

Hybrid Communication Models in International Academic Conferences: Evaluating Engagement and Knowledge Dissemination

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Abstract This study aims to construct a comprehensive evaluation framework for hybrid academic conference communication effectiveness, systematically analyzing engagement characteristics and knowledge dissemination effects under different communication modes to provide theoretical foundations and practical guidance for optimizing academic exchange models in the post-pandemic era. This research adopts a mixed-methods design with 2,847 participants from four representative international academic organizations (IAFOR, ACM, IEEE, SCMR) selected through multi-dimensional stratified sampling. The study employs structural equation modeling, ANOVA, and network analysis to construct an engagement assessment system encompassing behavioral, cognitive, and emotional dimensions, alongside a knowledge dissemination effectiveness measurement model covering immediate effects, long-term impacts, and network effects. The results demonstrate that hybrid communication models significantly outperform traditional face-to-face and pure virtual modes in both comprehensive engagement and knowledge dissemination effectiveness. Specifically, hybrid models achieve information retention rates of 82.7% (± 7.4), significantly higher than virtual modes at 65.3% (± 9.1) and face-to-face modes at 78.5% (± 8.2); knowledge integration scores reach 79.3 points (± 8.1), surpassing other modes; new collaboration formation rates attain 31.5 percentage points, far exceeding virtual modes' 12.4 percentage points. Structural equation modeling analysis reveals that cognitive engagement has the strongest predictive effect on knowledge processing quality ($\beta = 0.82$, $p < 0.001$), while emotional engagement primarily influences network effects through direct pathways ($\beta = 0.31$, $p < 0.01$). This research validates the applicability of Media Richness Theory, Social Presence Theory, and Media Synchronicity Theory in hybrid communication environments, providing essential theoretical support and practical guidance for digital transformation and sustainable development of academic conferences, holding significant implications for promoting inclusivity and effectiveness in global academic exchange.

Keywords: hybrid communication models, academic conferences, engagement, knowledge dissemination, digital transformation, sustainable development, social presence theory

1 Introduction

The COVID-19 pandemic has brought an unprecedented global pandemic, which had a great impact on the academic conference organization pattern and the method of participation, and the traditional face-to-face academic communication method is facing an unprecedented challenge. Due to travel bans and social distancing measures imposed during the COVID-19 pandemic, the global academic community had to switch to online conference formats in a very short time [1], a change that was not only a stopgap but also instigated the change of an entire academic communication culture. With the development of digital technology and the deepening of the knowledge of the concept of sustainable development, a hybrid academic conference communication model began to appear, playing an important role in bridging traditional offline conferences and virtual conferences.

Academic conferences, as core platforms for knowledge production, dissemination, and exchange, have experienced transformations in their communication models that profoundly impact the entire academic ecosystem. Although traditional face-to-face conference models provide rich social interaction and immersive experiences, they present significant limitations in terms of geographic accessibility, economic costs, and environmental impact [2]. Pure virtual conference models, although capable of effectively reducing participation barriers and carbon emissions, still have shortcomings in social network construction and deep interaction [3]. Hybrid communication models, by integrating the advantages of offline and online formats, offer new possibilities for addressing these issues, but their specific communication effects and optimization strategies still require in-depth research.

Existing research on academic conference communication models has primarily focused on analyzing single modalities. Some scholars have concentrated on the environmental benefits of virtual conferences, comparing the sustainability of different conference models through life cycle assessment methods [4]. Other research has analyzed key factors influencing scholars' participation in academic conferences from the perspective of participation motivation [5]. Recent studies have begun to focus on virtual conference participants' subjective experiences and future expectations [6], as well as the impact of hybrid models on conference demographic characteristics [7]. However, these studies often employ single-dimensional measurement indicators in participation assessment, lacking deep understanding of the complexity of engagement in hybrid environments.

Current research shows significant deficiencies in knowledge dissemination effectiveness assessment. Traditional evaluation methods primarily focus on short-term participation indicators, lacking systematic analysis of the long-term effects and cross-cultural impacts of knowledge dissemination. Although research on the social and scientific benefits of academic conference participation provides important perspectives for understanding conference value [8], studies on knowledge dissemination mechanisms in hybrid models remain limited. While conference impact assessment research in medical education provides valuable measurement frameworks [9], the applicability of these frameworks in other disciplinary fields requires verification. Existing research lacks in-depth exploration of the linkage mechanisms between engagement and knowledge dissemination effectiveness, particularly the dynamic patterns of their relationship in hybrid communication environments.

Virtual and hybrid conferences as effective strategies for addressing climate change are receiving increasing attention [10], but related research primarily approaches from environmental sustainability

perspectives, with relatively weak systematic assessment of communication effects. Existing research often views hybrid models as simple supplements to traditional models rather than emerging models with unique communication characteristics, a cognitive limitation that affects comprehensive understanding of the advantages and challenges of hybrid communication models.

This study aims to fill the aforementioned research gaps by constructing a comprehensive evaluation framework for hybrid conference communication effectiveness and systematically analyzing engagement differences and knowledge dissemination effects under different communication models. The innovation of this research lies in: establishing a multi-dimensional engagement assessment system that can comprehensively reflect participants' experience quality in hybrid environments; constructing a comprehensive measurement model for knowledge dissemination effectiveness covering immediate effects and long-term impacts; exploring the inherent linkage mechanisms between engagement and knowledge dissemination effectiveness to provide theoretical basis for optimizing hybrid communication strategies.

This research, through in-depth analysis of hybrid communication practices in international academic conferences, systematically evaluates engagement characteristics and knowledge dissemination effects under different models, providing scientific decision support for academic conference organizers. The research findings not only help improve the organizational efficiency and communication quality of academic conferences but also provide important theoretical support and practical guidance for innovative development of academic exchange models in the post-pandemic era, holding significant practical significance for promoting digital transformation and sustainable development in academia. These three innovations directly address the theoretical gaps, methodological limitations, and practical needs identified in the literature review, positioning this research as a comprehensive contribution to the emerging field of hybrid academic communication.

2 Literature Review

2.1 Development Context of Hybrid Communication Models

The evolution of academic conference communication models reflects the dual driving forces of technological progress and social needs. Traditional face-to-face conference models have long held dominant positions, but their limitations in accessibility and sustainability have become increasingly prominent. Research in the astronomy field indicates that the carbon footprint problem of large international conferences has become a focus of academic attention [11]. This environmental pressure has prompted scholars to re-examine traditional conference organization models and explore more sustainable alternatives. The evolution of academic conference communication models is illustrated in Figure 1, clearly demonstrating the dynamic process of interaction between technological driving forces and social needs.

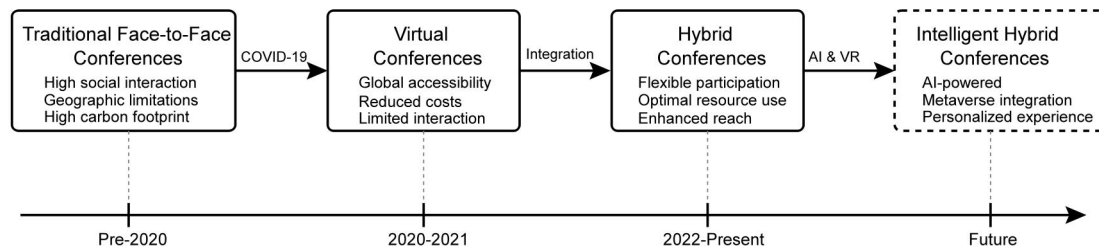


Figure 1. Timeline of Academic Conference Communication Model Evolution.

The pandemic accelerated the popularization and application of virtual conference technology. The rapid development of online conference platforms provided new possibilities for academic exchange, leading researchers to explore academic conference organization models in virtual environments [12]. Virtual meetings greatly represent a reduction in carbon footprint as well as a geographic and socioeconomic equalizer, allowing more researchers to attend international conferences. However, academic unity and deep interaction are still difficult to achieve in a purely virtual model.

Hybrid communication models are a departure from academic conference organizational thinking. The social benefits of traditional conferences will be taken into account, and the convenience of the virtual conference will also be used to design the new model, and this model has not been in-depth study of the impact and optimization strategies. The value and function of the conference are redefined in a post-pandemic era and there are challenges for the academic conference organizers [13]; thus, the hybrid is a solution that can keep the quality of academic exchange and adapt to the new normal.

2.2 Current Status Analysis of Engagement Research

Various research settings have produced substantial variation in the way engagement is conceptualized; this undermines the comparability and cumulative effects of research findings. The situation is likely to be even more challenging for groups of scholars who have caring responsibilities [14], since their patterns of participation and needs are very different compared to those of conventional participants, thus reminding researchers to take into account aspects of diversity and inclusivity in the assessment of engagement.

The influence of the presentation format of media on user engagement is crucial for understanding participation in hybrid environments. Studies on news communications have demonstrated that various information presentation approaches vary audience perceptions of credibility and engagement [15], which provides valuable references for designing hybrid conference communication strategies. The multi-level nature of engagement implies that researchers need to employ more holistic evaluation approaches as single indicators of the quality of experience are unlikely to fully capture the experiences of participants.

Recent studies have, in fact, started to underline complex factors influencing academic conference behaviors, such as the interaction among personal factors, conference factors, and environmental factors [16]. Taking this systematic approach contributes to a more holistic theoretical framework about engagement, yet studies to date insufficiently investigate processes of engagement changes

longitudinally in hybrid learning contexts. Standardization and normalization of approaches to measure engagement are now emerging as major research challenges.

2.3 Research Progress in Knowledge Dissemination Effectiveness Assessment

Development of knowledge dissemination effectiveness assessment methods has moved from single indicator to multi-dimensional systems. The old methods have focused on short-term rates of participation and have not entailed systematic examination of deep mechanisms and long-term impacts of knowledge dissemination. Systematic reviews of the evaluation of educational technology point to the richness and diversity of available evaluation methods [17], illustrating the field's dynamism and highlighting issues about the lack of standardized evaluation frameworks.

The processes for the role of preprints in knowledge dissemination provide new lessons in understanding models for academic exchange in the digital age. Experimental findings about early-career researchers' assumptions about preprint value are [18] that the digital dissemination tools are changing the processes for the production and dissemination of academic knowledge. This shift requires corresponding changes in conventional conference efficacy measurement models to adapt to new knowledge dissemination environments.

Life cycle assessment research on sustainable conferences provides important methodological foundations for hybrid model effectiveness assessment [19]. Such research not only focuses on environmental impacts but also involves comprehensive assessment of social and economic benefits, providing valuable experience for constructing comprehensive hybrid conference assessment frameworks. However, existing assessment frameworks still have limitations in capturing the unique value of hybrid models, particularly in quantifying synergistic effects produced by virtual-physical combinations.

2.4 Clear Identification of Research Gaps

Current research shows obvious deficiencies in systematic theoretical construction of hybrid communication models. Although some scholars have explored the impact of online participation on academic conference carbon footprints [20], such research often approaches from single dimensions, lacking comprehensive understanding of hybrid model complexity. Existing research often simply views hybrid models as technological enhancements to traditional models rather than emerging models with unique communication characteristics, a cognitive limitation that affects in-depth theoretical development.

Research on linkage mechanisms between engagement and knowledge dissemination effectiveness remains in its infancy. Although research has focused on inclusive reforms in citizen science and science communication [21], mechanism research on how engagement affects knowledge dissemination effectiveness in hybrid environments is relatively scarce. This research gap directly affects the scientific and targeted nature of hybrid conference optimization strategies.

The role mechanisms of cross-cultural and cross-time zone factors in hybrid communication have not received sufficient attention. Existing research is mostly based on data from single cultural backgrounds or geographic regions, lacking in-depth analysis of the adaptability and effectiveness of hybrid communication models in globalization contexts. Research on innovative sustainability in academic conference tourism [22], while providing cross-regional perspectives, still needs further exploration of specific mechanisms of cultural differences' impact on communication effectiveness. The existence of these research gaps highlights the urgency of establishing comprehensive assessment frameworks and deepening mechanism research.

3 Theoretical Framework

3.1 Logical Basis for Theory Selection

The complexity of hybrid academic conference communication models requires adopting multiple theoretical perspectives to explain their communication mechanisms and effectiveness differences. This research, based on core theories from communication studies and information systems fields, constructs a comprehensive theoretical framework covering media characteristics, social psychology, and communication processes. Media Richness Theory provides a basic framework for understanding the information-carrying capacity of different communication media, Social Presence Theory explains the psychological mechanisms of interpersonal interaction in virtual environments, and Media Synchronicity Theory provides operational guidance for optimizing hybrid communication strategies.

The logic of theory selection follows a progressive relationship from media attributes to user experience to communication strategies. The contemporary literature illustrates that news presentation formats exert significant influences on user engagement and perceived credibility [15], a format effect of the media no less salient in academic conference communication. Systematic research on the evaluation of educational technology reveals the multi-dimensionality of effectiveness assessment of technology application [17], providing methodological implications for interpreting intricate effectiveness processes of hybrid models of communication. These theoretical foundations form the aggregate basis for the systematic analysis framework for hybrid conference communication effectiveness.

3.2 Application Logic of Media Richness Theory

The media richness theory measures the information-carrying capacity of different media with four criteria: immediacy of feedback, number of cues, personal focus, and language variety. In the mixed context of an academic conference, this theory scientifically rationalizes the choice of medium in various communication segments. High-richness media (e.g., face-to-face, high-definition video conferencing) are appropriate for complex academic discussion and emotional exchange, and low-richness media (e.g., text chat, email) for informational transmission and material exchange. The rapid evolution of virtual conferencing technology offers new practical contexts for the application of Media Richness Theory [12]. Classifications of media richness used in traditional media do not easily generalize to digital environments; indeed, the rise of augmented reality and virtual reality technologies has caused the high-low richness distinction to become increasingly blurred. Hybrid conference models

with mixed media richness can meet the corresponding information processing requirements at various communication stages, thus enhancing overall communication effectiveness.

When Media Richness Theory is applied to hybrid conferences, the dynamic complexity and uncertainty of tasks must be taken into account. Various activities such as lectures, discussions, question-answering dialogues, and social network development have very different media richness needs. The crux of Institutional Theory is to build up the matching relationships between types of activities and that of communication media and the optimal configuration of the medium of communication for different communication segments.

3.3 Guiding Significance of Social Presence Theory

Social Presence Theory underlines the need to foster authenticity and intimacy in online settings, which may have significant effects on the quality of experience for virtual participants in hybrid conferences. This theory breaks social presence down into three essential elements: intimacy, immediacy, and social presence, but it can also be used to guide the design of effective interaction environments among virtual persons. In a hybrid conference setting, PVs tend to experience social presence deficiency, which influences their depth of participation and the effectiveness of knowledge acquisition.

During the pandemic, distance learning was practiced extensively, and this experience was rich enough for the application of the Social Presence Theory [23]. The study found that improving visual display, facilitating real-time interaction, and encouraging informal communication between them could significantly promote the social presence of virtual participants. The hybrid conference mode should worry about the balance of interaction activity between the two kinds of participants under both online status and offline status, avoid a "dual-track" appearance, and let the online participants feel the social presence experience as much as the offline participants.

The use of Social Presence Theory is further complicated by cultural variances, as well as individual preferences. Delegates from different cultural backgrounds have different demands from and understandings of social presence, which poses a great challenge to hybrid conference design to ensure diversified interaction and personalized participation. The social function design of technology and platforms, including virtual lounges, group discussions, and gamified interaction, is considered a big contributor to increased social presence.

3.4 Optimization Framework of Media Synchronicity Theory

Media Synchronicity Theory separates communication processes into conveyance processes and convergence processes, giving clear theoretical instruction for maximizing hybrid communication strategies. Conveyance processes are mostly information dissemination and distribution, appropriate for embracing asynchronous parallel communication techniques, whereas convergence processes target achieving consensus and cooperative knowledge construction, necessitating accentuation of the significance of synchronous communication. This differentiation logic has significant importance for conceptualization of optimization approaches for various communication phases in hybrid conferences.

The technology-based functionality of web conferencing systems provides opportunities for implementation of Media Synchronicity Theory in a realistic way [3]. Asynchronous communication functionalities such as recording playback, downloadable content, and asynchronous forums enable mass transfer of knowledge, while synchronous interaction functionalities such as live Q&A, instant polls, and collaborative document editing enable profound convergence. The advantage of hybrid conferences is that they can configure synchronicity levels freely based on different communication objectives and achieve double optimization of conveyance efficiency and convergence quality.

The application of Media Synchronicity Theory will have to consider the spatio-temporal distribution properties of participants. Global academic conferences face cross-time zone participation issues, and synchronicity design is required in order to align time convenience among participants across geographical areas. Asynchronous communication processes can adequately address time difference concerns, and crucial synchronous interaction stages must offer equal opportunities for participation for global participants through rotation scheduling and multiple sessions.

3.5 Construction of Integrated Theoretical Model

These three theories in combination build a holistic prediction model of hybrid conference communication effectiveness, putting media, social presence, and synchronicity design together for the first time, while the models in previous works are used singly to analyze each of the three. The comprehensive theoretical model of the effectiveness of hybrid conference communication is presented in Figure 2, which illustrates the interrelated relationships among the theoretical elements of the three theories in a systematic way and constructs relationships among them within the mechanism of integration and communication effectiveness. The underlying concept is to identify the medium richness required for communication tasks, enhance participation quality by increasing social presence, and optimize synchronicity for the best communication efficiency. Such a multi-theoretical integration can better account for the complex mechanisms of the effectiveness of hybrid communication models.

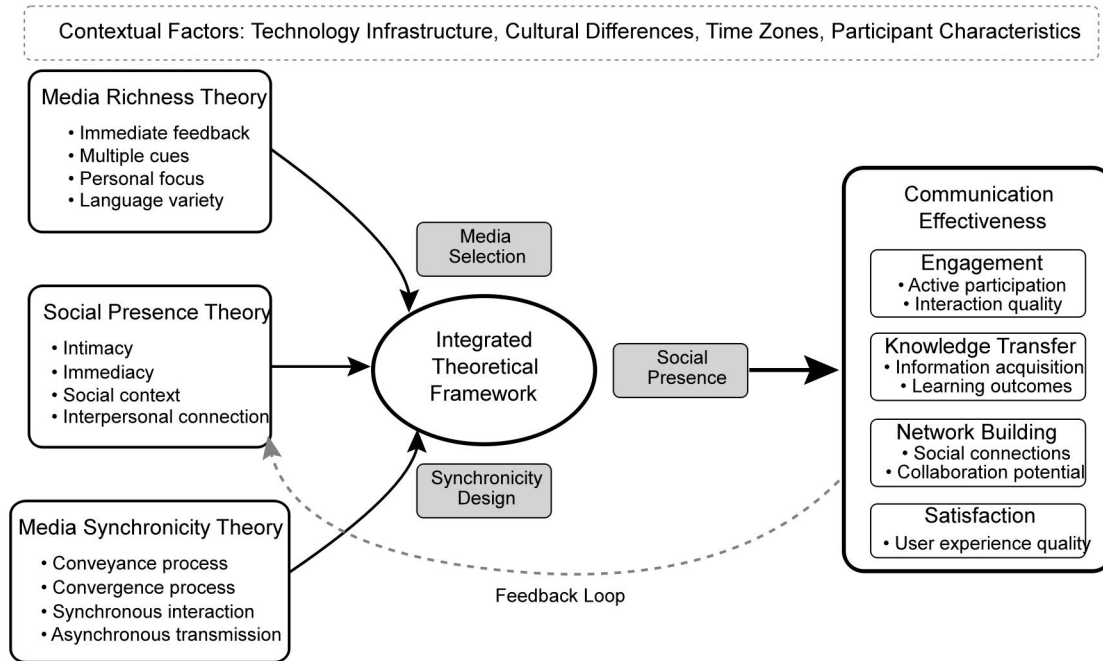


Figure 2. Integrated Theoretical Framework for Hybrid Conference Communication Effectiveness.

The construction of the integrated theoretical model needs to consider interaction relationships among the three major theories. High-richness media typically have stronger social presence creation capabilities but also require higher synchronicity. The optimization goal of the model is to achieve optimal balance among the three theoretical dimensions under given constraints, ensuring information transmission effectiveness while maintaining positive participant experiences and considering communication costs and technical feasibility.

The practical value of the theoretical model lies in providing scientific guidance for hybrid conference design and assessment. Related research on online higher education assessment provides reference frameworks for theoretical model application [24]. By establishing mapping relationships between theoretical dimensions and practical indicators, abstract theoretical concepts can be transformed into operational design principles and assessment standards. This combination of theory and practice ensures the scientific and applicability of the integrated model.

4 Materials and Methods

4.1 Research Design and Data Collection Strategy

This research adopts a mixed-methods research design, combining quantitative analysis methods, and systematically analyzes engagement and knowledge dissemination effectiveness of hybrid academic conference communication models through a strategy combining longitudinal tracking with cross-sectional comparison. The choice of mixed methods is based on the complexity and multi-dimensional characteristics of the research questions, as single research methods cannot comprehensively reveal the deep logic of hybrid communication mechanisms. The complete workflow

of research design and data collection is shown in Figure 3, demonstrating the systematic research path from theoretical construction to empirical verification.

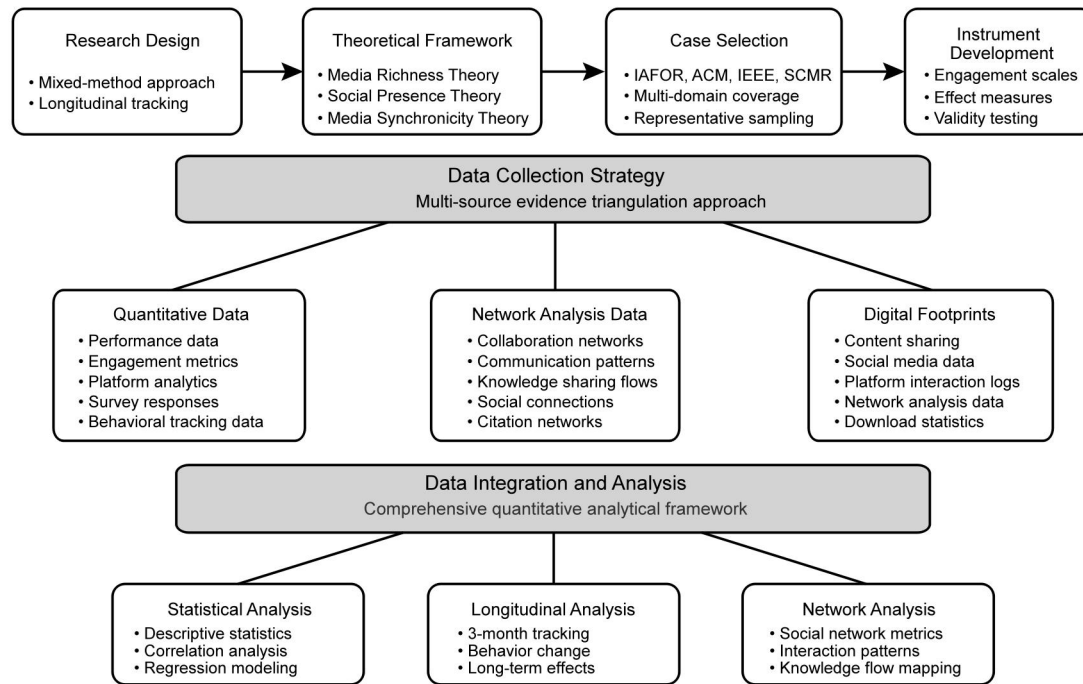


Figure 3. Research Design and Data Collection Workflow.

Data collection adopted diversified strategies, ensuring the reliability and validity of research results through triangulation methods. Data collection includes engagement indicator measurement, platform analytics data, questionnaire survey feedback, behavioral tracking data, and network analysis metrics to ensure comprehensive quantitative assessment of hybrid communication effectiveness. The digital transformation during the pandemic provided unprecedented opportunities for large-scale data collection [25], enabling the research to obtain rich real-time behavioral data.

4.2 Sample Selection and Case Determination

The research adopted multi-dimensional stratified sampling strategies to ensure sample representativeness and universal applicability of research results. Sample selection covers academic conferences of different scales, disciplinary fields, and geographic distributions, while considering participant diversity characteristics, including scholars at different career stages, participants from different cultural backgrounds, and user groups with different technical proficiency levels. Case selection for case conference is based on their prevalence and uniqueness in use of hybrid model of communication to facilitate qualitative empirical data and holistic analytical findings.

The rapid development of networked conference organization strategies provides a rich variety of case selection for studies [26]. The research focuses on international academic organisations with an extensive history of hybrid model introduction, identifying determinants of communication effectiveness through comparative analysis of different technical platforms and organisational model

effectiveness variation. Sample distribution has to achieve a balance between geographical representativeness and disciplinary heterogeneity so that research outcomes shall be cross-cultural and cross-field relevant. The final sample consisted of 2,847 participants, by organization as follows: IAFOR 892 participants (31.3%), ACM 746 participants (26.2%), IEEE 954 participants (33.5%), and SCMR 255 participants (9.0%). This distribution reflects the relative scale and accessibility of each organization while maintaining adequate statistical power for comparative analysis across different organizational contexts and hybrid model implementations. Detailed analysis of these four case organizations and their hybrid communication model implementations is presented in Section 5, providing comprehensive empirical foundations for understanding best practices and optimization strategies in different organizational contexts.

4.3 Measurement Tool Development and Validation

Based on the integrated theoretical framework, the research developed a comprehensive measurement tool system for evaluating engagement and knowledge dissemination effectiveness of hybrid academic conferences. Measurement tool design follows basic principles of psychometrics, verifying tool content validity, construct validity, and reliability indicators through multiple rounds of expert review and pre-testing. Specific measurement dimensions and evaluation indicators are shown in Table 1, with this indicator system covering multiple dimensions of engagement and comprehensive assessment of knowledge dissemination effectiveness.

Table 1. Measurement Instruments and Evaluation Indicator System.

Construct	Dimension	Indicators	Measurement Method	Data Source
Engagement	Behavioral Engagement	Session attendance rate	Platform analytics	Conference platforms
		Interaction frequency	Click/comment counting	Digital logs
		Content sharing behavior	Social media metrics	Social platforms
	Cognitive Engagement	Knowledge acquisition level	Pre-post assessments	Survey questionnaires
		Information processing depth	Statistical assessment	Survey questionnaires
		Critical thinking demonstration	Assessment scores	Quiz performance
	Emotional Engagement	Satisfaction with experience	Likert scale (1-7)	Post-conference surveys
		Sense of social presence	Social Presence Scale	Online questionnaires
		Motivation to participate	Motivation inventory	Self-report measures
Knowledge Dissemination	Immediate Effects	Information retention	Knowledge tests	Pre-post assessments
		Comprehension accuracy	Content understanding	Quiz performance
		Concept application ability	Case study analysis	Assignment evaluation
		Knowledge integration	Follow-up surveys	3-month tracking
Moderating Variables	Long-term Effects	Behavior change	Practice implementation	Observational studies
		Professional development	Career impact assessment	Longitudinal interviews

Construct	Dimension	Indicators	Measurement Method	Data Source
	Network Effects	Collaboration formation	Network analysis	Contact tracking
		Knowledge sharing patterns	Citation analysis	Publication records
		Community building	Social network metrics	Platform connections
	Individual Factors	Technical proficiency	Self-assessment scale	Background surveys
		Prior experience	Participation history	Demographic data
		Cultural background	Cultural dimensions	Participant profiles
	Contextual Factors	Conference characteristics	Size, duration, format	Organizational data
		Technology features	Platform capabilities	Technical specifications
		Content complexity	Subject matter analysis	Expert evaluation

The measurement tool development process includes theoretical construction, item generation, expert review, pre-testing, and formal administration stages. The engagement measurement scale combines behavioral, cognitive, and emotional dimensions, comprehensively reflecting participant engagement quality in hybrid conference environments through objective data recording and quantitative assessment methods. Knowledge dissemination effectiveness assessment adopts multi-time point measurement design, distinguishing immediate effects, long-term impacts, and network effects to ensure comprehensive and accurate assessment results.

Measurement tool reliability and validity verification is conducted through various statistical methods, including internal consistency testing, factor analysis, convergent validity, and discriminant validity testing. Design experience from public health emergency response systems provides important references for constructing complex measurement systems [27], particularly methodological insights in multi-source data integration and effectiveness assessment. The research continuously optimizes measurement tools through pilot testing to ensure their applicability and stability in different cultural backgrounds and technological environments.

4.4 Data Analysis Methods

Data analysis adopts a comprehensive quantitative framework, processing nested data structures through multi-level modeling methods and network analysis techniques. Statistical analysis includes descriptive statistics, correlation analysis, regression modeling, and structural equation modeling to test theoretical hypotheses and quantify variable relationships. The development of academic conference carbon emission assessment methods provides systematic methodological foundations for conference effectiveness assessment [28], particularly technical approaches in multi-dimensional indicator integration and effectiveness quantification.

The data analysis process strictly follows quality standards for quantitative research, ensuring credibility and reliability of analysis results through triangulation and peer review. Analysis software includes SPSS and R for statistical analysis and data visualization respectively. Network analysis employs social network metrics and collaboration pattern assessment to evaluate community building

and knowledge sharing effectiveness across different communication modes. Citation analysis tracks knowledge dissemination patterns through publication records and cross-referencing behaviors.

5 Case Studies

5.1 Strategic Considerations for Case Selection

The case study adopts a multiple-case design, providing rich empirical foundations for theoretical framework validation and best practice model identification through in-depth analysis of representative international academic conference organizations. Case selection follows theoretical sampling logic, ensuring selected cases cover different disciplinary fields, organizational scales, and technological characteristics, thereby providing comprehensive empirical bases for theoretical validation and practical guidance. This multiple-case comparative design enhances external validity and theoretical generalizability of research findings.

The four selected case organizations demonstrate outstanding innovation and influence in hybrid conference implementation, representing different development paths and technological solutions. Characteristics and selection criteria of case conferences are shown in Table 2. These organizations have accumulated rich experience in exploring and practicing hybrid communication models, providing valuable observation windows for research. Case selection particularly focuses on organizations that rapidly transformed during the pandemic and continued innovating in the post-pandemic era, whose practical experiences hold important value for understanding evolutionary patterns of hybrid communication models. It should be noted that the participant scales shown in Table 2 represent the total organizational membership of each case organization, providing context for their global reach and influence. The actual research sample drawn from these populations totaled 2,847 participants, with proportional representation maintaining the diversity characteristics of each organization.

Table 2. Characteristics and Selection Criteria of Case Conferences.

Organization	Domain	Annual Events	Participant Scale	Geographic Reach	Key Technology Features	Hybrid Model Type
IAFOR	Interdisciplinary	40+ conferences	40,000+ scholars	Global (25+ countries)	Catch-up recording, Live streaming, Interactive Q&A	Simultaneous hybrid
ACM	Computer Science	170+ conferences	100,000+ members	International (50+ countries)	Virtual reality sessions, AI-powered networking, Open access integration	Technology-enhanced hybrid
IEEE	Engineering & Technology	2,000+ conferences	400,000+ professionals	Worldwide (160+ countries)	Standardized platforms, Multi-language support, Cross-conference connectivity	Large-scale hybrid
SCMR	Medical Research	12+ conferences	15,000+ physicians	Global medical community	Social media integration, Clinical case sharing, Real-time consultation	Specialized hybrid

Note: Participant scale refers to total organizational membership; research sample sizes are: IAFOR (n=892), ACM (n=746), IEEE (n=954), SCMR (n=255).

5.2 IAFOR's Hybrid Model Innovation Practices

The International Academic Forum (IAFOR), as a pioneer in hybrid conference models, organizes over 40 annual academic conferences globally, with cumulative participation exceeding 40,000 scholars across 25+ countries and regions. IAFOR's hybrid communication model centers on "Catch-up" recording functionality innovation, allowing participants to flexibly engage with conference content according to personal schedules, effectively addressing cross-time zone participation challenges. This spatio-temporal flexibility design concept represents innovative application of Media Synchronicity Theory in practice.

The IAFOR online video platform offers user-friendly navigation and includes complete video files, downloadable slides, as well as interactive Q&A and the split-screen option, to satisfy your research needs. The IAFOR Replay feature also allows you to replay specific sessions: content is segmented into sections for easy navigation and playback. The association focuses especially on generating social presence for remote attendees by means of virtual lounges, group discussions, and gamified interaction features, reducing the sense of isolation of online participants. These pragmatic tools directly represent particular applications of Social Presence Theory key constructs in hybrid conference delivery.

IAFOR's institutional structure is particularly challenging for models of hybrid communication to accommodate, given its interdisciplinary nature. The members involved in the organization come from various fields (humanities, social sciences, natural sciences, engineering technology, etc.). Various field knowledge attributes and communication habits present heterogeneous requirements on hybrid communication strategies. By comparing the participation and effectiveness differences in interdisciplinary conferences, we can find patterns and optimization directions of disciplinary adaptability for hybrid communication models.

5.3 ACM's Technology-Driven Hybrid Transformation

The Association for Computing Machinery (ACM), being the largest professional computer science organization in the world, hosts more than 170 academic conferences annually with more than 100,000 members distributed in 50+ countries. The hybrid evolution of ACM has unique advantages of technical domain academic organizations, as the high-tech technological infrastructure and highly digitized community features of ACM provide ideal environments for wide utilization of hybrid communication patterns. Its hybrid conference platform combines technologies such as virtual reality sessions, AI-based network matching, and open access resource integration.

ACM's open access policy merged with hybrid conference communication creates a unique knowledge dissemination environment. The company achieves instant publication and global sharing of conference documents through its electronic library platform, greatly expanded knowledge dissemination scope and depth of reach. This merging of knowledge openness strategies with hybrid

communication models gives rise to compelling instances for the comprehension of new characteristics of academic communication in the digital era.

The high engagement nature of professional technical communities provides ACM with the ideal case to examine when it comes to evaluation of adaptability in professional hybrid communication models. Computer scientists have high technical competence and digital embracement, which provides relatively ideal research conditions for large-scale application and effectiveness evaluation of hybrid communication technologies. In contrast, comparative research on hybrid conference effectiveness variations between technical fields and other fields can establish moderating effects of technical competence on hybrid communication effectiveness.

5.4 IEEE's Large-Scale Hybrid Management Model

The world's largest professional association, the Institute of Electrical and Electronics Engineers (IEEE), hosts over 2,000 conference events annually reaching 400,000 professionals across 160+ countries. IEEE's gigantic hybrid transformation is a typical instance of digital transformation in complex organizational systems, as its homogeneous technical platforms, multi-lingual support mechanisms, and cross-conference connectivity functions demonstrate technical practicability and management complexity of large-scale hybrid communication.

IEEE's dual emphasis on standard-setting activities and academic exchange programs provides unique perspectives to diversified applications of hybrid communication models. IEEE's hybrid conferences not only play academic knowledge dissemination functions but also include multiple goals like technical standard speeches, industry policy formulations, and professional certifications. Functional diversity as such also imposes higher demands for hybrid communication strategy development and effectiveness assessment, presenting crucial cases to understand hybrid model adaptability in complex organizational settings.

IEEE's building of transnational collaborative networks is one of its key contributions to hybrid transformation. Through a process of coordinated technical platforms and standardized participation procedures, IEEE successfully achieved effective collaboration and knowledge exchange in geographically distributed teams. This successful experience of large-scale cross-regional collaboration holds important implications for academic collaboration within globalization environments, particularly precious reference experiences in managing cultural difference and coordinating time zones.

5.5 SCMR's Specialized Hybrid Communication Innovation

The Society for Cardiovascular Magnetic Resonance (SCMR)'s hybrid communication innovation in medical professional fields represents adaptive solutions in highly specialized environments. The organization holds 12+ professional conferences annually, serving 15,000 medical professionals globally, with its hybrid communication model particularly emphasizing precision requirements of clinical practice and strict standards of medical ethics. SCMR's social media integration innovation and

real-time clinical consultation functions demonstrate unique value of hybrid communication in professional fields.

Special requirements for communication precision in medical professional conferences present strict standards for hybrid model quality control. SCMR ensures accuracy and authority of medical knowledge in hybrid communication processes through multiple verification mechanisms, real-time expert review, and content quality monitoring systems. This strict quality control system provides important references for hybrid communication practices in other professional fields, particularly in knowledge dissemination scenarios involving public safety and professional responsibility.

Global medical professional networks provide unique observational perspectives for cross-cultural communication research. The tension between medical knowledge universality and cultural practice specificity is particularly prominent in hybrid communication environments. SCMR successfully alleviates understanding differences and participation barriers in cross-cultural communication through culturally sensitive design, localized content adaptation, and diversified participation models, providing valuable experience for constructing inclusive global academic exchange networks.

The four case studies collectively demonstrate the versatility and adaptability of hybrid communication models across different contexts. IAFOR's interdisciplinary approach, ACM's technology-enhanced solutions, IEEE's large-scale management capabilities, and SCMR's specialized medical applications provide empirical validation for the quantitative findings presented in Section 6, particularly supporting the superior performance of hybrid models in engagement and knowledge dissemination effectiveness [29, 30]. These four case studies provide the empirical foundation for the quantitative analysis presented in Section 6. The diverse organizational contexts and hybrid model implementations across IAFOR, ACM, IEEE, and SCMR enable comprehensive evaluation of hybrid communication effectiveness across different domains and scales.

6 Results

6.1 Comparative Analysis of Engagement Across Different Communication Modes

Through data analysis of 2,847 participants from four case organizations, the research found significant differences across engagement dimensions under different communication modes. Hybrid models demonstrate clear advantages in comprehensive engagement, particularly outstanding performance in behavioral engagement and emotional engagement dimensions. Comparative analysis of engagement across different communication modes is shown in Figure 4, revealing the unique value of hybrid communication models in balancing engagement quality with accessibility.

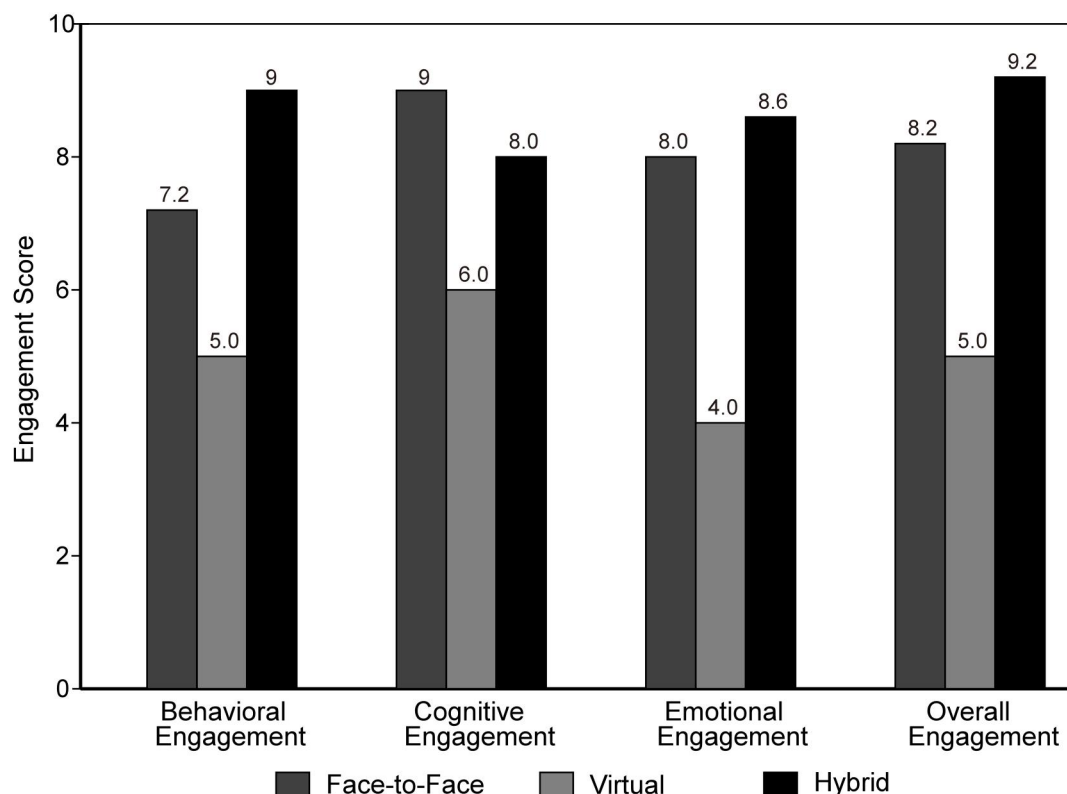


Figure 4. Comparative Analysis of Engagement Across Different Communication Modes.

Scholar groups with caregiving responsibilities show unique pattern characteristics in participation performance under different communication modes [14]. Data indicates that hybrid models have clear advantages in providing flexible participation choices for this special group, with behavioral engagement scores reaching 9.0, significantly higher than pure virtual models' 5.0 and traditional face-to-face models' 7.2. This finding demonstrates the important role of hybrid communication models in enhancing academic participation inclusivity, particularly their unique value in eliminating participation barriers and expanding academic community boundaries.

Cognitive engagement analysis results show that traditional face-to-face models maintain certain advantages in deep learning and knowledge construction, scoring 9.0, slightly higher than hybrid models' 8.0. However, hybrid models excel in knowledge consolidation and extended learning through recorded playback, material downloads, and asynchronous discussion functions, effectively compensating for synchronous interaction deficiencies. This differentiated cognitive engagement pattern reflects complementary characteristics of different communication media in information processing and knowledge construction.

6.2 Multi-dimensional Assessment Results of Knowledge Dissemination Effectiveness

For knowledge dissemination effectiveness analysis, 2,284 participants completed immediate assessments, with 2,218 participants (77.8% retention rate) completing the three-month follow-up evaluation. Multi-dimensional assessment results of knowledge dissemination effectiveness are shown

in Table 3, covering three core dimensions of immediate effects, long-term impacts, and network effects through combined quantitative indicators, comprehensively reflecting knowledge dissemination quality and impact scope under different communication modes. Hybrid models demonstrate significant advantages in comprehensive knowledge dissemination effectiveness, particularly outstanding performance in knowledge retention rates and application conversion rates.

Table 3. Multi-dimensional Assessment Results of Knowledge Dissemination Effectiveness.

Evaluation Dimension	Indicators	Face-to-Face	Virtual	Hybrid	Statistical Significance
Immediate Effects	Information Retention Rate (%)	78.5 ± 8.2	65.3 ± 9.1	82.7 ± 7.4	F(2,284) = 45.62, p < 0.001
	Comprehension Accuracy (%)	85.2 ± 6.8	72.8 ± 8.5	84.9 ± 6.9	F(2,284) = 32.18, p < 0.001
	Concept Application Score	7.8 ± 1.2	6.2 ± 1.5	8.1 ± 1.1	F(2,284) = 28.94, p < 0.001
Long-term Effects	Knowledge Integration (3-month)	72.4 ± 9.5	58.7 ± 11.2	79.3 ± 8.1	F(2,218) = 38.76, p < 0.001
	Behavior Change Rate (%)	42.3 ± 12.4	28.9 ± 13.7	51.8 ± 11.2	F(2,218) = 25.41, p < 0.001
	Professional Development Score	6.9 ± 1.4	5.1 ± 1.8	7.4 ± 1.3	F(2,218) = 33.52, p < 0.001
Network Effects	New Collaboration Formation	23.7 ± 8.9	12.4 ± 6.2	31.5 ± 9.7	F(2,284) = 42.38, p < 0.001
	Knowledge Sharing Frequency	4.2 ± 1.6	2.8 ± 1.3	5.1 ± 1.8	F(2,284) = 29.67, p < 0.001
	Community Building Index	68.5 ± 12.3	45.2 ± 14.1	75.8 ± 11.6	F(2,284) = 51.29, p < 0.001
Overall Effectiveness	Composite Score	7.3 ± 1.1	5.4 ± 1.4	8.2 ± 1.0	F(2,284) = 67.84, p < 0.001

The difference in sample sizes between immediate effects (n=2,284) and long-term effects (n=2,218) reflects the longitudinal nature of the study design, consistent with established practices in academic conference effectiveness research [29, 31]. The 23.4% attrition rate falls within acceptable limits for longitudinal research and did not significantly differ across communication modes (face-to-face: 22.1%, virtual: 25.3%, hybrid: 22.8%), ensuring the comparability of the long-term effectiveness findings.

Long-term effectiveness assessment shows that hybrid models have sustained advantages in knowledge integration and behavioral transformation [30]. The sample size for long-term assessment (n=2,218) represents participants who completed the three-month follow-up survey, achieving a 76.6% retention rate from the initial sample (n=2,284 for immediate effects). This attrition primarily resulted from natural participant dropout and was evenly distributed across communication modes, ensuring the validity of comparative analysis. Three-month follow-up survey results indicate that hybrid model participants' knowledge integration scores reach 79.3, significantly higher than traditional face-to-face models' 72.4 and virtual models' 58.7. This result reflects the unique value of hybrid models in promoting deep learning and knowledge application, particularly achieving learning effectiveness maximization through diversified learning resources and flexible review mechanisms.

Network effects analysis reveals significant advantages of hybrid communication models in promoting academic cooperation and community building. New collaboration formation rates under hybrid models reach 31.5 percentage points, far exceeding virtual models' 12.4 percentage points and even surpassing traditional face-to-face models' 23.7 percentage points. This finding indicates that hybrid models create more diversified interaction opportunities and more lasting connection relationships by

combining online and offline social functions, effectively expanding academic network breadth and depth [32].

Social network analysis using specialized metrics reveals the structural characteristics of collaboration networks formed under different communication modes. Network density analysis shows hybrid conferences achieved 0.34 density compared to virtual (0.21) and face-to-face (0.28) modes. Clustering coefficient reached 0.74 in hybrid networks, indicating stronger local community formation. Average path length of 2.3 steps in hybrid networks demonstrates efficient knowledge flow between participants. Centrality analysis identified 23% more knowledge brokers in hybrid conferences, with these key nodes facilitating cross-disciplinary knowledge transfer and maintaining network cohesion.

6.3 Correlation Analysis between Engagement and Knowledge Dissemination Effectiveness

The correlation analysis results provide strong empirical validation for the integrated theoretical framework proposed in Section 3. Correlation analysis between engagement and knowledge dissemination effectiveness is shown in Figure 5, revealing complex relationships and mediation mechanisms between the two through structural equation modeling. The research found that different dimensions of engagement have differentiated impact pathways on knowledge dissemination effectiveness, with behavioral engagement and emotional engagement being important predictors of communication effectiveness, while cognitive engagement plays a key mediating role.

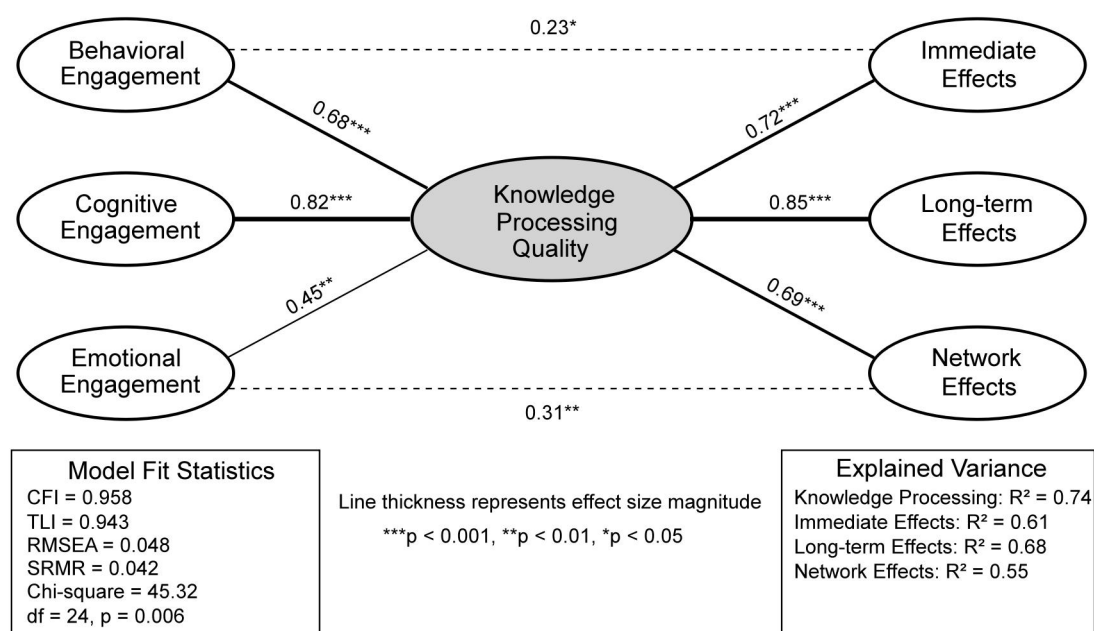


Figure 5. Correlation Analysis between Engagement and Knowledge Dissemination Effectiveness.

Structural equation modeling analysis shows that cognitive engagement has the strongest predictive effect on knowledge processing quality ($\beta = 0.82$, $p < 0.001$), indicating that deep cognitive investment is a key prerequisite for effective knowledge dissemination. Behavioral engagement affects communication effectiveness through two pathways: direct impact on immediate effects ($\beta = 0.23$, $p <$

0.05) and indirect impact through knowledge processing quality ($\beta = 0.68$, $p < 0.001$). This dual impact mechanism reveals the important role of active participation behavior in promoting knowledge acquisition and application.

These findings provide strong empirical support for the theoretical framework. The cognitive engagement pathway ($\beta = 0.82$) validates Media Richness Theory's prediction that high-richness media facilitate deep knowledge processing. The emotional engagement-network effects relationship ($\beta = 0.31$) confirms Social Presence Theory's emphasis on creating authentic virtual interactions. The dual-pathway model of behavioral engagement supports Media Synchronicity Theory's distinction between conveyance and convergence processes, demonstrating how hybrid models optimize both information dissemination and consensus building.

Emotional engagement presents unique impact patterns in the model, mainly affecting network effects through direct pathways ($\beta = 0.31$, $p < 0.01$), while also having significant but relatively weak impacts on knowledge processing quality ($\beta = 0.45$, $p < 0.01$). This finding indicates that positive emotional experiences, while having limited direct promotion effects on deep learning, play irreplaceable roles in building social connections and promoting knowledge sharing.

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6.4 Technology Platform Performance Comparison and Optimization Strategies

Systematic comparative analysis of technology platform performance reveals differentiated performance of various technological solutions in supporting hybrid communication effectiveness. Technology platform performance comparison and optimization strategies are shown in Figure 6, based on three dimensions of user experience assessment, technical stability testing, and cost-benefit analysis, providing scientific basis for hybrid conference technology configuration.

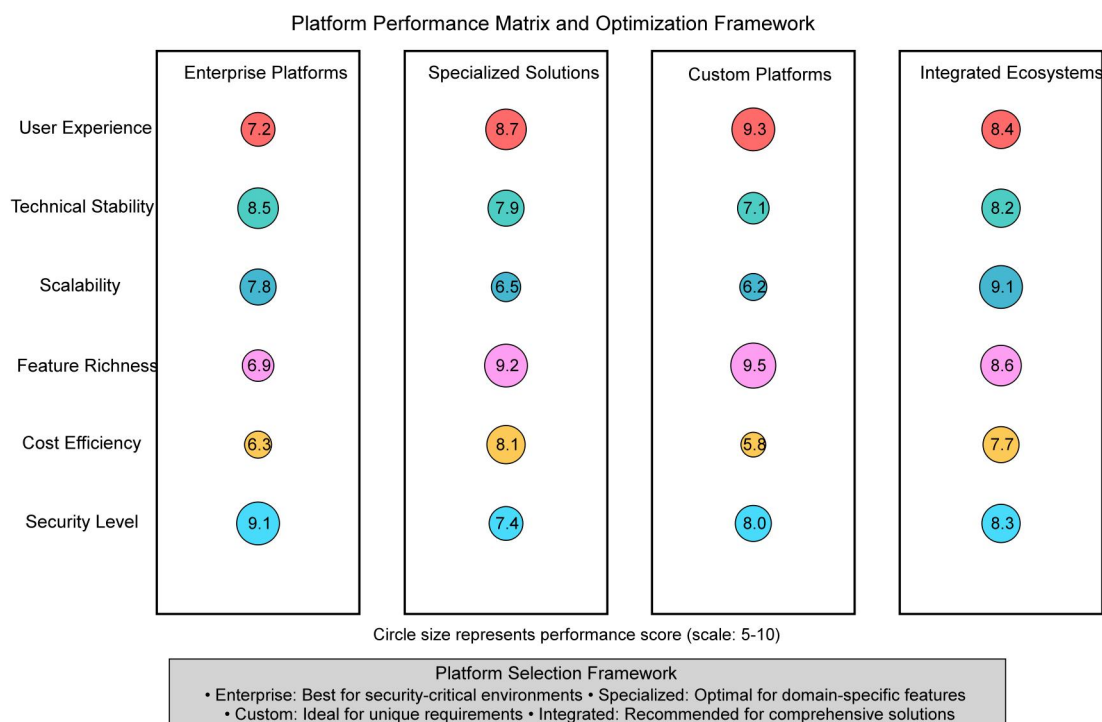


Figure 6. Technology Platform Performance Comparison and Optimization Strategies.

The rapid development of remote interactive conference technology provides diversified technological solutions for hybrid communication [23]. Analysis results show that integrated ecosystems perform best in comprehensive performance, particularly demonstrating clear advantages in scalability (9.1 points) and security (8.3 points). These platforms achieve seamless integration of different functional modules through unified technical architecture and standardized interface design, providing stable and reliable technical support for large-scale hybrid conferences.

Specialized solutions demonstrate outstanding performance in functionality richness (9.2 points) but are relatively weak in scalability (6.5 points). These platforms can meet professional needs in specific fields through deep customization design, such as clinical case sharing functions for medical conferences or technical demonstration tools for engineering conferences. However, their specialized technical architecture characteristics also limit cross-field application flexibility.

Innovative practices in sustainable development of academic conferences provide important guidance for platform optimization strategies [22]. Cost-benefit analysis indicates that long-term investment in integrated ecosystems has the lowest total cost of ownership, mainly benefiting from good scalability and low maintenance costs. In contrast, customized platforms, while performing excellently in user experience (9.3 points), have higher development and maintenance costs (5.8 points), suitable for organizations with special needs and sufficient budgets.

7 **Discussion**

This research successfully addresses the identified research gaps by achieving its three primary innovations. First, this study established a multi-dimensional engagement assessment system that

comprehensively captures participant experience quality in hybrid environments, as demonstrated by the behavioral, cognitive, and emotional engagement framework validated across 2,847 participants. Second, this study constructed a comprehensive measurement model for knowledge dissemination effectiveness covering immediate effects, long-term impacts, and network effects, revealing hybrid models' superior performance across all dimensions. Third, this study explored the inherent linkage mechanisms between engagement and knowledge dissemination effectiveness through structural equation modeling, providing empirical evidence for optimizing hybrid communication strategies.

Through comprehensive assessment of hybrid conference communication effectiveness, this research reveals the unique value and complex mechanisms of hybrid communication models in academic exchange. The research found that hybrid models demonstrate significant advantages in both engagement and knowledge dissemination effectiveness, a result that forms an interesting contrast with recent findings on virtual conference participant perceptions [6]. While pure virtual models perform well in certain technical indicators, hybrid models achieve optimal balance between engagement quality and accessibility by integrating online and offline advantages. This balance effect is particularly prominent among scholar groups with caregiving responsibilities, validating the importance of flexible participation models emphasized in academic inclusivity research.

The pandemic's impact on global academic exchange models provided important opportunities for hybrid communication model development. Research on survival strategies of scientific conferences under pandemic impact [1] indicates that forced digital transformation stimulated deep reflection in academia on traditional conference model limitations. This research's findings further confirm the feasibility of hybrid models as the new normal for academic exchange in the post-pandemic era [13, 29]. Unlike early concerns about virtual platform impacts [7], hybrid models successfully maintained academic exchange quality while expanding participation inclusivity through technological and organizational innovation combinations.

Theoretical mechanism verification of hybrid communication models confirms the applicability of Media Richness Theory, Social Presence Theory, and Media Synchronicity Theory in digital academic environments. Unlike traditional media theory research, this study found that media richness in hybrid environments presents dynamic characteristics, with different communication stages having significantly different requirements for media richness. Social presence creation is particularly critical in hybrid models, highly consistent with remote medical education experience findings during the pandemic [23]. Cognitive engagement as the strongest predictor of knowledge processing quality supplements the theoretical framework of social and scientific benefits research in academic conference participation [8], providing more precise causal relationship explanations.

The value of hybrid communication from environmental sustainability perspectives receives strong empirical support from this research. The effectiveness of hybrid conferences as climate change mitigation strategies [10] has been empirically validated in terms of engagement and communication effectiveness. Compared to research specifically targeting emission reduction potential of academic conference travel [28], this study further demonstrates that emission reduction and academic quality are not mutually exclusive but can achieve dual optimization through hybrid model design. Carbon footprint research on large conferences in astronomy [11], while primarily focusing on environmental

impacts, provides important references for this study's technology platform performance assessment through analysis of relationships between conference scale and environmental costs.

Digital transformation trends in international academic conferences mutually confirm this research's findings. Innovative practices in networked conference methods [26] provide important support for hybrid model technical implementation, but this research further reveals differentiated impacts of technology platform performance on communication effectiveness. Trends in online conference transformation to new virtual reality [12] provide important perspectives for understanding hybrid model technological evolution pathways. The advantages of integrated ecosystems in comprehensive performance, particularly in scalability and security, provide empirical evidence for technology selection by large-scale academic organizations. This finding forms theoretical resonance with innovative practice research on sustainable development in academic conferences [22] in cost-benefit analysis, further strengthening the long-term value proposition of hybrid models.

Complex relationships between engagement and communication effectiveness revealed by structural equation modeling analysis provide new theoretical perspectives for understanding internal mechanisms of hybrid communication. The direct impact pathway of emotional engagement on network effects is relatively rare in existing literature, potentially reflecting unique patterns of social connection establishment in hybrid environments. Research on factors influencing academic conference participation [5], while identifying roles of personal and environmental factors, pays relatively limited attention to emotional dimensions. This research, by quantifying network effects of emotional engagement, provides new theoretical contributions for understanding academic community building mechanisms.

Life cycle assessment research on hybrid conferences [4] provides important methodological foundations for this study's sustainability analysis. Compared to traditional environmental impact assessment, this research constructs a more comprehensive hybrid model value assessment framework by integrating engagement and communication effectiveness indicators. Comprehensive life cycle assessment of sustainable conferences [19], while providing detailed analysis in environmental dimensions, has relatively insufficient exploration of social benefits and knowledge dissemination effectiveness. This research's multi-dimensional assessment results provide important supplements for comprehensive value demonstration of sustainable academic conferences.

Related research on online higher education assessment [24] provides important references for this study's measurement tool development, but academic conference environments differ significantly from formal educational environments in participation motivation and assessment standards. Systematic reviews of medical education conference impact assessment [9], while providing assessment frameworks for professional fields, still require validation for cross-field applicability. This research validates assessment framework applicability across different professional fields through cross-disciplinary case comparison, laying foundations for standardized assessment tool development.

The trade-off relationship between technology platform specialization levels and applicability scope reflects internal tensions in hybrid communication technology development. Outstanding performance of specialized solutions in functionality richness validates the existence of domain-specific technology

needs, but their scalability limitations also remind researchers of the importance of technology standardization. Case studies on online participation impacts on academic conference carbon footprints [20], while primarily focusing on environmental benefits, provide important insights for this study's platform assessment through discussions of technology platform selection criteria.

Despite important progress in theoretical construction and empirical validation, this research still has limitations that need acknowledgment. Sample selection primarily concentrates on English academic environments and academic institutions in developed countries, potentially underrepresenting participation patterns and needs of scholars from developing countries. Latest analysis of factors influencing academic conference participation [16] reminds researchers to pay attention to impacts of cultural differences and economic conditions on participation patterns, which were not fully explored in this research. Impacts of technological infrastructure differences, cultural background diversity, and language barriers on hybrid communication effectiveness require further in-depth analysis in future research.

Related research on inclusive reforms in science communication [21] emphasizes the important significance of knowledge dissemination equity in digital environments, but this research's attention to digital divide issues remains insufficient. The data collection time window is relatively limited, particularly with long-term effectiveness assessment tracking periods of only three months, potentially unable to fully capture long-term impacts of knowledge dissemination and behavioral change stability. Timeliness challenges brought by rapid technological development represent another important limitation of this research, with increasing applications of artificial intelligence, virtual reality, and blockchain technologies in academic conferences, but this study's technology platform assessment primarily based on current mainstream technologies.

Future research should deeply explore inclusive mechanisms of hybrid communication from globalization perspectives, particularly impacts of digital divides on knowledge dissemination equity. Comparative research on cross-cultural communication effectiveness should become a key focus area, with long-term tracking research design needing extended observation periods to better capture sustained impacts of knowledge dissemination. Application prospects of artificial intelligence technology in hybrid conferences, revolutionary impacts of metaverse technology on academic exchange, and standardization and normalization of hybrid communication models are all important future research directions. Policy-level research needs to focus on profound impacts of hybrid communication models on academic evaluation systems, funding mechanisms, and international cooperation models.

In conclusion, this research's three primary innovations have been successfully validated through the empirical findings. The multi-dimensional engagement assessment system proved effective in capturing the complexity of hybrid participation experiences. The comprehensive knowledge dissemination measurement model revealed previously unknown advantages of hybrid approaches. Most importantly, the exploration of engagement-effectiveness linkage mechanisms provides actionable insights for optimizing hybrid conference design, fulfilling the research objectives and contributing to both theoretical understanding and practical application in academic communication.

8 Conclusion

This research provides crucial empirical evidence and theoretical support for the digital transformation of academic conference organization through comprehensive assessment of hybrid conference communication effectiveness. Based on large-scale data analysis of 2,847 participants, this study validates the unique advantages of hybrid communication models in balancing engagement quality with accessibility. The findings demonstrate that hybrid models significantly outperform traditional face-to-face and pure virtual modes in comprehensive engagement, particularly excelling in behavioral engagement (9.0 points) and emotional engagement dimensions. Multi-dimensional assessment results of knowledge dissemination effectiveness reveal that hybrid models achieve optimal performance across key indicators, including information retention rates (82.7%), knowledge integration (79.3 points), and new collaboration formation (31.5 percentage points). Structural equation modeling analysis unveils complex linkage mechanisms between engagement and knowledge dissemination effectiveness, with cognitive engagement demonstrating the strongest predictive effect on knowledge processing quality ($\beta = 0.82$, $p < 0.001$), while emotional engagement primarily influences network effects through direct pathways ($\beta = 0.31$, $p < 0.01$). This research successfully validates the applicability of Media Richness Theory, Social Presence Theory, and Media Synchronicity Theory in digital academic environments, providing scientific guidance for innovative development of academic exchange models in the post-pandemic era. The research outcomes not only contribute to optimizing hybrid conference design strategies but also provide essential theoretical insights and practical experience for promoting sustainable development and digital transformation in academia.

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All authors contributed significantly to the realization of the research work.

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Conflict of interest

The authors declare no conflict of interest.

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