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Generative Artificial Intelligence in Dermatology Training: Advances and Applications in Educational Scenarios

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Abstract

Generative Artificial Intelligence (GAI) refers to a class of AI systems capable of creating novel, coherent, and contextually relevant content—such as text, images, audio, and video—based on patterns learned from extensive training datasets. The public release and rapid refinement of large language models (LLMs) like ChatGPT have accelerated the adoption of GAI across various medical specialties, offering new tools for education, clinical simulation, and research. Dermatology training, which heavily relies on visual pattern recognition and requires extensive exposure to diverse morphological presentations, faces persistent challenges such as uneven distribution of educational resources, limited patient exposure for rare conditions, and variability in teaching quality. Exploring the integration of GAI into pedagogical frameworks offers innovative approaches to address these challenges, potentially enhancing the quality, standardization, scalability, and accessibility of dermatology education. This comprehensive review examines the core concepts and technical foundations of GAI, highlights its specific applications within dermatology teaching and learning—including simulated case generation, personalized learning pathways, and academic support—and discusses the current limitations, practical challenges, and ethical considerations surrounding its use. The aim is to provide a balanced perspective on the significant potential of GAI for transforming dermatology education and to offer evidence-based insights to guide future exploration, implementation, and policy development.

Keywords Artificial Intelligence; Medical Education; Dermatology; Generative AI; Teaching

1 Introduction

Dermatology occupies a unique position in medical education due to its foundational reliance on visual pattern recognition and the morphological interpretation of cutaneous signs[1]. Mastering the specialty requires familiarity with a vast number of conditions—each characterized by diverse presentations across skin types, age groups, and disease stages—necessitating extensive and repeated visual exposure to develop diagnostic proficiency. However, the current landscape of dermatology education is often hampered by several inherent challenges. These include the visual-cognitive disconnect that arises when verbal descriptions or textual information fail to adequately convey critical lesion characteristics essential for accurate diagnosis; clinical fragmentation due to brief, episodic patient encounters that prevent observation of disease evolution and treatment response; and significant learner heterogeneity, where trainees enter with varied backgrounds requiring differentiated instructional approaches[2]. Compounding these issues are seasonal variations in disease prevalence, the inherent rarity of many dermatological conditions, and ethical or practical constraints in reproducing certain clinical scenarios for teaching, all of which can create predictable and consequential gaps in clinical exposure and competency development.

Concurrently, the rapid advancement and proliferation of artificial intelligence (AI), particularly generative AI (GAI), are reshaping educational paradigms across disciplines. Artificial intelligence, at its intersection with medical education, represents the confluence of computer science, advanced data analytics, and pedagogical theory[3]. A key distinction lies between discriminative AI—which classifies or predicts based on input data—and generative AI

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(GAI), which creates novel, realistic content spanning text, images, and multimodal outputs. GAI leverages complex algorithms, deep learning architectures, and very large datasets to generate new, realistic outputs that closely mimic the patterns and structures of its training data[4]. Its capabilities—including natural language understanding, synthetic image generation, and interactive simulation—hold particular promise for a visually intensive, pattern-based field like dermatology, suggesting potential to overcome traditional educational barriers.

This review explores the emerging role of GAI in dermatology education, framing it as a tool to augment—not replace—traditional teaching and clinical mentoring. It will define GAI and its underlying mechanisms, detail its potential applications in enhancing teaching quality, optimizing learning strategies, and supporting academic endeavors within dermatology, and critically examine its current limitations, practical implementation challenges, and associated ethical considerations. The objective is to provide a comprehensive, evidence-based overview for educators, program directors, and institutions considering integrating GAI into dermatology training programs, thereby fostering a future-ready educational ecosystem that leverages technology to train more competent, confident, and patient-centered dermatologists.

2 Generative Artificial Intelligence

2.1 Definition and Technical Foundations of GAI

Generative Artificial Intelligence (GAI) represents a rapidly advancing subset of AI algorithms specifically designed to generate novel, realistic, and coherent data samples—including text, images, video, audio, and synthetic data—that closely resemble the patterns and structures of its training dataset[4]. Unlike discriminative models that focus on classifying or predicting labels for given inputs, generative models learn the underlying probability distribution of the data to create new instances that are statistically plausible and contextually relevant. Techniques such as Generative Adversarial Networks (GANs), which pit two neural networks (a generator and a discriminator) against each other to produce increasingly realistic outputs, and transformer-based architectures (like those underpinning large language models), which use self-attention mechanisms to process sequential data, form the backbone of many contemporary GAI systems. These models are trained on massive, multimodal datasets, enabling them to capture intricate patterns and generate high-fidelity content across domains.

2.2 Current Applications of GAI in Medicine

The application of GAI in medicine is expanding rapidly beyond initial exploratory stages into tangible tools and platforms, encompassing areas such as medical education[4], where it creates interactive learning materials and virtual patients; medical image analysis[5], enhancing interpretation through synthetic data augmentation and anomaly detection; clinical decision support, offering differential diagnoses and evidence summaries; and patient communication, through automated, personalized education resources. Dermatology, being a quintessential visual and data-rich specialty, is particularly well-suited for GAI integration. The field's reliance on image recognition and pattern interpretation aligns perfectly with GAI's strengths in generating and analyzing visual data. GAI's capabilities can be leveraged for tasks including generating highly realistic synthetic dermatoscopic and clinical images for training, creating branching narrative clinical vignettes with multiple diagnostic pathways, simulating patient responses during history-taking exercises, and building intelligent tutoring systems that adapt to individual learner performance[6]. These applications collectively promise to enrich training, improve diagnostic accuracy, and expand access to specialized dermatological expertise.

3 Applications of GAI in Dermatology Education

A growing body of evidence suggests that GAI platforms possess the sophisticated ability to process and synthesize vast amounts of medical literature, guidelines, and clinical data to generate coherent, context-aware educational content, making them valuable potential resources for medical education[7]. By leveraging GAI, dermatology educators can create more interactive, dynamic, personalized, and scalable learning experiences that transcend geographical and institutional resource limitations. Furthermore, GAI can enhance the efficiency of knowledge retrieval, support evidence-based learning through instant literature synthesis, and provide just-in-time learning support during clinical rotations. Integrating GAI into dermatology education could effectively foster self-directed learning, enhance

critical thinking and diagnostic reasoning skills, and ultimately produce better-prepared clinicians. This section elaborates on these potential applications across the educational spectrum.

3.1 Enhancing Teaching Quality and Engagement

GAI offers transformative tools for enhancing the quality, consistency, and engagement of dermatology instruction by moving beyond traditional passive learning methods towards immersive, interactive, practical, and reproducible educational experiences.

3.1.1 Creating Realistic Simulated Clinical Scenarios

One significant contribution of GAI is its ability to generate highly realistic, diverse, and customizable clinical simulation scenarios that mirror the complexity and variability of real-world practice. These virtual environments provide a safe, repeatable, standardized, and scalable platform for trainees to practice diagnostic reasoning, differential diagnosis construction, management planning, and patient communication skills without any risk to actual patients. This is especially valuable in dermatology for practicing the identification of rare disorders (e.g., pemphigus variants, cutaneous lymphomas), subtle morphological variations (e.g., early melanoma vs. benign nevi), conditions across diverse skin types (Fitzpatrick I-VI), and navigating high-stakes situations like severe drug eruptions. Furthermore, GAI presents a potent solution to the longstanding challenges associated with standardized patient (SP) programs, such as limited availability, high costs, actor training, and variability in portrayal accuracy [8]. The integration of GAI with immersive technologies like Virtual Reality (VR) and Augmented Reality (AR) further amplifies its impact, allowing for the creation of deeply authentic, multi-sensory simulation scenarios featuring complex skin morphologies, realistic procedural feedback, and interactive patient avatars that respond dynamically to trainee actions[9].

3.1.2 Supporting Interactive and Adaptive Learning

Generative AI offers transformative potential in creating dynamic, responsive, and highly interactive learning environments that foster active participation, stimulate curiosity, and promote deeper cognitive engagement. By leveraging natural language processing and generative capabilities, GAI can power next generation digital tools tailored for modern pedagogical strategies such as flipped classrooms and Problem Based Learning (PBL). For instance, it can automatically create nuanced clinical cases reflecting varied demographics, disease stages, and comorbidities, along with critical thinking questions, differential diagnosis exercises, and structured prompts that encourage collaborative discussion and peer learning. These interactive, Socratic-style dialogues are instrumental in developing essential competencies including clinical reasoning, evidence-based diagnostic justification, and empathetic patient communication—skills particularly vital in dermatology, where visual interpretation and patient rapport are paramount. Furthermore, GAI-driven virtual tutors can simulate realistic conversational encounters, answer learner questions with detailed explanations, offer contextual hints during diagnostic problem-solving, and emulate challenging patient interactions. Examples include discussing a new diagnosis of psoriasis with a distressed patient, addressing concerns around isotretinoin therapy, or managing expectations in chronic conditions like eczema. Such repeated, low-stakes practice allows trainees to build clinical competence, communication skills, and confidence in a safe, feedback-rich environment, ultimately supporting the formation of skilled, patient-centered dermatologists.

3.2 Optimizing Personalized Learning Strategies

GAI can significantly personalize, streamline, and enhance the efficiency of the learning process for dermatology trainees, adapting in real-time to individual needs, knowledge gaps, learning pace, and preferred styles. The powerful information processing, retrieval, and summarization capabilities of GAI can drastically improve the efficiency of knowledge acquisition and synthesis. A key pedagogical advantage is its potential to offer truly personalized learning pathways and targeted feedback tailored to an individual resident's or student's current knowledge level, specific areas of weakness, and learning objectives [10]. This adaptive learning approach, powered by continuous assessment and data analytics, can help reinforce foundational knowledge while providing targeted support and advanced challenges exactly when needed. Furthermore, GAI shows considerable promise in assisting with exam preparation—such as for board certifications—by generating unlimited customized practice questions based on specific topics, difficulty levels, or question formats, complete with detailed explanations and references to key guidelines or studies.

3.3 Supporting Scientific Writing and Research Endeavors

GAI is increasingly playing a supportive role in assisting students, residents, and faculty with academic endeavors, though its use requires careful oversight and ethical adherence. In literature review and synthesis, GAI tools can help researchers quickly analyze vast numbers of papers, extract key findings, summarize evidence, identify knowledge gaps, and even suggest potential research questions based on current trends. In the manuscript writing process, GAI can assist with organizing ideas, drafting sections, improving language clarity and flow for non-native English speakers, and ensuring consistent formatting. It is crucial to emphasize and reiterate that the human author remains entirely responsible for the intellectual content, accuracy, validity, and integrity of the work; GAI should act strictly as an assistant in polishing expression and streamlining the writing process, not as a substitute for critical thinking, experimental design, or data interpretation. All AI-generated content must be rigorously fact-checked against authoritative sources.

4 Limitations and Ethical Considerations of GAI in Dermatology Education

Despite its significant potential and promising applications, the integration of GAI into dermatology education is not without substantial limitations, practical implementation challenges, and profound ethical considerations that must be proactively addressed. A well-documented and serious limitation is the tendency of GAI models to "hallucinate" or confabulate—generating plausible-sounding but incorrect, fabricated, or fictitious information, including non-existent references, inaccurate disease descriptions, or erroneous treatment recommendations[4]. In dermatology education, if trainees uncritically accept AI-generated content, it could lead to the acquisition and reinforcement of incorrect knowledge, ultimately compromising patient safety. The knowledge of any GAI model is also constrained by its training data, which has a pre-determined cut-off date and may not include the very latest medical research, clinical trials, or society guidelines, a significant issue in a rapidly evolving field like dermatology where new biologics and therapies emerge frequently.

The use of GAI raises several critical ethical issues that educators and institutions must confront. These include significant privacy and data security risks if sensitive patient information is inadvertently input into public or unsecured platforms; concerns about copyright infringement regarding training data; threats to academic integrity if AI is used inappropriately for assignments or publications; questions of accountability and liability for errors in AI-generated educational content; and the potential for GAI to perpetuate, amplify, and even automate biases present in its training data (e.g., under-representation of dark skin tones in dermatological images), leading to unrepresentative, inequitable, and potentially harmful educational content that disadvantages certain patient populations. Furthermore, detailed guidelines and regulatory frameworks specifically governing the development, validation, and use of GAI in medical education are still in their infancy, creating uncertainty for institutions and educators regarding best practices, quality assurance, and validation requirements. A cautious, principled, and transparent approach is essential.

5 Conclusion

Generative Artificial Intelligence represents a powerful and transformative set of technologies with considerable potential to address longstanding challenges in dermatology education. Its applications in creating realistic simulations, personalizing learning experiences, and supporting academic productivity offer exciting avenues for enhancing training. However, significant limitations, including the propensity for hallucination, knowledge currency issues, and profound ethical concerns, necessitate a cautious and critically evaluative approach. Collaborative efforts are essential to develop robust ethical frameworks, establish clear guidelines, and continuously monitor the impact of these tools. By doing so, the dermatology education community can harness the benefits of GAI while mitigating its risks, ultimately aiming to improve patient care through better trained clinicians.

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