

Research on AI-Driven Personalized Science Communication Pathways

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Abstract: *Against the backdrop of scientific communication evolving toward refinement and intelligence, the traditional one-way model aimed at broad coverage can no longer meet the cognitive needs of diverse audiences. The development of artificial intelligence offers a dynamically adaptive approach to scientific communication based on individual interests, knowledge structures, and cognitive preferences, enabling precise knowledge delivery and deep assimilation. This paper elaborates on the connotation and cognitive characteristics of personalized scientific communication, analyzes the empowering role of artificial intelligence in semantic understanding, knowledge graph construction, and multimodal generation, and constructs a communication pathway centered on content generation, audience profiling, and integrated pathway linkage. It also explores optimization strategies for multimodal interaction and iterative updating. The study points out that artificial intelligence is driving a shift in scientific communication from linear diffusion to data-driven and cognitively coordinated approaches, offering new theoretical and methodological support for personalized and intelligent communication.*

Keywords: *artificial intelligence; personalized scientific communication; semantic reorganization; audience profiling; communication pathway optimization*

Introduction

As a crucial bridge connecting scientific knowledge with public understanding, scientific communication significantly affects both the dissemination efficiency of science and the level of societal cognition. With the growing complexity of the information environment and the increasing diversity of audience demands, traditional scientific communication models based on unidirectional information transmission are revealing limitations—broad in reach yet lacking in specificity, singular in presentation, and insufficient in cognitive adaptability. Breakthroughs in artificial intelligence technologies—such as natural language processing, semantic understanding, knowledge graphs, and multimodal generation—have injected new momentum into scientific communication, making it possible to dynamically adapt to individual cognitive characteristics and deliver information with precision. Investigating personalized scientific communication pathways driven by artificial intelligence is not only an important manifestation of the evolution of scientific communication theory from macro-level universality to micro-level adaptability, but also a key requirement for achieving deep understanding and cognitive co-construction of scientific knowledge. By exploring the foundational elements, relational structures, and optimization strategies of personalized communication pathways, this study aims to provide theoretical support and technical insights for innovating scientific communication models and promoting their development toward greater intelligence, personalization, and systematization.

1. Theoretical Foundations of AI-Driven Personalized Scientific Communication

1.1 Connotation and Cognitive Characteristics of Personalized Scientific Communication

Personalized scientific communication refers to a model of scientific knowledge dissemination based on individualized cognitive needs and information adaptation principles. Its core lies in dynamically adjusting communication content and modes of expression according to the audience's specific interests, knowledge structures, and cognitive levels. Unlike traditional scientific communication, which emphasizes wide coverage and one-way transmission, personalized scientific

communication focuses more on directional filtering, refined expression, and enhanced interactivity. Its connotation encompasses not only differentiated content selection and targeted semantic expression but also the flexible restructuring of information architecture and the contextual arrangement of knowledge presentation. Through continuous analysis of audience preferences and cognitive patterns, personalized scientific communication enables multidimensional deep processing and precise distribution of knowledge, making scientific information more aligned with individual comprehension paths and processing rhythms.

Cognitively, personalized scientific communication is characterized by sensitive adaptation to individual cognitive structures and dynamic response to interactive feedback. Fundamentally, it is an audience-centered cognitive optimization process that relies on multilayered information filtering and semantic association mapping to achieve hierarchical regulation from macro knowledge frameworks to micro information units. This communication model emphasizes the interpretability of knowledge and the coherence of semantics, enabling the audience to form continuous conceptual connections and structured cognition throughout the comprehension process. Through dynamically updated content matching and context-driven narrative design, personalized scientific communication not only enhances the efficiency of knowledge acquisition but also facilitates the deep assimilation and meaning construction of scientific information ^[1].

1.2 Technological Empowerment Logic of Artificial Intelligence in Scientific Communication

The empowering role of artificial intelligence in scientific communication is mainly reflected in its ability to intelligently extract information, reorganize semantics, and generate multimodal content. This technological logic is grounded in the integration of large-scale data learning, natural language processing, and knowledge graph construction. Through deep learning and semantic analysis, AI can structurally analyze multi-source information such as scientific texts, images, and audio, enabling the automatic identification of knowledge elements and the precise annotation of semantic relationships. Based on this, scientific knowledge can be expressed through algorithm-driven, diversified presentation paths adapted to different cognitive levels, rather than relying solely on linear forms of delivery. In this process, AI serves as an intermediary between knowledge and the audience, with its semantic comprehension and generative capabilities effectively addressing the high complexity and abstraction inherent in scientific information.

AI's technological empowerment also manifests in the dynamic optimization of communication pathways and the iterative updating of content generation. By analyzing audience behavioral data and interactive feedback in real time, AI constructs accurate audience profiles, adjusting the pace, depth, and form of information delivery accordingly. Through the integration of knowledge graphs and recommendation algorithms, systems can maintain the accuracy of scientific content while achieving associative expansion and structural optimization of information, thereby enabling adaptive modulation of communication paths. Multimodal generation technologies further expand the expressive dimensions of scientific communication, allowing the integration of text, images, voice, and virtual interaction. This facilitates the presentation of scientific knowledge in forms more attuned to cognitive psychology, enhancing both visual comprehension and immersive experience.

1.3 Value and Academic Significance of Research on Personalized Scientific Communication Pathways

Research on AI-driven personalized scientific communication pathways represents both a significant extension of scientific communication theory and a central direction for innovation in knowledge dissemination models. Its value lies in revealing the dynamic adaptation process of scientific knowledge from generation to reception through the deep integration of algorithms and cognitive mechanisms. This approach establishes a data-driven model for optimizing communication pathways, providing new theoretical support for the systematic study of scientific communication. It moves beyond traditional experience-based dissemination models by proposing a precision communication framework centered on individual cognitive differences, thereby offering more targeted theoretical foundations for the effective transmission of scientific knowledge and the enhancement of public scientific literacy ^[2].

Academically, the study of personalized scientific communication pathways offers a new perspective for interdisciplinary integration among communication studies, cognitive science, and artificial intelligence. By systematically analyzing content generation, audience cognitive construction,

and interaction behavior patterns, this research forms a complete analytical chain—from data collection and semantic parsing to pathway optimization. Such research not only contributes to the refinement of the scientific communication discipline but also promotes the evolution of dissemination models from linear logic to multidimensional dynamic network structures. More importantly, it provides new insights into how AI can participate in the cognitive processing and semantic generation of knowledge, advancing scientific communication from simple information transfer to deep cognitive collaboration powered by intelligent algorithms, and opening new academic frontiers for future intelligent communication studies.

2. Constructive Elements and Associative Structures of Personalized Scientific Communication Pathways

2.1 Personalized Expression Logic of Content Generation and Semantic Reorganization

Content generation and semantic reorganization constitute the core foundation of personalized scientific communication, with their logical basis rooted in deep semantic analysis of scientific information and the structured reconstruction of multidimensional knowledge units. Through natural language processing, knowledge extraction, and semantic network modeling, artificial intelligence identifies and annotates conceptual nodes, causal chains, and logical relationships in scientific texts at multiple levels, transforming highly abstract, linear scientific knowledge into stratified and interconnected knowledge networks. By leveraging contextual inference and semantic similarity calculations in generative models, AI can produce versions of varying complexity and depth tailored to audiences' cognitive levels and informational needs, achieving precise adaptation and dissemination from macro-level knowledge frameworks to micro-level informational details.

Semantic reorganization involves not merely the rearrangement of information, but also the optimization and reshaping of knowledge expression structures and narrative logic. Artificial intelligence can dynamically adjust the presentation sequence and narrative pacing of scientific concepts based on an audience's knowledge graph, semantic comprehension ability, and cognitive preferences, thereby constructing a progressive expression framework centered on core concepts and expanding toward related knowledge. This expression logic enhances semantic coherence and cognitive fluency in scientific communication, enabling audiences to form stable conceptual chains and structured cognitive patterns during information processing. The integration of multimodal generation technologies further enriches expressive forms—through the logical refinement of text, intuitive visualization via images, and perceptual reinforcement through audio—jointly creating an immersive and cognitively engaging communication experience that stimulates curiosity and facilitates the internalization of scientific concepts^[3].

2.2 Associative Construction of Audience Profiling and Dynamic Adaptation

Audience profiling is a central component of personalized scientific communication. Its essence lies in the in-depth modeling of audience interests, semantic comprehension abilities, and knowledge reserves based on multi-source behavioral data and cognitive characteristics. Artificial intelligence continuously mines interaction behaviors, learning trajectories, information absorption patterns, and interest preferences to build multidimensional, evolvable audience models. These models represent not only static attribute descriptions but also dynamic cognitive structures that update in response to changes in knowledge levels and behavioral patterns, providing stable yet flexible support for subsequent content matching and communication pathway optimization.

Dynamic adaptation relies on the efficient linkage between audience profiling and content generation modules. Through real-time data feedback and dynamic adjustment of feature weights, artificial intelligence optimizes the accuracy and pacing of information delivery for different audience types, enabling the communication pathway to accommodate the gradual progression from superficial understanding to deep comprehension. Adaptation algorithms based on knowledge graph associations and reinforcement learning continuously update dissemination strategies, giving content recommendations adaptive and evolutionary characteristics. This associative construction reinforces the coupling relationship between scientific knowledge and individual cognition, shifting scientific communication from passive information provision to proactive cognitive guidance and, over time, enhancing audience engagement and steadily improving scientific literacy.

2.3 Systematic Integration of Pathway Association Structures

The pathway association structure is key to achieving the systematization and intelligentization of personalized scientific communication. Its objective is to construct a closed, flexible, and scalable communication network through the coordinated integration of content generation, audience profiling, and dynamic adaptation. Based on knowledge graphs, semantic networks, and interaction data, this structure models logical connections and semantic couplings among multi-level nodes, forming ordered and progressive dissemination chains among different knowledge units. The dynamic updates of audience profiling and the real-time involvement of feedback mechanisms provide continuous optimization power for the pathways, endowing the communication structure with complex network characteristics—multi-level, multi-node—and enabling personalized transfer and differentiated presentation across various audience groups ^[4].

Systematic integration is realized not only through the networking of communication pathways but also through their self-organizing and evolutionary capacities. In this process, artificial intelligence assumes dual roles of information coordination and pathway restructuring. Algorithmic optimization enables efficient linkage and information flow between communication nodes, allowing pathways to be dynamically reconfigured according to audience interests and cognitive progression. This integration model forms an efficient closed loop among content expression, audience cognition, and interactive behavior, thereby enhancing the specificity and logicity of scientific knowledge dissemination. The systematic integration of pathway association structures supports the shift from local adaptation to global optimization in personalized scientific communication and lays a solid foundation for the future development of intelligent communication systems with high adaptability and evolutionary capacity.

3. Optimization of Personalized Scientific Communication Pathways Driven by Artificial Intelligence

3.1 The Role of Multimodal Interaction in Communication Pathway Optimization

The core value of multimodal interaction in optimizing personalized scientific communication pathways lies in its capacity to deeply integrate multisource perceptual information and construct semantic associations, thereby enabling immersive knowledge presentation aligned with human cognitive mechanisms. By leveraging deep neural networks, multimodal fusion, and feature embedding technologies, artificial intelligence extracts layered features from various forms of scientific information—such as images, speech, and text—and achieves cross-modal mapping within a unified semantic space. This process enables consistent expression and dynamic complementarity at the perceptual level. Visual cues enhance spatial understanding of structured scientific information; speech input reduces the cognitive load of abstract concepts; textual descriptions provide detailed and logical support. The synergy among these channels significantly improves the fluency and stability of knowledge absorption. The introduction of multimodal interaction not only transforms the traditionally unidimensional structure of scientific communication but also offers new pathways for the visualization and perceptual accessibility of complex scientific knowledge.

The optimization effects also extend to dynamic propulsion and real-time regulation of communication pathways. Based on multimodal perceptual data, artificial intelligence captures audiences' observable behaviors and latent cognitive states—such as visual attention, voice feedback, and interactive operations—and models attention distribution and emotional tendencies to accurately infer audience interests and comprehension levels. The coupling of multimodal perception and behavioral analysis provides real-time evidence for pathway optimization, enabling systems to dynamically adjust the rhythm, content depth, and expressive form of information delivery according to cognitive load. This facilitates cross-level adaptation evolving from static matching to continuous transformation. Such an optimization model, centered on multimodal interaction, not only enhances interactivity and audience engagement in scientific communication but also provides a scalable data foundation for the self-adaptive optimization and ongoing evolution of communication pathways ^[5].

3.2 Optimization Strategies for Knowledge Recommendation and Iterative Updating

Knowledge recommendation is a critical component in optimizing personalized scientific communication pathways, with its core function rooted in deep modeling of audience interests, cognitive levels, and knowledge needs to enable precise information delivery and progressive

expansion. Through collaborative filtering, deep semantic matching, and knowledge graph reasoning, artificial intelligence applies multi-layered algorithms to calculate the semantic relevance and logical dependency weights of scientific knowledge nodes, thereby generating progressive recommendation sequences that expand from core concepts to related knowledge. This multilayered, semantically networked recommendation approach enhances the specificity of scientific communication while avoiding redundancy and cognitive overload caused by generalized information dissemination. It also provides a clear pathway for the systematic understanding of complex scientific content.

Iterative updating achieves dynamic optimization and continuous evolution of communication pathways through feedback-driven and self-learning mechanisms. Upon receiving real-time interaction data and feedback from audiences, artificial intelligence systems adaptively reconstruct recommendation models by adjusting parameters and updating weights, ensuring that content delivery dynamically evolves with changes in audience cognition and shifting interests. This strategy not only guarantees the timeliness and relevance of information transmission but also supports the self-organizing growth of knowledge chains. In this way, communication pathways facilitate gradual cognitive penetration while maintaining scientific rigor and logical coherence. The synergy between knowledge recommendation and iterative updating forms a closed-loop mechanism encompassing information filtering, pathway optimization, and cognitive guidance, thereby providing technological support for the sustained improvement of scientific literacy and long-term cognitive development among audiences.

3.3 Future Trends in the Optimization of Personalized Communication Pathways

Future optimization of personalized scientific communication pathways will increasingly rely on breakthroughs in artificial intelligence related to algorithm transparency, semantic generation, and cognitive modeling. The integration of explainable AI will shift pathway construction and optimization from opaque, black-box recommendations to traceable reasoning chains, ensuring the verifiability and academic reliability of content generation and recommendation logic. Advances in semantic generation technologies will further enhance the flexibility and granularity of scientific knowledge expression, enabling generative models to adaptively adjust content in dynamic narrative structures based on real-time audience feedback. This will facilitate individualized expression while maintaining scientific rigor. In addition, research integrating cognitive psychology and brain-computer interface technologies will provide new theoretical and technical support for pathway optimization, enabling systems to more directly capture and predict audience cognitive states and emotional responses, thus promoting a shift from passive adaptation to proactive guidance ^[6].

The trend toward interdisciplinary integration will also become a vital direction for future optimization. The fusion of insights from cognitive science, linguistics, and human-computer interaction with AI algorithms will offer theoretical frameworks and implementation methods that are more aligned with human cognitive mechanisms. Through associative mining based on large-scale knowledge graphs and cross-domain data, communication pathways will move beyond single-discipline knowledge recommendations, progressively constructing cross-disciplinary knowledge networks to meet audiences' comprehensive cognitive needs regarding complex scientific topics. In the future, personalized scientific communication pathways will evolve into intelligent communication systems characterized by self-learning, self-optimization, and self-adaptation, driven by intelligent evolution, semantic adaptability, and cognitive synergy. This evolution will lay a solid theoretical and technological foundation for the efficient dissemination and deep understanding of scientific knowledge.

Conclusion

The study on AI-driven personalized science communication paths reveals a transformational trend in science communication from linear dissemination to networked and adaptive evolution. Through the integrated application of technologies such as semantic reorganization, multimodal interaction, audience profiling, and dynamic adaptation, science communication can achieve full-chain optimization from content generation to dissemination paths, thereby aligning knowledge expression more closely with individual cognitive patterns and enhancing the immersion and interactivity of the communication process. Future development will increasingly rely on the deep integration of explainable artificial intelligence and semantic generation technologies to realize transparent optimization and intelligent evolution of communication paths. Interdisciplinary collaboration will also

become a key trend, as research outcomes from cognitive science, linguistics, and human-computer interaction, in conjunction with large-scale knowledge graphs, will jointly construct cross-disciplinary knowledge networks to meet the comprehensive cognitive demands of complex scientific issues. Personalized science communication paths, propelled by continuous advancements in intelligent evolution, semantic adaptability, and cognitive synergy, will provide more solid theoretical and technological support for the efficient dissemination of scientific knowledge and the comprehensive enhancement of scientific literacy.

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