Multidimensional Breakthrough: Practical Bottlenecks and Future Pathways for Emergency Science Communication in the New Era

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Abstract: *In the context of the new era, strengthening the development of emergency science communication is an objective requirement for enhancing public awareness of emergency responsibility, improving emergency response capabilities, and fortifying public safety. Currently, emergency science communication efforts in China face multiple practical challenges: fragmented resource allocation leads to insufficient synergistic effectiveness; a lack of precision in content provision fails to meet diverse needs; outdated dissemination mechanisms constrain coverage and influence; insufficient depth in technology integration results in low levels of intelligence; and an incomplete support system undermines sustainable development momentum. Based on these observations, this paper proposes practical pathways for emergency science communication from five dimensions: synergistic coordination, content optimization, dissemination innovation, technology empowerment, and strengthened support. It aims to provide theoretical reference and practical guidance for overcoming the bottlenecks in the development of emergency science communication and promoting its high-quality, sustainable progress.*

Keywords: *Emergency Science Communication; Emergency Management; Science Communication Development*

Introduction

Strengthening the development of emergency science communication in the new era constitutes a crucial component in advancing the modernization of the national governance system and governance capabilities. It represents a significant measure to deeply comprehend and fully leverage the strengths of the national governance system, as well as to prevent and mitigate major risks through systematic thinking. This effort will effectively enhance the capacity for safety risk prevention and control, boost societal participation, and consolidate the level of public safety.[1] Emergency science communication encompasses both responsive science communication services during public emergencies and routine preventive science education targeting frequent or common risks. Together, they form the core vehicle for raising public emergency awareness and improving response capabilities.China places great emphasis on the development of emergency science communication. A review of existing research reveals that academic explorations have largely focused on isolated aspects of emergency science communication. For instance, Liu Jida et al.[2], based on synergy theory, concentrated on multi-agent collaboration mechanisms and proposed pathways for breaking down departmental barriers, yet they did not resolve the issue of fragmented resources. Zhang Haibo[3], drawing on the whole-process equilibrium theory of emergency management, highlighted imbalances in content supply and suggested optimization directions but did not address the personalized needs of different groups. Zhou Rongting et al.[4], aligning with media convergence trends, constructed a "traditional media + new media" dissemination matrix but failed to integrate other aspects such as content and resources. Overall, existing studies lack systematic analysis of practical challenges and the construction of holistic solutions.Building on this, this paper, grounded in the macro-context of emergency management in the new era, systematically examines the core challenges in emergency science communication and proposes practical pathways for its development. The aim is to lay a solid safety foundation for embarking on the new journey of fully building a modern socialist country.

1. Practical Bottlenecks in Emergency Science Communication in the New Era

1.1 Fragmented Resource Allocation and Ineffective Collaborative Coordination Mechanisms

Emergency science communication involves multiple stakeholders, including government departments, science and technology associations, research institutions, media platforms, and social organizations, encompassing the entire chain of content creation, platform operation, and event organization. Currently, the allocation of resources for emergency science communication in China exhibits notable fragmentation, and collaborative coordination mechanisms remain underdeveloped. On one hand, the functional boundaries between departments are ambiguous, resulting in a lack of overall coordination and planning. Departments responsible for operations, publicity, science and technology, among others, independently formulate science communication plans and conduct activities. The absence of integrated coordination leads to redundant resource investment and wastage. In some regions, emergency management departments and science and technology departments operate separate science communication platforms, resulting in overlapping content, disconnected data systems, and unshared resources, which hampers the formation of a cohesive effort. On the other hand, government-society collaboration lacks effectiveness, and social participation remains insufficient. The intellectual resources and mobilization advantages of science and technology associations, academic societies, and professional associations have not been fully utilized. Meanwhile, enterprises and social organizations show limited enthusiasm for participation, leading to a scarcity of market-driven science communication products. Consequently, a diversified collaborative framework characterized by "government leadership, social participation, and market operation" has yet to be established.

1.2 Insufficient Precision in Content Provision and Weak Capacity to Meet Diverse Needs

With social development and the refinement of public safety governance, public safety demands have become increasingly diverse and personalized, with significant variations across groups and regions. However, emergency science communication content remains homogeneous, and the capacity for precise adaptation is insufficient. First, there is a mismatch between content supply and demand, and precise alignment with diverse needs is lacking. Generic safety knowledge constitutes a disproportionately high share of the content supply, while specialized, scenario-based science communication-such as for high-rise building fires in urban areas or geological disasters in rural areas-is scarce. A differentiated supply system based on audience profiles and regional risks has not been established, making it difficult to meet personalized needs. Second, the content framework is incomplete, and coverage across the entire life cycle is not comprehensive. A complete knowledge system covering the entire life cycle of "prevention – preparedness – response – recovery" has not been developed. There are structural gaps in the provision of knowledge for critical phases such as risk identification, emergency psychological adjustment, and post-disaster recovery and reconstruction. This results in situations where the public, when facing emergencies, may be "adequate in avoiding risks but insufficient in self-rescue" or "timely in response but weak in recovery." Third, content presentation remains monotonous, and the supply of immersive and interactive formats is insufficient. Science communication content is still predominantly presented in traditional forms such as text and static images, while immersive formats like animations and short videos are in short supply. There is a lack of formats that align with the scenario-based and participatory information preferences of newer generations of audiences, which constrains the effectiveness of science communication dissemination[5].

1.3 Lagging Dissemination Mechanisms Limiting Coverage and Influence

In the era of media convergence, the mode of information dissemination has profoundly transformed from the traditional "one-way indoctrination" to a pattern of "multi-dimensional interactive participation." However, the dissemination mechanisms for emergency science communication have failed to upgrade accordingly, resulting in limitations in both its reach and radiating influence. On one hand, dissemination channels remain homogeneous, and the effectiveness of multi-dimensional coverage is insufficient. Current emergency science communication relies excessively on traditional carriers such as government websites and community bulletin boards, while underutilizing new media applications like short videos and live streaming. A multi-layered dissemination network has not been established,[6] making it difficult to precisely reach key audiences such as younger demographics and failing to fully unleash the potential for comprehensive dissemination effectiveness. On the other hand, there is a lack of innovation-driven dissemination methods, and interactive experiences are weak.

Emergency science communication is still predominantly led by traditional, one-way formats such as "notification-style delivery" and "offline lecture-style" events. There is a shortage of interactive content like case deconstruction and scenario simulations, which fails to align with the public's preference for participatory information reception. Consequently, public engagement remains low, coverage is narrow, and both the appeal and impact of the dissemination efforts need enhancement.

1.4 Insufficient Depth in Technology Integration and Low Level of Intelligence

New-generation information technologies such as big data, artificial intelligence, and VR/AR provide crucial support for innovating models and enhancing the effectiveness of emergency science communication. However, the integration and application of these new technologies within the field of emergency science communication currently remain at a superficial exploration phase, with both the depth and breadth of technology-driven empowerment yet to be expanded.

First, the integrated application of big data is inadequate, and the closed-loop process for data governance and demand analysis is not yet robust. A unified and efficient big data governance platform for emergency science communication has yet to be established. There is insufficient capability in collecting, integrating, and conducting in-depth analysis of multi-source data, such as public demand preferences and regional risk profiles. Consequently, it is difficult to construct a full-chain closed-loop encompassing "demand identification – content production – precise delivery – feedback optimization." In some regions, the foundational science communication databases contain limited data dimensions, often comprising only basic user information without linking to critical indicators such as risk preferences, making the implementation of personalized delivery mechanisms challenging.

Second, the scenario-based application of virtual simulation technology is insufficient, and the empowering effect of immersive drills remains weak. Immersive interactive technologies like VR/AR have not been widely popularized in the field of emergency science communication. Emergency drills are still predominantly conducted in traditional formats, lacking high-fidelity experiential platforms for risk scenarios. Virtual safety experience resources are scarce in rural and remote areas, limiting the public’s ability to enhance practical skills through contextualized practice. As a result, the practical effectiveness of technology empowerment has not been fully realized.

Third, the application of intelligent dissemination technologies is inadequate, and mechanisms for precise adaptation and dynamic delivery are weak. There is a lack of intelligent content processing, scenario-based adaptation, and dynamic delivery mechanisms for science communication. Existing approaches fail to optimize presentation formats and delivery strategies based on user data such as browsing history and knowledge levels. The integration between technology and dissemination remains superficial, hindering the achievement of personalized and tailored science communication services for diverse audiences.

1.5 Incomplete Support System and Insufficient Momentum for Development

The high-quality and sustainable development of emergency science communication requires coordinated support from policies, talent, and industry. Currently, the support system exhibits structural deficiencies that constrain its developmental momentum. First, the effectiveness of policy implementation is insufficient, and supporting mechanisms urgently need improvement. Although top-level policies outline the developmental direction, some lack detailed implementation rules and rigid assessment criteria. Ambiguous division of responsibilities among departments leads to a "policy suspension" phenomenon, where policy requirements fail to translate effectively into practical actions.

Second, the development of professional talent lags, resulting in a shortage of interdisciplinary talent. Emergency science communication demands dual support from both emergency management expertise and science communication skills. Currently, there is a significant gap in interdisciplinary talent possessing cross-domain knowledge and practical abilities. Furthermore, the talent cultivation system is underdeveloped, with university programs lagging behind needs, on-the-job training lacking systematization, and unclear career advancement pathways, all of which undermine the stability and growth of the workforce.

Third, industrial development lacks momentum, and market-oriented operational mechanisms are not yet mature. The emergency science communication industry is still in its nascent stage, with an underdeveloped industrial ecosystem characterized by an imbalance of "public welfare dominance and insufficient marketization." The supply and quality of commercial products need enhancement, corporate participation remains weak due to unclear profit models, funding relies excessively on government sources, and social capital involvement is low. These factors hinder the formation of a scaled and professionalized industrial landscape.

2. Future Pathways for Emergency Science Communication in the New Era

2.1 Establishing Collaborative Coordination Mechanisms to Integrate Fragmented Resources

With the core objectives of intensively integrating resources and maximizing governance efficiency, it is essential to break down collaborative barriers among diverse stakeholders and construct a collaborative governance system for emergency science communication that is "cross-departmental, cross-domain, and cross-sector." On one hand, it is necessary to improve the delineation of cross-departmental authorities and responsibilities as well as process standardization, thereby solidifying the foundation for collaborative governance. This involves systematically clarifying the boundaries of authority and responsibility among relevant functional departments such as emergency management, publicity, and science and technology, formulating detailed implementation rules for cross-departmental collaborative work, and establishing regular collaborative mechanisms including joint operations and training, periodic consultations, and annual assessments. A categorized lead-governance model should be developed based on the types of emergencies to effectively avoid functional overlaps and accountability gaps, thereby comprehensively strengthening the effectiveness of cross-departmental collaborative performance.

On the other hand, it is crucial to deepen the mechanisms and pathways for multi-stakeholder government-society collaborative participation and build a co-constructed and shared science communication ecosystem. Leveraging the bridging role of science and technology associations, a specialized expert database for emergency science communication should be established to systematically integrate high-quality intellectual resources from universities and research institutions, providing solid support for the professional supply of science communication content. Through diverse policy incentives such as government procurement of services, project-specific subsidies, and tax benefits, enterprises and social organizations should be guided to deeply participate in the innovative research and development of science communication products and the provision of grassroots science communication services. This will foster an emergency science communication ecosystem characterized by collaborative development among multiple stakeholders[7].

2.2 Optimizing Content Provision to Enhance Precision and Adaptability

With the diverse, scenario-based needs of the public as the core, it is essential to construct a modernized emergency science communication content supply system that is precisely tailored, covers the entire process, and employs multiple presentation formats, thereby improving the efficacy of matching supply with demand. First, supported by a three-dimensional classification system encompassing groups, regions, and risks, diverse demands should be accurately addressed. This involves conducting comprehensive and detailed research on emergency science communication needs across all domains, and establishing a three-dimensional content provision framework based on audience groups, geographical characteristics, and risk types. Specifically, animated science communication courses that combine entertainment with knowledge should be developed for youth; professional emergency operation manuals should be compiled for practitioners in specific industries such as outdoor work; and dialect-based short science communication videos should be customized for rural and remote areas, thereby achieving differentiated content adaptation and scenario-based implementation.

Second, focusing on the entire closed-loop process, the structural coverage effectiveness of the content should be optimized. The entire chain of emergency management-"prevention, preparedness, response, disposal, and recovery"-must be comprehensively covered. Emphasis should be placed on strengthening knowledge provision for weak links such as risk identification, emergency psychological adjustment, and post-disaster recovery and reconstruction, thereby addressing structural gaps in the content system. In response to emerging risk scenarios and new demands in emergency management, the science communication resource library should be dynamically updated, and emergency knowledge should be promptly supplemented to ensure the timeliness and relevance of the content.

Third, science communication carriers and dissemination formats should be innovated to enhance immersive and interactive effects. Diverse science communication carriers such as short videos, live streaming, and interactive games should be developed. Initiatives could include creating a series of "One-Minute Emergency Operation" short videos, organizing online expert live Q&A sessions and interactive exchange activities, and designing interactive games for family emergency drills[8]. Additionally, employing case analysis and scenario-based presentation models is recommended. This involves selecting typical emergency incidents to build a standardized case library, deconstructing emergency response processes and key points, thereby improving the cognitive acceptance and practical guidance of the science communication content.

2.3 Innovating Dissemination Mechanisms to Expand Coverage and Influence

Adapting to the evolutionary characteristics of the communication ecosystem in the era of media convergence, it is essential to promote the transformation of emergency science communication mechanisms from one-way dissemination to multi-dimensional, interactive engagement. This will expand its reach, enhance its influence, and improve public cognitive acceptance.

On one hand, it is necessary to build an integrated online-offline communication channel system that enables precise coverage across multiple scenarios. Online, official accounts should be established on mainstream short-video and comprehensive social platforms, collaborating with high-quality content creators to conduct specialized, scenario-based promotions. For vertical platforms popular among younger audiences, thematic interactive science communication campaigns should be designed to stimulate participation and dissemination enthusiasm. Offline, standardized science communication demonstration sites should be established in key venues such as communities, schools, and enterprises. Leveraging tools like rural broadcasting systems and community bulletin boards will help address gaps in remote areas, ultimately forming a three-dimensional dissemination network that achieves comprehensive online penetration and targeted offline implementation.

On the other hand, innovative, multi-path dissemination strategies that integrate peacetime and emergency coordination should be developed to strengthen experiential science communication. A dual-mode dissemination approach that combines routine operations with emergency response should be established. During normal periods, thematic series of campaigns can be conducted to enhance public knowledge and risk awareness. In emergency situations, an immediate communication response should be activated, with content dynamically adjusted to align with the evolving risk scenario, thereby meeting the public's real-time needs[9]. Furthermore, immersive experience models should be vigorously promoted. This includes organizing public visits to science communication venues for hands-on learning and facilitating participation in emergency drills to improve practical skills. Through such scenario-based experiences, knowledge internalization can be deepened, thereby enhancing the effectiveness of dissemination and fostering emotional resonance.

2.4 Deepening Technology Empowerment to Enhance Intelligent Capabilities

Aligning with the trend of leveraging technology to modernize social governance, it is essential to deeply integrate new-generation information technologies to advance emergency science communication toward intelligent, immersive, and personalized iterations, thereby improving the precision and effectiveness of science communication services.

First, a multi-source integrated big data platform should be established to strengthen precise empowerment and closed-loop management. Multi-source user data from government agencies, media outlets, and social organizations should be consolidated to create a standardized public emergency literacy database. By employing algorithmic models to analyze core user characteristics such as risk preferences and learning habits, personalized delivery of science communication content can be achieved. Additionally, a science communication effectiveness analysis module should be developed to monitor dissemination trajectories and user reception in real time, providing data support for content optimization and strategy adjustments, thereby forming a closed-loop governance system across the entire chain.

Second, the application of virtual simulation in scenario-based contexts should be promoted to deepen immersive training. Standardized virtual safety experience venues should be strategically deployed, utilizing VR/AR technologies to recreate typical risk scenarios, allowing the public to engage in immersive emergency skill training. Specialized digital platforms for emergency science communication should also be developed, incorporating virtual drill modules that enable the public to conduct fragmented training beyond temporal and spatial constraints, thereby enhancing their practical emergency skills.

Third, an intelligent algorithm-driven dissemination system should be constructed to improve the efficiency of precise adaptation and delivery. Leveraging artificial intelligence, intelligent service terminals for emergency science communication should be developed to provide real-time consultation and guidance in settings such as communities and schools, accurately addressing public needs. Furthermore, intelligent recommendation models based on user behavior trajectories and interest preferences should be established to achieve precise adaptation and delivery of science communication content on mainstream platforms, thereby enhancing the targeting and effectiveness of dissemination.

2.5 Strengthening Support Systems to Consolidate the Foundation for Development

A tri-dimensional collaborative support system encompassing "policy, talent, and industry" should be established to solidify the institutional foundation and inject sustained momentum for the high-quality and sustainable development of emergency science communication.

First, a policy support system featuring sound top-level design and rigid constraints must be perfected. As good laws are the prerequisite for good governance, exploring the formulation of regulations on emergency science communication is a necessary response to practical needs[9]. Formulate guiding policy documents for emergency science communication that clarify phased development goals, core tasks, and implementation pathways, thereby strengthening strategic guidance from the top. Establish specialized assessment and evaluation mechanisms, incorporating related work into the performance evaluations of local governments in emergency management, using rigid constraints to enforce policy implementation. Introduce diversified incentive policies, such as providing financial subsidies and honorary recognition to high-quality science communication products and exemplary institutions, to stimulate participation enthusiasm among diverse stakeholders.

Second, an integrated system for building a professional talent workforce should be constructed. Introduce interdisciplinary programs in emergency science communication within universities, creating a talent cultivation system that integrates academic education with practical empowerment. Establish standardized training bases and implement a "theoretical instruction + practical drill" model to enhance the professional competence and practical skills of practitioners. Refine talent evaluation and incentive mechanisms by incorporating science communication achievements into the core indicators for professional title evaluations and performance assessments within the emergency management field, thereby strengthening professionals' sense of occupational belonging and fulfillment.

Third, an emergency science communication industry system characterized by integrated innovation and multi-stakeholder collaboration should be cultivated. Scientifically plan industrial layouts, establish specialized industrial parks, and nurture leading enterprises and key players to guide the standardized and scaled development of the industry. Innovate profit models by supporting enterprises in developing cross-sector products such as "science communication + education" and "science communication + cultural tourism" to expand the value boundaries of the industry. Expand the scale of government procurement of services to stimulate market demand, ultimately shaping a multi-stakeholder collaborative industrial landscape characterized by "public welfare leadership supplemented by commercial operations."

3. Conclusion

Emergency science communication in the new era serves as a foundational project for implementing the holistic national security approach and advancing the modernization of emergency management. It is also a core pillar for fortifying the public safety defense line. Currently, structural weaknesses still persist within the field of emergency science communication. The practical pathways proposed earlier from five dimensions provide key guidance for overcoming developmental bottlenecks and enhancing service effectiveness. In the future, it is essential to unite the collaborative efforts of multiple stakeholders, including the government, society, and the market, to continuously advance the transformation of emergency science communication toward greater precision, intelligence, and systematicity. By improving both quality and efficacy, the foundation of public safety can be consolidated, thereby establishing a robust security groundwork for the comprehensive construction of a modern socialist country.

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