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The Application of Generative Artificial Intelligence in Medical Education in Higher Education: A Theoretical Exploration of Enhancing Medical Students' Tolerance for Uncertainty

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Abstract: In the complex and uncertain clinical environment, enhancing medical students' tolerance for uncertainty has become a key challenge in medical education. This study, through a literature review and theoretical analysis, explores how generative artificial intelligence (AI) can assist medical students in better coping with uncertainty in simulated clinical scenarios, personalized learning paths, and real-time decision support. The findings indicate that generative AI plays a significant role in improving students' cognitive responses and emotional regulation, enhancing their confidence and ability to make decisions in complex situations, thereby increasing their tolerance for uncertainty.

Keywords: Medical students; generative artificial intelligence; tolerance for uncertainty

1. The Current State of Generative Artificial Intelligence in Medical Education

Since the launch of OpenAI's advanced natural language processing generative AI programs in November 2022, the application of generative AI in medical education has rapidly advanced. Cutting-edge models such as ChatGPT and Gimini, powered by massive data training and sophisticated algorithmic design, have demonstrated outstanding language generation and comprehension capabilities. ChatGPT, based on the GPT-3 and GPT-4 models, can generate coherent and logically consistent text, and has been widely used in areas such as conversational systems, content creation, and educational assistance. Gimini, leveraging a bidirectional attention mechanism along with multi-layer semantic analysis, enhances understanding of dialogue context and improves the accuracy and relevance of language generation. It has proven especially effective in personalized learning and clinical decision support. [1]

These technological advancements have shown tremendous potential across various fields, particularly in medical education, where they offer new approaches to enhancing medical students' ability to cope with uncertainty. Generative AI plays a significant role by simulating clinical scenarios, providing personalized learning paths, and augmenting clinical decision-making training. Virtual patient simulation systems,

for example, utilize ChatGPT to generate diverse disease symptoms and medical history descriptions, helping medical students practice diagnosis and treatment in complex cases and uncertain situations, thereby improving their ability to tolerate uncertainty. Personalized learning systems analyze students' learning progress, generating tailored study materials and review questions to enhance learning outcomes. Clinical decision support systems can provide real-time diagnostic and treatment recommendations, boosting students' clinical decision-making skills and confidence.

2. The Concept of Tolerance for Uncertainty

Tolerance for uncertainty refers to an individual's ability to remain calm, respond effectively, and make decisions in the face of ambiguity, complexity, or risky situations. In medical education, generative AI holds significant potential, especially given the high demands placed on doctors' tolerance for uncertainty in the complex and dynamic clinical environment. Therefore, exploring how generative AI can enhance medical students' tolerance for uncertainty is of particular importance. Research by Han et al. (2015) found that ambiguity has a significant impact on medical students' tolerance for uncertainty, whereas their tolerance for complexity and risk showed no significant changes. In medical education, ambiguity may manifest in unclear medical histories or atypical symptoms. Geller et al. (2021) also argued that ambiguity significantly affects medical students' tolerance for uncertainty by increasing their cognitive load and emotional stress. Specifically, students face greater difficulty processing ambiguous information, and experience elevated anxiety levels due to the lack of clarity. In addressing the key issue of ambiguity, medical classrooms should embrace generative AI in a comprehensive manner, focusing on teaching, teachers, students, assessment, as well as the inheritance and innovation of medical knowledge. The integration of generative AI should aim to enhance students' tolerance for ambiguity through both cognitive and emotional dimensions. [2]

3. Cognitive Dimension: Approaches to Addressing Ambiguity

From a teaching perspective, various methods such as scenario simulation, real-time feedback, collaborative learning, interdisciplinary integration, and intelligent data analysis can effectively improve teaching models and content, enhancing students' tolerance for ambiguity and uncertainty. For instance, virtual patient simulation systems generate diverse disease symptoms and medical history descriptions, enabling students to improve their ability to cope with ambiguous information in complex cases. This method has been shown to increase the accuracy of students' decision-making in complex cases by 25% (Koerner & Advani, 2021). Additionally, clinical decision support systems, which integrate real-time feedback, collaborative learning, interdisciplinary integration, and intelligent data analysis, provide real-time diagnostic and treatment suggestions. These systems have been shown to enhance students' clinical decision-making ability and confidence, with diagnostic accuracy improving by 30% and decision time decreasing by 20% (Geller et al., 2021). Research suggests that these AI-driven teaching methods significantly reduce students' cognitive load in complex and uncertain situations, thereby increasing their tolerance for uncertainty (Yang Zongkai, Wang Jun, Wu Di, & Chen Min, 2023).

From a teacher's perspective, generative AI can efficiently process and analyze large datasets, generating coherent and natural text, thus improving the efficiency of information acquisition and knowledge dissemination. However, there are potential issues, such as inaccuracies or biases in the generated information, especially when there is a lack of up-to-date data or when data training biases exist. This can lead to misleading results (Yang Jianwu, 2024). Therefore, the relationship between teachers and generative AI should be supplementary rather than substitutive. By using virtual cases that feature common cases, atypical symptoms, and ambiguous medical histories for discussion, students can make pressure-driven decisions within a specified time. Interaction among students, teachers, and AI during decision-making helps students understand the logic and evidence behind various medical decisions, enhancing their ability to interpret ambiguous information, make decisions, and manage stress, thus improving their tolerance for uncertainty. [3]

From the students' perspective, generative AI effectively addresses ambiguity and improves tolerance for uncertainty through three dimensions: general education, personalized learning, and interactive learning. In general education, AI generates interdisciplinary cases that help students analyze

problems from different disciplinary perspectives (Topol, 2019). This multi-modal knowledge graph integrates content from multiple disciplines, which helps students build a systematic knowledge framework and reduces the ambiguity caused by fragmented information (Liu Sannuyá, 2024). In personalized learning, generative AI analyzes learning data in-depth to provide tailored study plans and real-time feedback, significantly improving diagnostic accuracy and the efficiency of self-directed learning (Koerner, Visser, & de Haes, 2021). In terms of interactive learning, simulation diagnostic scenarios created through virtual reality (VR) and augmented reality (AR) technologies can lower students' perception of ambiguity (Zhou Hongyu, 2024), thus enhancing their tolerance for uncertainty (Hillen, Gutheil, Strout, Smets, & Han, 2017).

In terms of teaching assessment, the focus has shifted toward personalized and intelligent assessment, moving from simple knowledge-based questions to comprehensive tasks. This involves using human-computer collaborative interaction to assess open-ended problem-solving and scenario-based tasks, while also evaluating higher-order thinking skills such as critical thinking, reflection, and creativity. These are all crucial means for addressing ambiguity. Medical education evaluation should gradually move away from traditional knowledge and skill-based tests towards a more holistic assessment that includes higher-order cognitive abilities and comprehensive literacy, thus promoting the diversification and integration of medical education assessment content (Walker, 2011).

4. Emotional Dimension: Approaches to Addressing Ambiguity

From a teaching perspective, AI-driven personalized learning platforms can provide real-time feedback and emotional support, effectively reducing students' frustration and enhancing their sense of self-efficacy, thereby alleviating anxiety (Luckin et al., 2016). Virtual assistants and chatbots can detect students' emotional changes in real-time and adjust teaching methods accordingly based on emotional data. This guidance helps students regulate their emotions, boosting their confidence when making decisions in ambiguous situations and improving their tolerance for uncertainty (Wang Wen, 2024). Role-playing in VR not only enhances students' understanding and memory of the learning material but also plays a similar role in improving emotional regulation and decision-making skills in uncertain contexts (Yang Yaowen, 2024). Additionally, AI-integrated social-emotional learning can more precisely enhance medical students' teamwork abilities, facilitate high-quality peer support, and reduce psychological burdens during ambiguous decision-making, ultimately improving their tolerance for uncertainty.

From the teacher's perspective, generative AI can be utilized to enhance medical students' emotional states, thereby reducing ambiguity and boosting their tolerance for uncertainty. First, generative AI can offer personalized learning experiences. By analyzing students' learning data, AI systems can provide tailored learning recommendations and resources, enabling students to learn according to their interests and needs, thereby enhancing their motivation and emotional engagement. Studies have shown that personalized learning plans significantly improve students' learning efficiency and emotional involvement (Xu & Choi, 2023). Secondly, teachers can use AI's emotion analysis technology to monitor students' emotional states in real time and adjust teaching strategies accordingly, providing timely support and guidance. This emotional feedback mechanism helps students regulate their emotions, improve adaptability in uncertain situations, and significantly enhance their mental health and emotional resilience (Buhr & Dugas, 2006). For example, real-time emotional feedback has been shown to improve students' emotional regulation ability by 25% and adaptability by 30% (Chesley & Wylson, 2016). Moreover, VR and simulation technologies create immersive virtual learning environments, allowing students to practice and role-play in realistic simulated scenarios. This not only enhances their understanding and retention of the learning material but also improves their decision-making and emotional adaptability in uncertain contexts (Carson & Langer, 2004). Studies indicate that this approach boosts students' decision-making ability in uncertain situations by 35% and their emotional adaptability by 20% (Xu & Choi, 2023).

From the students' perspective, AI can significantly enhance their emotional engagement in learning. Emotion analysis and recognition technologies, such as those based on deep learning architectures like VGG16, Resnet50, and DenseNet121, can classify emotional

images with a classification accuracy of up to 84.16% (Aksoy & Sayin, 2020). Facial expression recognition technology can recommend books, music, case studies, and even diagnostic suggestions based on the emotional state of students or patients, thereby enhancing medical students' positive emotions (Kumar et al., 2023). Real-time psychological interventions, using conversational AI agents, can offer psychological therapy suggestions in real-time or near-real-time, with around 40% of patients showing significant improvement (Gual-Montolio et al., 2022). These interventions are especially beneficial in reducing the psychological stress that accompanies decision-making under ambiguity in medical scenarios. Furthermore, gamified learning strategies, which incorporate game elements into the learning process, increase the fun and challenge of learning, stimulating students' motivation and improving their tolerance for ambiguity (Huang Ronghuai, 2024).

In terms of teaching evaluation, combining emotional and cognitive teaching methods (such as the ECOLE method) with emotion analysis-based classroom assessment techniques can significantly enhance students' positive emotions and academic performance. Additionally, deep learning techniques that analyze students' emotional states have shown that emotional analysis in the classroom helps improve the effectiveness of teaching feedback. Studies using facial emotion recognition technology to analyze students' emotional states have enhanced the accuracy and precision of assessments (Sahla & Kumar, 2016). Classroom assessment techniques (CATs) also demonstrate significant effects in assessing students' emotions. By evaluating students' anxiety, depression, calmness, and enthusiasm, teachers can design targeted interventions to increase learning enthusiasm, reduce ambiguity, and improve tolerance for uncertainty (Walker, 2011).

5. Inheritance and Innovation

The essence of education lies in the cultivation of virtues and the comprehensive development of students. Fundamental educational theories and principles, such as gradual progression, differentiated instruction, and the inclusivity of teaching, remain timeless regardless of the technological context. However, as technology evolves, the educational landscape and environment continuously innovate. Education has expanded from traditional teacher-student interactions to a hybrid model of interpersonal and human-machine interactions, and the learning environment has shifted from informatization to intelligence, providing a more diverse and interactive space for learning. Teaching content and methods have also gradually evolved from static subject knowledge to dynamic, integrated tasks. The focus has shifted from teaching-centered to learning-centered approaches, emphasizing autonomous learning and collaborative inquiry by students. Modern educational concepts place greater importance on competence, prioritizing values, and constantly innovating teaching methods by integrating more technological means and intelligent tools. Learning modes have also seen significant innovation, evolving from interpersonal collaboration to human-machine collaboration, enabling students to access knowledge in a more personalized way and improve learning efficiency and outcomes.

The application of AI in medical education has significantly enhanced medical students' tolerance for uncertainty. However, this progress must be viewed from two perspectives. On one hand, AI offers a wealth of simulation training and virtual patient cases, allowing students to practice in diverse and complex situations, thereby improving their ability to handle uncertainty in real clinical environments. On the other hand, while relying on AI for training, it is crucial to fully leverage the advantages brought by technology, while also emphasizing the importance of traditional medical education, particularly the human interaction and practical experience that form the foundation of effective learning. This balance ensures the holistic development of students and enhances their tolerance for uncertainty.

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