Dermatology Practical & Conceptual

Instructional Strategies to Enhance Dermoscopic Image Interpretation Education: a Review of the Literature

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ABSTRACT

Introduction: In image interpretation education, many educators have shifted away from traditional methods that involve passive instruction and fragmented learning to interactive ones that promote active engagement and integrated knowledge. By training pattern recognition skills in an effective manner, these interactive approaches provide a promising direction for dermoscopy education.

Objectives: A narrative review of the literature was performed to probe emerging directions in medical image interpretation education that may support dermoscopy education. This article represents the second of a two-part review series.

Methods: To promote innovation in dermoscopy education, the International Skin Imaging Collaborative (ISIC) assembled an Education Working Group that comprises international dermoscopy experts and educational scientists. Based on a preliminary literature review and their experiences as educators, the group developed and refined a list of innovative approaches through multiple rounds of discussion and feedback. For each approach, literature searches were performed for relevant articles.

Results: Through a consensus-based approach, the group identified a number of theory-based approaches, as discussed in the first part of this series. The group also acknowledged the role of motivation, metacognition, and early failures in optimizing the learning process. Other promising teaching tools included gamification, social media, and perceptual and adaptive learning modules (PALMs).

Conclusions: Over the years, many dermoscopy educators may have intuitively adopted these instructional strategies in response to learner feedback, personal observations, and changes in the learning environment. For dermoscopy training, PALMs may be especially valuable in that they provide immediate feedback and adapt the training schedule to the individual's performance.

Introduction

Curricular requirements for medical education emphasize the importance of teaching students how to apply acquired knowledge in solving problems and exercising critical judgment [1].[1] The ability to manipulate knowledge in this manner is difficult if declarative concepts (e.g., key terms and definitions) are rigid and decontextualized. In the preclinical phase of medical education, learning often entailed attending organized lectures and memorizing isolated facts specific to the organ systems under study [2]. In light of the evolving educational environment, this traditional structure is being supplanted as educators incorporate classroom technology tools and experiment with different approaches (eg group discussions, case presentations, patient contact experiences) [2].

These emerging approaches aim to integrate knowledge across different specialties while improving long-term retention and preparing learners for real-world practice. In medical education, an instructional approach that promotes integrated knowledge is the illness script theory, derived from schema theory. In psychology, "schemas" are bundles of pre-existing knowledge structures in long-term memory, where information is stored indefinitely, and "scripts" refer to those knowledge structures representing generic event sequences that can be retrieved from long-term memory and activated in the appropriate real-world context. For instance, conceptual knowledge pertaining to a specific illness can be quickly retrieved upon recognition of associated triggers, such as a set of symptoms [3]. In contrast with the container model introduced in the first part of this series, the illness script theory promotes integration of declarative knowledge and pattern recognition and reinforces the development of clinical reasoning skills [3].

In image interpretation education, recent shifts away from the container model as the dominant instructional approach have occurred in radiology education [4]. Radiograph interpretation represents a complex skill since learners must apply their knowledge of anatomy and pathology and their problem-solving skills to assess each image and reach a diagnosis or conclusion [5]. In addition to absorbing relevant declarative knowledge, learners must restructure and adapt their knowledge for each new image [4]. In radiology education, traditional teaching methods have been gradually replaced by more interactive approaches, such as case-based instruction [6]. Here learners are engaged as problem solvers, actively processing and integrating information [6].

As with radiology education, pathology education has also demonstrated similar shifts away from conventional approaches in favor of more interactive ones [4,5]. Through an integrated pathology curriculum, learners become more active in their own learning, and pathology more integrated with other medical subjects [7]. As a result, acquired knowledge is more flexible and primed for application across multiple different contexts.

Similar educational methods that confer conceptual understanding and train pattern recognition through real-life cases represent a promising new direction for dermoscopy education. Combined with developments in technology, these reflect contemporary trends in teaching strategies in medical education. This review seeks to explore an array of emerging instructional strategies in image interpretation education that could meaningfully support dermoscopy training programs.

Objectives

This article represents the second part of a two-part review series on instructional approaches in image interpretation education that may translate to dermoscopy education. The first part of this series discussed limitations of traditional approaches based on the container model and considered contemporary learning theories including whole-task learning, microlearning, perceptual learning, and adaptive learning. In this second part, we will explore instructional strategies and methods—such as gamification, social media, perceptual and adaptive learning (PALMs), metacognition, and productive failure—that may also support dermoscopy education. While these strategies and methods could apply to general dermatology education, the scope of this series is limited to dermoscopy education.

Methods

The methods employed for our literature review are described in detail in the first part of this series [8]. This article presents additional instructional strategies identified during the group consensus and literature search processes of this study. The instructional strategies presented in this second part include: gamification, social media, perceptual and adaptive learning modules (PALMs), metacognition, and productive failure.

Results

Gamification

Overview

In gamification, principles of game design are strategically applied to the learning environment to enhance motivation and engagement. This strategy is derived from motivation theory, which emphasizes the importance of individual motivation in the learning process [9]. Motivation is defined as the process by which goal-directed activities are initiated and sustained [10]. In games, factors shown to enhance player motivation include challenge, curiosity, autonomy, fantasy, competition, collaboration, and recognition [10]. Conveniently, many of these factors may be incorporated into educational games to make the learning process more engaging.

By taking advantage of familiar game mechanics and dynamics, games in the educational setting induce goal-directed activity in an artificial social context, producing quantifiable outcomes [11]. The pursuit of clearly defined goals in games has been associated with increased affective measures and decreased cognitive load [12]. In other words, students have more fun when learning in a gamified environment, where they also benefit from the ability to control their own learning process.

Game Design Elements

To invoke a sense of challenge and novelty among learners, educators may incorporate the following classical elements of game design: avatars, points, badges, performance graphs, and leaderboards [11]. Avatars are digital representations of the player within the game and may be as simple as a customizable icon chosen by the player. Points are numerical representations of the player progress, and badges are emblems of achievements that can be earned and collected. For instance, a player may earn a badge for reaching a specified number of points or completing activities. Both points and badges provide immediate feedback and function as rewards. Finally, performance graphs display a player performance over time, focusing on improvements.

Each of the above elements are highly personalized aspects of the player experience that serve to sustain learner motivation [13]. By providing clear feedback, many of the elements may also enhance self-regulated learning in which learners control their own learning process and monitor their own performance. The performance data generated by player activity enables educators to analyze learner performance in order to optimize the educational program.

Applications in Dermoscopy Education

In dermoscopy education, educational applications (or "apps") such as YouDermoscopy (developed by Meeter Congressi in Italy), DermaChallenge (developed by a team from the Medical University of Vienna in Austria), and DiagnosUs (developed by Centaur Labs in the U.S.) have all embraced a gamified approach [14-16]. The YouDermoscopy app divides dermoscopic cases into different levels that can be unlocked and provides feedback on learner performance, such as through point rewards [14]. Targeted towards dermatologists, DermaChallenge features quizzes containing dermosopic images, and for each image, players select the corresponding diagnosis from choices representing common dermoscopic diagnoses [15]. If incorrect, players receive immediate feedback and review the correct answer. Quizzes are similarly organized into multiple levels that players may unlock.

More broadly, the DiagnosUs app allows players to practice image interpretation for dermoscopy in addition to other specialties, such as radiology, ophthalmology (retinography), and obstetrics/gynecology (ultrasonography) [16]. While the app contains other noteworthy features such as crowd-based labeling, its educational component is mainly geared towards medical learners, and the dermoscopy section primarily covers melanoma detection training [16]. Quizzes, called "missions," may contain dermoscopic images of nevi that players classify as benign or malignant. Once players submit their answer, they can review the correct answer, see the number of users who answered correctly or incorrectly, and participate in the discussion forum for that case [16].

Social Media

Overview

With the pervasiveness of social media in daily life, educators are also seeking to leverage social media platforms to enhance curriculum design, promoting classroom interaction and facilitating peer-to-peer learning [17]. Educators may use these platforms to either deliver or complement curriculum delivery. As active participants, learners may contribute discussion points and comments and collaborate with peers via group chats. These interactions may occur in either a synchronous fashion with real-time responses or an asynchronous fashion with delayed responses.

Applications in Medical Education

In a study in China, investigators evaluated the feasibility of a social networking platform called Microblog among pharmacotherapy students [18]. Learners completed pharmacotherapy case studies through Microblog, and the end-of-course survey results indicated that a majority of learners agreed that the platform enhanced their learning experience by increasing their active engagement in the course. Some shared that compared to meeting face-to-face, meeting online was more convenient, allowing team members to collaborate from any location "with a simple click"[18] However, some still expressed a preference for face-to-face communication, citing issues such as delayed responses and online chatter. Instructors needed to balance between maintaining a discreet online presence to promote student participation and monitoring discussion threads for potential issues (eg wrong/misleading information, repetitive comments).

Ideally, social media platforms in the educational setting create opportunities for students to share ideas and learn from peers [19]. An example in radiology education is a de novo social media platform called Collective Minds Radiology (developed by a team in Sweden) [20]. Available to download as a smartphone app, this platform enables users to share their expertise and collaborate on challenging radiology cases [20].

While the development of these platforms de novo may be time-consuming and labor-intensive, the incorporation of existing platforms into the learning environment represents an alternative route. For example, an online research methodology course implemented a collaborative space on the Twitter platform to enhance student engagement [21]. In this course, students discussed topics of interest on Twitter through tweets (text-based posts constrained by 140-280 characters) and course-specific hashtags (indexed keywords or phrases preceded by the "#" symbol). A significant majority of learners in this study agreed that the collaborative groupwork via the social media platform positively contributed to their learning.

Applications in Dermoscopy Education

As an online platform for dermatologists to discuss interesting dermoscopic cases, the International Dermoscopy Society (IDS) forum represents an example of social media in dermoscopy education [22]. Here users can share their opinions for cases (eg dermoscopic features, dermoscopic diagnoses, treatment plans) and provide their rationale, sometimes supported by references. By facilitating academic discussion, the forum allows users to learn from each other and enables new ideas to emerge. Similarly, the IDS Facebook group offers another virtual space for users to network and discuss interesting cases [23].

On Instagram, a popular photo- and video-sharing app, the handle for the most popular dermoscopy account is "@dermoscopy_."[24] Managed by a team of dermatologists in Brazil, the account boasts over 40,000 followers. The content producers frequently post short educational videos and dermoscopic images with the diagnoses or answers in the captions. Many dermatology residency programs also employ group text messaging apps such as WhatsApp and GroupMe. In these virtual spaces, trainees may share interesting de-identified dermoscopic cases from their training experiences and solicit ideas from attending physicians and other trainees.

Many educational apps that incorporate elements of game design also benefit from social media features. These apps may present cases in a game-like format and then incorporate a forum for users to discuss the cases. For example, the "Play Live" function on the YouDermoscopy app allows players to provide an opinion or request assistance from others in real time [14]. The DiagnosUs app also has a discussion forum for each case that players may use to ask clarifying questions and share their findings [16].

While the advantages of social media include increased learner engagement through opportunities for collaboration, its incorporation into the learning environment may require administrative training and technical support [17,25]. To ensure a high-quality learning experience, administrative staff may need to routinely monitor online activity to ensure accuracy of information and provide further guidance as needed.

Perceptual and Adaptive Learning Modules (PALMs)

Overview

Perceptual and adaptive learning modules (PALMs) represent a novel teaching tool in medical education that combines the strengths of both perceptual learning and adaptive learning in order to accelerate expertise [26]. As discussed in the first part of this series, the perceptual learning technique is an interactive approach that introduces a specific visual feature and then exposes learners to numerous examples so that learners can quickly and accurately identify that feature in new cases [27]. The adaptive learning technique optimizes learning outcomes through continuous performance tracking and personalized modifications [28]. This method equates low response times and high accuracy rates with content mastery [28].

The combination of these two approaches in PALMs has the potential to transform education in medical fields that rely on pattern recognition skills. Learners using PALMs may be asked to classify a number of images from a training library after being introduced to a specific visual feature. Adaptive algorithms analyze their individual performance — as assessed in terms of response time and accuracy — and make personalized modifications to their future training [29]. Learners continue training until they achieve content mastery, demonstrated by their fulfillment of the objective learning criteria. Through this training method, learners develop expert-level pattern recognition skills in an efficient manner while learning how to perform relevant clinical tasks. While the perceptual learning and adaptive learning approaches can be applied individually, learning outcomes seem to be optimized when they are strategically combined.

Applications in Medical Education

In transesophageal echocardiography (TEE) and electrocardiography (EKG) interpretation education, PALMs have enabled learners to develop pattern recognition skills comparable to those of experts. In a non-randomized controlled study on TEE interpretation, anesthesiology residents completed PALMs that showed about 180 video clips, provided feedback, and measured response time and accuracy [30]. Compared to both their baseline and the control group, learners in the PALM group performed significantly better in terms of accuracy and fluency after six months. In another before-and-after study on EKG interpretation, learners used PALMs containing over 400 unique EKG tracings and similarly retained accuracy and fluency gains after one year compared to their baseline [31].

In dermatology education, PALMs have also been successful in training pattern recognition, as demonstrated in a before-and-after study among medical students [32]. For different visual features, the PALMs presented example images in a flashcard style and measured response time and accuracy. As learner performance improved, images from that category were spaced further apart to assess long-term retention.

Applications in Dermoscopy Education

PALMs may be developed for dermoscopy education in which educators teach key dermoscopic features for common dermatologic diagnoses and then expose learners to numerous example images for each feature. Learners practice identifying features on new images and receive feedback, while adaptive algorithms measure response times and accuracy rates and retire specific learning concepts based on objective mastery criteria. To promote optimal learning, the number of example images required for these modules remains to be explored. A study on radiograph interpretation found that reusing images was similarly effective to only using unique images in terms of learning outcomes [33]. While an extensive number of unique example images may thus not be necessary for PALMs, components that seem essential include opportunities for immediate feedback and repetitive practice.

Metacognition

Overview

Metacognition, a term originally coined in the 1970s, refers to the awareness of one's own cognitive processes, or cognition about cognition [34]. In medical education, learners who apply metacognition reflect on their study strategies and learning outcomes and correct errors in order to improve performance [35]. In becoming more aware of their learning processes, students may strategically allocate their learning efforts and simultaneously reduce their cognitive load. As medical knowledge and healthcare systems continue to evolve, providers must be able to continually assess their own knowledge, performance, and possible biases to maintain good clinical practice in a rapidly changing world [36].

Applications in Medical Education

While metacognitive processes may be difficult to measure given their complexities, researchers have developed various instruments to evaluate metacognition and self-regulation, the latter referring to the ability to control one own learning through planning, monitoring, and evaluation [36]. In the literature, the following methods have been adopted for medical education:

1. The Metacognitive Awareness Inventory (MAI) measures two broad categories of metacognition, knowledge of cognition and regulation of cognition [37].
2. The Inventory of Learning Styles (ILS) measures aspects of self-regulation, external regulation, and lack of regulation [38]. The self-regulation scale measures the degree to which students reflect on their learning processes, identify the cause of their learning problems, and manage their efforts in achieving their own learning objectives. The external regulation scale measures the degree to which students rely on didactic aids, such as formal learning objectives, and external support, such as feedback and assignments from instructors. The lack of regulation scale concerns the inability of students to regulate learning and the perceived lack of external support.
3. The Self-Regulated Learning Perception Scale (SRLPS) measures motivation and action to learning; planning and goal setting; strategies for learning and assessment; and lack of self-directedness [39].

The above instruments may be employed on a routine basis to gain further insight into metacognitive processes and learning experiences. For example, a study on metacognition across four medical schools employed both the MAI and SRLPS and found that students in the clinical phase of their training demonstrated higher levels of metacognition, especially in terms of planning and goal setting, compared to those in the preclinical phase [39]. Students enrolled at schools that applied learner-centered teaching methods, such as problem-based learning, also displayed higher levels of metacognition compared those learning via conventional methods [39]. Similar scales may be employed in dermoscopy education to assess changes in metacognitive awareness over the course of a training program.

Applications in Dermoscopy Education

A proposed strategy to prime metacognitive awareness in dermoscopy learners involves prospective judgments of learning (JOLs) in which learners rate how likely they would remember an item on a test [40]. The act of making JOLs has been shown to enhance long-term memory and improve learning performance on cued recall tests [41]. In dermoscopy education, this strategy may be applied by prompting learners to rate their level of confidence in answering a question, such as whether a dermoscopic image contains a specific feature. Learners may track changes in their performance as well as changes in their confidence throughout the training program in order to better understand their strengths and weaknesses.

Metacognition allows learners to more actively engage in their own learning as they consider their knowledge, personal abilities, and learning strategies [42]. To better understand their strengths and weaknesses for metacognitive processes, learners require some form of feedback on their performance. Digital solutions, such as mobile apps, may facilitate metacognitive awareness through auto-generated displays of performance data, encouraging proactive adjustments of learning strategies. In incorporating elements of game design, the process of reflecting on learning progress may become more engaging for both learners and educators.

Beyond the classroom setting, learners may also contemplate instances of cognitive error in real-life clinical practice. Cognitive errors specific to skin cancer diagnosis include inattentional blindness (overlooking a melanoma) and diagnostic error (evaluating a melanoma but incorrectly diagnosing it as a benign skin growth). When presented with feedback and performance data, learners may reflect upon errors in their learning strategies and adjust accordingly.

In real-life clinical practice, most expert dermoscopists describe systematically capturing dermoscopic images of all biopsied lesions and then reviewing those images when their clinical diagnosis is discordant with the histopathologic diagnosis. In reviewing the images, overlooked clues may be identified, improving the provider proficiency. Metacognitive awareness thus has the potential to improve performance and long-term learning outcomes in the clinical setting.

Productive Failure

Overview

Productive failure is a relatively novel concept in education that uses early failures to activate retrieval of prior knowledge and promote problem-solving skills [43]. It plays on the proverbial wisdom of failing before succeeding and encourages creative risk-taking [44]. This method is conceptualized as a two-phase process [43]. In the first phase, learners are given a challenging problem to solve on their own or in groups prior to any, or minimal, didactic training (Generation and Exploration). After struggling to generate their own solutions to the challenging problem, learners are provided formal training (Consolidation and Knowledge Assembly). The learner initial struggle with the challenging problem may facilitate conceptual understanding and meaningful future learning [45]. Learners who are prepared for future learning demonstrate the ability to apply key learning concepts in solving new problems [45].

By inducing early failures within a safe learning environment, productive failure may create conditions in which learners become more motivated to obtain and retain a solution to the problem given the effort already invested into solving it [46]. This phenomenon is known as the endowment effect: once learners endow a problem with resources, such as time and effort, it may become more emotionally valuable to know and learn the solution [46].

In a testing-oriented learning environment, instructional design that incorporates productive failure may also benefit from the testing effect, which refers to the positive effects of test-taking on long-term memory and knowledge retention [47]. While the challenging problem is not necessarily presented as a test, students may perceive it as a form of assessment as they practice retrieving their prior knowledge. Though these difficult exercises may hamper learning performance in the short run, they may improve learning outcomes in the long run [48].

Applications in Medical Education

In implementing the productive failure approach, it is important that students actively generate mistakes themselves rather than observe the mistakes of others [49]. Yet, the productive failure approach may be uncomfortable for learners with strong aversion to failure. To minimize negative psychological consequences of failure, instructors may apply a classroom strategy called error management training in which errors are framed as "positive" occurrences and natural byproducts of the learning process [50]. In a randomized study, medical students assigned to error management training were encouraged to probe freely, make errors during ultrasound practice, and reflect on their errors [50]. In a simulation-based test conducted a week later with real patients, students in the error management arm performed better than those in the error avoidance arm.

Technology tools may also ease learners aversion to failure by creating a low-stakes learning environment, allowing students to explore new problems in a safe and non-threatening setting. The use of technology enables small failures to be "contained and managed" within an external system [44].

Applications in Dermoscopy Education

Productive failure recognizes the inherent value of mistakes and the educational utility of errors. By inducing early failures within a safe learning environment and activating the problem-solving process, productive failure can be an effective teaching tool. In dermoscopy education, productive failure can be implemented by providing challenging cases before each module, followed by feedback and guidance. This will help activate a shift towards planning and goal-setting and probe metacognitive awareness of potential weaknesses. Incorporation of technology tools may also help establish a safe learning environment that permits learners to make mistakes and understand their mistakes, spurring them towards later success in their learning journey.

Conclusions

A summary of the instructional strategies and methods explored in the second part of this review series is included in Tables 1 and 2. Over the years, many dermoscopy educators may have intuitively adopted these approaches in response to learner feedback, personal observations, and changes in the learning environment. In dermoscopy education, the strategic integration of these emerging approaches may support the development of pattern recognition skills, such as global interpretation and holistic processing.

In light of our review, we envision a hypothetical dermoscopy training program with active learning strategies informed by contemporary learning theories. In this program, learning concepts, such as a specific diagnosis, could be organized as their own unit, and each unit could be prefaced by a challenging problem that simulates productive failure and activates problem-solving processes. For each diagnosis, learners could learn and review educational content using PALMs that teach key diagnostic features and expose

Table 1. Summary of the instructional methods presented in the second part of this review series plus examples of existing or potential applications in dermoscopy education.

Educational Method	Description	Application(s) in Dermoscopy Education
Gamification	• Factors that contribute to learner motivation include challenge, curiosity, autonomy, fantasy, competition, collaboration, and recognition. • In gamification, principles of motivation theory and elements of game design are applied to the educational context to enhance learner engagement and promote goal-directed learning.	*Existing Applications* • YouDermoscopy, created and developed by Meeter Congressi SRL • DermaChallenge (Dermonaut), created by H. Kittler, P. Tschandl, and C. Rinner • DiagnosUs, created and developed by Centaur Labs

PALMs	• PALMs combine both perceptual learning techniques and adaptive learning algorithms to efficiently train pattern recognition skills.
	• Learners classify unique images and receive immediate visual feedback, and adaptive algorithms determine whether to re-sequence or retire specific learning concepts.
		Potential Application
		• dermoscopy PALMs:
		  • educators teach key diagnostic features and expose learners to numerous example images
		  • learners identify features on new images and receive feedback
		  • adaptive algorithms retire specific learning concepts based on objective mastery criteria

Social Media	• Social media platforms are leveraged by educators to increase learner engagement and foster peer-to-peer interaction. • Learners benefit from opportunities for collaboration on cases plus the convenience of a web-based platform. • Disadvantages may include delayed responses, poor quality of interaction, and wrong or misleading information from peers.	*Existing Applications* • IDS Forum • Facebook pages (e.g., IDS page) • Instagram accounts (e.g., @dermoscopy_) • WhatsApp groups (e.g., dermatology trainee groups)

IDS = International Dermoscopy Society; PALMs = perceptual and adaptive learning modules.

Table 2. Summary of the educational concepts presented in the second part of this review series plus examples of existing or potential applications in dermoscopy education.

Educational Concept	Description	Application(s) in Dermoscopy Education
Metacognition	• Learners who apply metacognition (awareness of one own cognitive processes) reflect on their learning processes and learning outcomes. • When presented with visual feedback and performance data, learners may identify potential errors in their learning strategies and adjust accordingly.	*Potential Application* • JOLs: learners "bet" on whether they will remember a given item or rate their level of confidence in answering a question (e.g., whether a dermoscopic image contains a specific feature)
Productive Failure	• Learners are given a challenging problem to solve prior to didactic training (Exploration). After struggling to generate their own solutions, learners are then provided the didactic training (Consolidation). • The learner initial struggle with the challenging problem facilitates meaningful future learning.	*Potential Applications* • challenging problem: learners annotate dermoscopic images prior to instruction • error management: learners receive instructions that frame errors as positive occurrences

JOLs = judgments of learning.

learners to numerous example images. Learners identify features on new images and receive feedback, and adaptive algorithms retire specific learning concepts based on objective mastery criteria. The PALMs may involve elements of game design such as points and badges that enhance learner engagement.

The program could also be supplemented by group forums, hosted either in-person or on social media platforms, where learners collaborate with their peers on challenging cases. Using real-time feedback and performance data from multiple components of the course, learners may apply metacognitive processes to identify strengths and weaknesses and modify their learning strategies.

This hypothetical program represents just one way to apply active learning strategies in dermoscopic image interpretation education. For a complex multi-component program, technical challenges are to be expected, but existing technology tools, such as virtual delivery formats and smartphone apps, may represent smart solutions to these challenges. As medical educators seek to apply innovative methods to dermoscopy education, the development of appropriate technology will support the seamless integration of multiple methods.

Collectively, these emerging approaches in image interpretation education illuminate an exciting direction for the future of dermoscopy education. Compared to traditional approaches, these strategies may enable the dermoscopy learner to develop expert-level pattern recognition skills more effectively. PALMs may be especially valuable in that they provide immediate feedback and adapt the training schedule to the individual's performance. The development of technology tools that enable the integration of these different approaches in dermoscopy education will greatly facilitate endeavors to optimize knowledge acquisition and skills development.

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