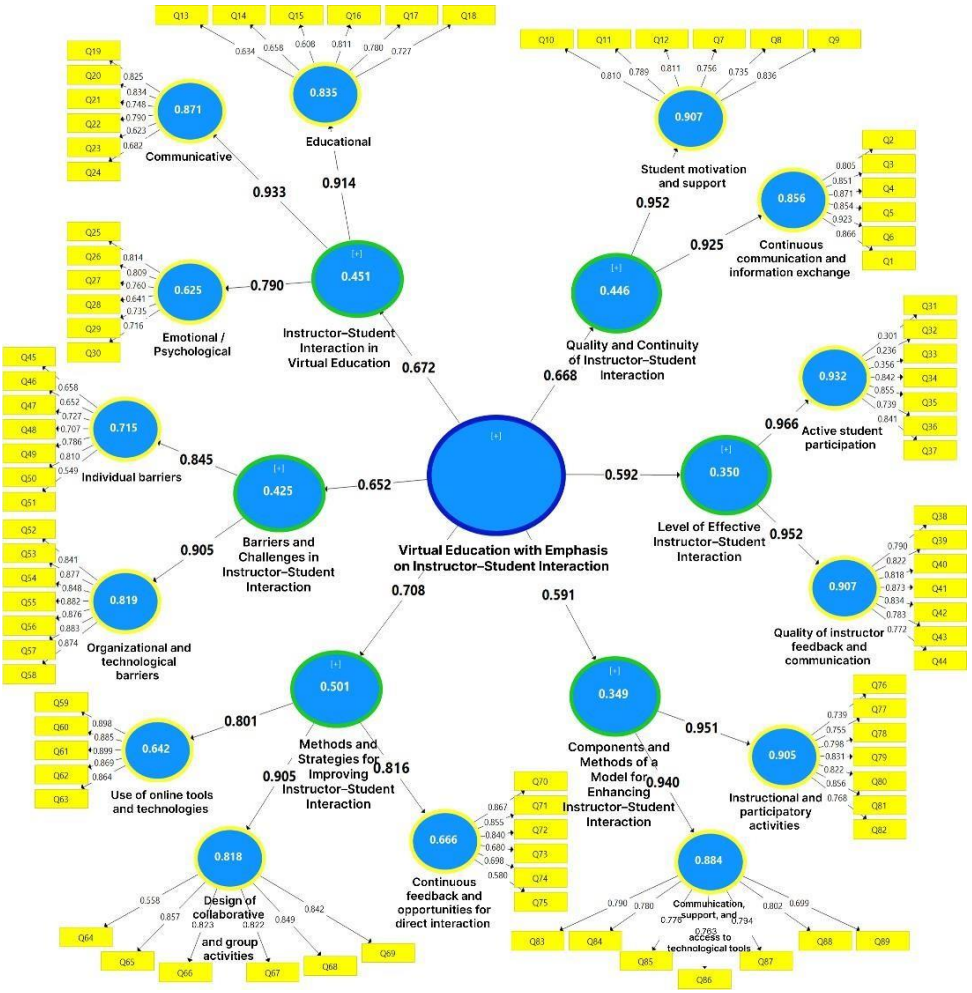

Figure 1. Relationship between Virtual Education with Emphasis on Instructor–Student Interaction and Its Dimensions (Path Coefficient Estimation)

Based on the results of structural equation modeling using the PLS approach and relying on path coefficients, t-statistics, and significance values (P values), a comprehensive explanation can be provided regarding how various dimensions and components influence the main research variable, namely virtual education with emphasis on instructor–student interaction. Overall, the high t-statistics (well above the threshold of 1.96) and P values equal to 0.000 indicate that all tested relationships in the model exhibit very strong statistical significance, and the causal structure of the model is empirically confirmed. At the first level, the relationship between virtual education with emphasis on interaction and the main dimensions of the model is fully significant. The path coefficient from this variable to the dimension of instructor–student interaction in virtual education ($\beta = 0.672$, $t = 18.383$) indicates that the more virtual education design and implementation focus on interaction, the more significantly the overall quality of instructor–student interaction increases. This dimension, as the conceptual core of the model, plays a key mediating role in transferring the effects of virtual education to other dimensions and outcomes. Moreover, the effect of interaction-focused virtual education on methods and strategies for improving instructor–student interaction ($\beta = 0.708$, $t = 20.057$) represents one of the strongest relationships in the model, indicating that an interactive approach directly leads to the selection and application of practical strategies such as collaborative activity design, continuous feedback, and purposeful use of technology. In other words, interactive virtual education cannot be realized without strategic and

methodological support. The significant relationship between virtual education and the level of effective instructor–student interaction (β = 0.592, t = 16.122) shows that emphasizing interaction leads to an improvement in the actual and practical level of interaction in virtual classrooms, manifested in observable behaviors such as active student participation and quality of instructor communication. Similarly, the significant effect of this variable on the quality and continuity of instructor–student interaction (β = 0.668, t = 17.378) indicates that interaction in virtual education must not only be established but also sustained over time, which requires continuous communication and motivational support. On the other hand, the relationship between virtual education and barriers and challenges to instructor–student interaction (β = 0.652, t = 17.119) is also significant, suggesting that as virtual education becomes more interaction-oriented, the identification and management of individual and organizational–technological barriers become increasingly important. Therefore, barriers are not merely peripheral elements of the model but play a decisive role in the ultimate effectiveness of interaction. Finally, the results related to the components and methods of the model for enhancing instructor–student interaction and the quality and continuity of interaction, with very high coefficients (β > 0.94), confirm that technological support, participatory instructional activities, continuous communication, and student motivation constitute the final and stabilizing pillars of the model.

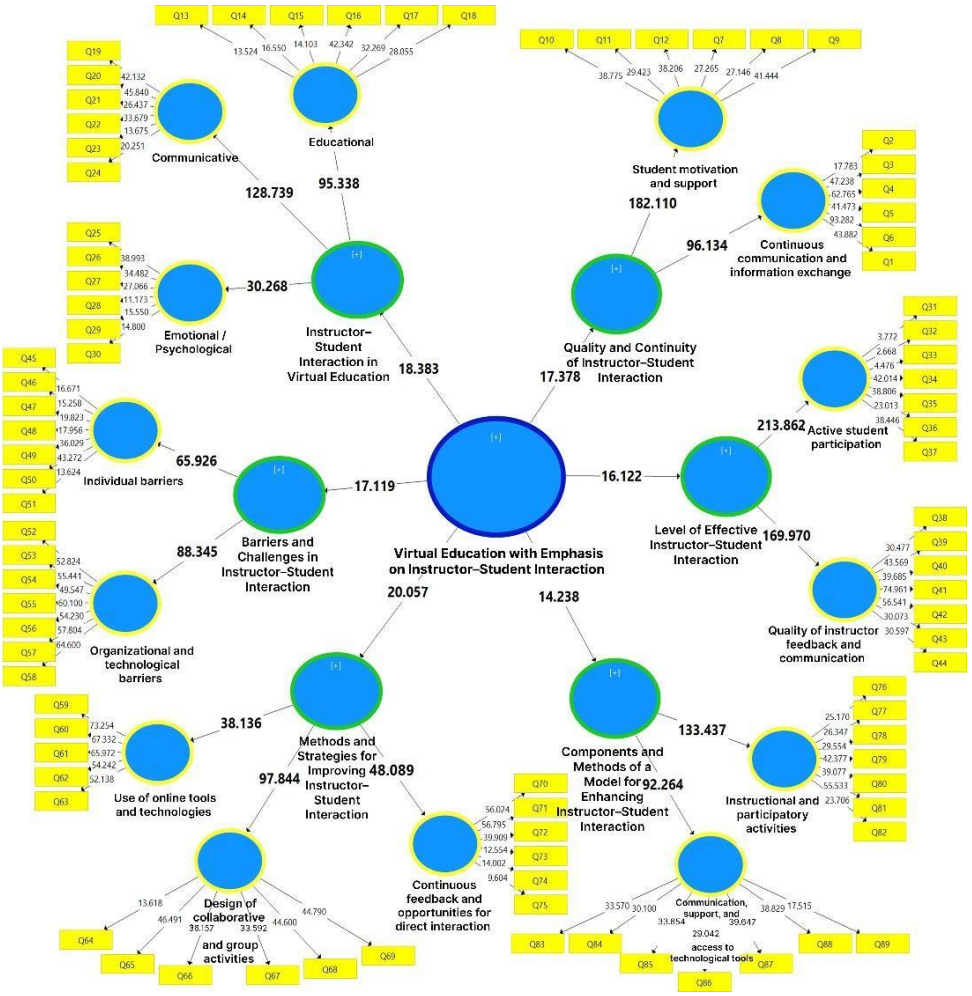

Figure 2. Relationship between Virtual Education with Emphasis on Instructor–Student Interaction and Its Dimensions (Path Significance Mode)

Discussion and Conclusion

The purpose of this study was to design and validate a comprehensive model of virtual education with an emphasis on instructor–student interaction. The findings provide strong empirical support for the multidimensional nature of interaction in virtual learning environments and demonstrate that effective interaction emerges from the dynamic integration of educational, communicative, emotional–psychological, technological, and organizational components. Overall, the results confirm that interaction in virtual education cannot be reduced to simple information exchange, but rather represents a complex pedagogical system that directly shapes learning quality, student engagement, and instructional sustainability.

One of the most significant findings of this study is the high explanatory power of the educational dimension in predicting effective instructor–student interaction. The strong standardized coefficients associated with instructional design quality, continuous assessment, feedback mechanisms, and participatory learning activities indicate that pedagogical structure remains the backbone of interaction in virtual environments. This finding aligns closely with heutagogical and learner-centered theories, which emphasize the role of instructional design in empowering learners, fostering autonomy, and facilitating meaningful engagement (5, 6). The results also corroborate prior empirical evidence showing that structured content, active learning strategies, and formative feedback significantly enhance interaction and learning outcomes in online and blended settings (8, 9). Therefore, interaction quality is deeply rooted in how learning activities are intentionally designed and pedagogically aligned.

The communicative dimension also emerged as one of the strongest predictors of effective interaction. High path coefficients related to continuous communication, clarity of messages, bidirectional dialogue, and accessibility of instructors suggest that communication functions as the primary conduit through which pedagogical intentions are realized in virtual education. These findings are consistent with comparative and cross-cultural studies demonstrating that transparent, timely, and reciprocal communication significantly strengthens students' sense of presence, trust, and engagement (7). Similarly, Shahvardi et al. emphasized that the strategic use of synchronous and asynchronous communication tools plays a decisive role in sustaining interaction and preventing learner disengagement in virtual classes (8). The present study extends this literature by empirically validating communication not merely as a supportive factor, but as a central structural component of interaction models.

Another key contribution of this study lies in highlighting the importance of the emotional–psychological dimension of interaction. Although this dimension demonstrated relatively lower coefficients compared to educational and communicative components, its effects remained statistically significant and theoretically meaningful. This suggests that emotional and psychological factors act as enabling conditions that reinforce and stabilize interaction rather than functioning as sole determinants. These results are in line with previous research indicating that motivation, emotional support, psychological safety, and a sense of belonging are critical for sustaining engagement and persistence in virtual learning environments (9, 10). Particularly in online contexts, where learners may experience isolation or reduced social cues, instructors' emotional responsiveness and supportive behaviors can mitigate disengagement and promote continuity of interaction.

The strong effects observed for the "student motivation and support" component further emphasize that interaction quality is inseparable from learners' internal states and perceptions. Motivation, encouragement, and recognition were found to significantly explain variance in interaction continuity, which supports earlier findings that students' willingness to participate actively in virtual education is closely tied to perceived instructor support and acknowledgment (1, 15). This is especially relevant in medical and paramedical education contexts, where studies have reported that students' satisfaction with virtual education largely depends on the quality of instructor interaction and motivational support (4, 15).

The technological dimension of the model also demonstrated substantial explanatory power, confirming that effective interaction is contingent upon reliable infrastructure, usability of platforms, and availability of diverse digital tools. These findings are consistent with prior studies emphasizing that learning management systems, communication tools, and emerging technologies shape not only access to content but also the quality and frequency of interaction (13). Moreover, the results align with recent research on advanced educational technologies, such as virtual and augmented reality, which highlights their potential to enhance interaction by creating immersive and experiential learning environments (12). However, the present study also demonstrates that technology alone is insufficient; its effectiveness depends on pedagogical integration and instructor competence.

Importantly, the identification of individual, organizational, and technological barriers as significant components of the model adds a critical dimension to the understanding of interaction in virtual education. The significant but inverse effects of these barriers indicate that unresolved technical issues, limited digital literacy, institutional constraints, and individual resistance can undermine even well-designed interactive models. This finding resonates with research documenting the challenges faced by students and instructors during large-scale transitions to virtual education, particularly during crisis contexts such as the COVID-19 pandemic (3, 4). Furthermore, concerns related to ethical and legal issues in virtual education, including privacy, academic integrity, and responsible online behavior, may indirectly affect interaction quality by shaping participants' trust and willingness to engage (11, 14).

The structural equation modeling results further confirm the mediating role of key interaction constructs within the proposed model. Dimensions such as "instructor–student interaction in virtual education" and "quality and continuity of interaction" functioned as pivotal intermediaries that transmit the effects of educational, communicative, emotional, and technological components to overall interaction effectiveness. This supports theoretical perspectives that conceptualize interaction as a systemic process rather than a collection of isolated behaviors. The moderate-to-high R^2 values observed across these constructs indicate that the proposed model possesses substantial explanatory power and structural coherence, reinforcing its validity as an integrative framework.

When considered in relation to previous literature, the findings of this study contribute to bridging existing gaps by offering a validated, multidimensional model that integrates diverse strands of research. While earlier studies often focused on singular aspects such as student satisfaction, communication tools, or emergency remote teaching outcomes (1, 3), the present study synthesizes these perspectives into a unified model that captures the complexity of interaction in virtual education. In doing so, it responds to calls for more theoretically grounded and empirically robust frameworks capable of informing instructional design, faculty development, and institutional policy (2, 13).

Overall, the discussion of results suggests that effective instructor–student interaction in virtual education emerges from the alignment of pedagogical intentionality, communicative clarity, emotional support, technological facilitation, and organizational readiness. The proposed model not only validates this alignment empirically but also provides a conceptual lens through which interaction can be systematically analyzed and enhanced. By situating these findings within existing research, the study reinforces the notion that interaction quality is a decisive factor in the success and sustainability of virtual higher education systems (2, 9).

Despite the strengths of this study, several limitations should be acknowledged. First, the quantitative phase relied on self-reported data from students, which may be influenced by response bias or subjective perceptions of interaction quality. Second, the sample was drawn from a specific regional and institutional context, which may limit the generalizability of the findings to other higher education systems or cultural settings. Third, although the model was rigorously validated using structural equation modeling, the cross-sectional design does not allow for causal inferences or examination of changes in interaction over time.

Finally, the study focused primarily on students' perspectives, while instructors' experiences and institutional viewpoints were not examined in equal depth.

Future research could build on the present findings by testing the proposed model in diverse academic disciplines, institutional types, and cultural contexts to enhance its external validity. Longitudinal studies are recommended to examine how instructor–student interaction evolves over time and how sustained interaction influences learning outcomes and retention in virtual education. Additionally, qualitative or mixed-methods research focusing on instructors' perspectives could provide deeper insight into pedagogical decision-making and interaction facilitation strategies. Experimental or intervention-based studies may also be useful to assess the effectiveness of targeted strategies derived from the model in improving interaction and learning performance.

From a practical standpoint, the findings highlight the importance of designing virtual education programs that explicitly prioritize interaction as a core quality indicator. Universities should invest in faculty development programs that enhance instructors' competencies in interactive instructional design, digital communication, and emotional support strategies. Instructional designers are encouraged to integrate collaborative activities, continuous feedback mechanisms, and flexible communication channels into online courses. Institutions should also strengthen technological infrastructure and technical support services to minimize interaction barriers. Finally, policymakers and educational leaders can use the proposed model as a strategic framework for evaluating, monitoring, and continuously improving the quality of interaction in virtual education systems.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adhered in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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