



Theory-Based Approaches to Support Dermoscopic Image Interpretation Education: A Review of the Literature

Tiffany Tran¹, Niels K Ternov², Jochen Weber³, Catarina Barata⁴, Elizabeth G Berry⁵, Hung Q Doan¹, Ashfaq A Marghoob³, Elizabeth V Seiverling⁶, Shelly Sinclair⁷, Jennifer A Stein⁸, Elizabeth R Stoos⁵, Martin G Tolsgaard⁹, Maya Wolfensperger¹⁰, Ralph P Braun¹⁰, Kelly C Nelson¹

- 1 Department of Dermatology, The University of Texas MD Anderson Cancer Center, Houston, TX, USA
2 Department of Plastic Surgery, Herlev Hospital, Herlev, Denmark
3 Dermatology Service, Memorial Sloan Kettering Cancer Center, New York, NY, USA
4 Institute for Systems and Robotics; Instituto Superior Técnico, University of Lisbon, Lisbon, Portugal
5 Department of Dermatology, Oregon Health & Science University, Portland, OR, USA
6 Division of Dermatology, Maine Medical Center, Portland, ME, USA; Department of Dermatology, Tufts University School of Medicine, Boston, MA, USA
7 Department of Biology, Davidson College, Davidson, NC, USA
8 The Ronald O. Perelman Department of Dermatology, New York University School of Medicine, New York, NY, USA
9 Copenhagen Academy for Medical Education and Simulation; Department of Obstetrics, Copenhagen University Hospital Rigshospitalet, Copenhagen, Denmark
10 Department of Dermatology, University Hospital of Zürich, University of Zürich, Zürich, Switzerland

Key words: dermoscopy education, image interpretation education, pattern recognition, educational theory, container model

Citation: Tran T, Ternov NK, Weber J, et al. Theory-Based Approaches to Support Dermoscopic Image Interpretation Education: A Review of the Literature. *Dermatol Pract Concept*. 2022;12(4):e2022188. DOI: <https://doi.org/10.5826/dpc.1204a188>

Accepted: February 1, 2022; **Published:** October 2022

Copyright: ©2022 Tran et al. This is an open-access article distributed under the terms of the Creative Commons Attribution-NonCommercial License (BY-NC-4.0), <https://creativecommons.org/licenses/by-nc/4.0/>, which permits unrestricted noncommercial use, distribution, and reproduction in any medium, provided the original authors and source are credited.

Funding: None.

Competing Interests: None.

Authorship: All authors have contributed significantly to this publication.

Corresponding Author: Kelly C. Nelson, MD, Department of Dermatology, The University of Texas MD Anderson Cancer Center, 1400 Pressler Street, Unit 1452, Houston, TX 77030, USA, Telephone: 713-745-1113, Fax: 713-745-3597, E-mail: kcnelson1@mdanderson.org

ABSTRACT **Introduction:** Efficient interpretation of dermoscopic images relies on pattern recognition, and the development of expert-level proficiency typically requires extensive training and years of practice. While traditional methods of transferring knowledge have proven effective, technological advances may significantly improve upon these strategies and better equip dermoscopy learners with the pattern recognition skills required for real-world practice.

Objectives: A narrative review of the literature was performed to explore emerging directions in medical image interpretation education that may enhance dermoscopy education. This article represents the first of a two-part review series on this topic.

Methods: To promote innovation in dermoscopy education, the International Skin Imaging Collaborative (ISIC) assembled a 12-member 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 emerging directions in image interpretation education. The following theory-based approaches will be discussed in this first part: whole-task learning, microlearning, perceptual learning, and adaptive learning.

Conclusions: Compared to traditional methods, these theory-based approaches may enhance dermoscopy education by making learning more engaging and interactive and reducing the amount of time required to develop expert-level pattern recognition skills. Further exploration is needed to determine how these approaches can be seamlessly and successfully integrated to optimize dermoscopy education.

Introduction

As a visual specialty, dermatology relies on the recognition of characteristic features and patterns within clinical and dermoscopic images of skin lesions. Other fields in medicine, such as radiology and pathology, also rely on pattern recognition to formulate diagnoses and plans of care. In these fields, experts are distinguished from novices by their speed and accuracy in interpreting medical images and completing diagnostic tasks. While analyzing images of skin lesions, viewers may perform global interpretation, which encompasses holistic processing with immediate pattern recognition. Viewers may also perform feature search, which involves the identification of specific features (eg, dermoscopic criteria) associated with normalcy or pathology.

Experts and novices differ in the order that they perform these mental processes during medical image analysis. Novices usually start by attempting to search deliberately for features and comparing their findings with their prior, albeit limited, knowledge and experiences. In contrast, experts typically reach a diagnostic conclusion relatively quickly through global interpretation and then seek to justify their conclusion with an efficient feature search.

Visual diagnostic skills at the expert level require the ability to perform global interpretation—or efficient pattern recognition without deliberate search strategies. Traditional educational methods that primarily drill declarative knowledge (e.g., specific features) have been largely ineffective in teaching novices the pattern recognition skills required for real-world practice. With these conventional training modalities, expert-level proficiency in dermoscopy has typically required extensive training and years of practice. A diagnostic accuracy study performed among medical students and

healthcare providers estimated that at least six years of experience may be necessary to develop a sufficient level of competency [1].

The container model embodies a traditional instructional approach centered on the idea that the acquisition of knowledge is comparable to filling one mind, or one mental filing cabinet, with as many facts and concepts as possible [2,3]. This learning theory was developed on the metaphor of our minds acting as containers capable of accumulating and retaining different items, whether real or metaphorical [4]. Using this metaphor, knowledge is regarded as a commodity to be transferred from one medium to another [3].

The expectation that diagnostic concepts can be placed in a fixed cognitive “container,” where they can then be easily accessed, is misleading, especially in the setting of medical education. The successful recall of knowledge in the real-world context seems to be strongly influenced by the learning context [5]. However, knowledge acquired using the container model is usually isolated from its context and thus static and inflexible. In practice, knowledge, even if highly case-specific, is not a readily available object to retrieve but something to reconstruct and adapt when faced with different situations [2].

Thus, opponents to the container model point out that in solving new problems, learners who have diligently absorbed declarative knowledge (eg facts and concepts that can be verbalized) under the container model may still fail to appropriately retrieve and apply that knowledge [6]. Alternatively, learners may be able to successfully adapt their knowledge in the problem-solving process, but this successful retrieval and application may require a high cognitive load [6].

The cognitive load theory is an instructional theory derived from current understanding of cognitive architecture [7]. The term cognitive load refers to the learner

mental bandwidth to complete tasks [7]. It is based on the idea that working memory—where information is stored temporarily—has limited capacity to store and use new information [7]. As a result, if the amount of new information exceeds mental capacity, further learning and accurate decision making will be impaired [8]. It is important for educators to consider cognitive load when designing instructional materials to maintain the overall load within the optimal range for learning and performance.

For difficult tasks, learners may primarily rely on deliberate and purposeful thinking, and this process may strain their working memory, negatively affecting their ability to complete the tasks. In cognitive psychology, the dual process theory recognizes two thought systems: slow (deliberate) thinking and fast (automatic) thinking [9]. For medical image interpretation, the dual process theory manifests as a two-component diagnostic strategy in which the fast system facilitates pattern recognition and the slow system facilitates analytical reasoning [10]. Within a medical simulation, accessing relevant knowledge and skills while assessing the simulated clinical environment may create a high extraneous cognitive load for learners, causing poor performance [8]. The high cognitive load experienced by learners in medical simulations may be explained by their extensive use of slow thinking as opposed to fast thinking, the former requiring considerable mental effort and use of mental resources.

Fast thinking, or non-analytical reasoning, is a key component of expert performance for diagnostic tasks that rely on pattern recognition, such as skin lesion classification in dermatology and X-ray interpretation in radiology [11]. For image interpretation education, an important goal is for novices to gradually develop a degree of automaticity in pattern recognition, which translates to a low cognitive load [10]. Traditional teaching methods based on the container model have been generally ineffective in both teaching flexible knowledge and training automaticity in novices.

In dermoscopy education, educators who use the container model usually provide instruction to passive learners on a defined set of diagnostic features, adding to their “containers.” In teaching learners to detect the relative presence or absence of a feature, this approach in effect requires real-world stimuli to likewise fit a binary interpretation (eg present/absent, melanoma/non-melanoma). However, real-world stimuli frequently present on a continuum, or a sliding scale, where concerning features may be completely non-existent, obviously present, or extremely subtle.

Dermoscopy education requires instructional approaches that transfer flexible knowledge on the continuous nature of features and their clinically relevant contexts. This review seeks to explore an array of emerging theory-based approaches in image interpretation education that may displace the container model and enhance dermoscopy training programs.

Objectives

This article represents the first of a two-part review series on novel instructional approaches in image interpretation education that could translate to dermoscopic educational interventions. In this first part, we will present a collection of theory-based approaches—such as whole case learning, microlearning, perceptual learning, and adaptive learning—that could enhance dermoscopic image interpretation education. While these emerging directions may also apply to general dermatology education, the scope of this series is limited to dermoscopy education.

Methods

To promote innovation in dermoscopy education, the International Skin Imaging Collaborative (ISIC) assembled a 12-member Education Working Group that comprises international dermoscopy experts and educational scientists. For this initiative, the group convened virtually on a regular basis to discuss novel methods in medical image interpretation education that could be translated to dermoscopy training programs. Based on a preliminary literature review as well as 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 in the PubMed and Google Scholar databases for relevant English-language articles. Search strategies included terms for concepts of dermoscopy education, image interpretation education, and health science education in addition to the instructional approach under investigation. Articles published since 2000 were preferred for inclusion, but articles published before 2000 were also considered, especially when seeking to understand the historical and theoretical underpinnings of some approaches. Additional articles were identified among the references of retrieved articles and through discussions with educational scientists.

Relevant literature findings on the educational theories, methods, and concepts identified during the consensus process are presented in this review series. The theory-based approaches described in the first part of this series include: whole-task learning, microlearning, perceptual learning, and adaptive learning.

Results

Whole-Task Learning (4-C/ID)

Overview

Whole-task learning is a time-efficient instructional design in medical education that teaches complex skill development

through authentic clinical scenarios [12]. For learners, spontaneous transfer of knowledge from the learning situation to the clinical environment is challenging [13]. Through incorporation of real-life problems and fragmentation of instruction, whole-task learning aims to teach foundational knowledge in a way that fosters the “transfer out” of knowledge to actual practice. This approach also seeks to facilitate skill transfer in a manner that attends to cognitive load [12].

A specific whole-task learning strategy is four-component instructional design (4-C/ID). The four components in 4-C/ID are: (1) learning tasks, (2) supportive information, (3) just-in-time information, and (4) part-task practice [12]. Learning tasks, which function as the backbone of 4-C/ID, are authentic tasks sequenced from simple to complex in terms of difficulty and organized into “task classes.” Supportive information may be presented at the beginning of a task class and provide foundational knowledge. Just-in-time information may be provided right when the learner needs it for a specific task. Part-task practice is an optional component in which the learner is given the opportunity to practice a specific task in order to develop a degree of automaticity. By shifting the focus of learning from lectures to clinical scenarios, learners may better appreciate the educational content and its relevance to their professional roles [14].

Whole-task learning is similar to case-based learning in that both emphasize realistic clinical situations in the instructional design. In case-based learning, learners engage in group-based discussions of authentic patient cases and receive guidance and feedback from instructors [15]. Learners are usually expected to prepare on their own through self-directed learning in advance of the case-based learning sessions [15]. In whole-task learning, learners are presented with authentic clinical scenarios prior to receiving formal instruction. As learners navigate the scenarios, they are provided further information relevant to the scenarios in a structured delivery format.

Applications in Medical Education

Task-based learning has been applied in surgical education in recent years. A randomized controlled study conducted among surgical interns implemented task-based learning in an inanimate surgical skills laboratory setting [16]. Compared to the control group, the intervention group performed better on post-intervention assessments and required less time to complete the clinical procedure [16]. Another qualitative study evaluated the feasibility and efficacy of whole-task learning in a web-based doctoral-level pharmacotherapy course and garnered positive results [14]. Learners expressed that by posing authentic scenarios, the complex delivery format provided them an opportunity to identify with their future health profession [14].

Applications in Dermoscopy Education

In whole-task learning, authentic scenarios, structured in a way to facilitate skill transfer to clinical encounters, serve as the framework for learning. This approach contrasts with conventional teaching models that focus on didactic lectures, which are then supported by hypothetical scenarios. Whole-task learning could be applied to dermoscopy education to promote problem-solving skills and foster professional independence. Learning tasks may involve addressing skin complaints in hypothetical patient encounters. Learners then receive instruction on the dermoscopic appearance of common dermatologic diagnoses (supportive information).

Dermoscopic training programs that involve case-based learning could be adapted to whole-task learning by re-structuring the curriculum with cases at the forefront and re-imagining each case as a series of learning tasks [17]. For example, dermoscopic cases are introduced prior to receiving instruction. As they navigate through cases, learners may receive further information on specific dermoscopic features and management approaches in the form of didactic lectures, multimedia content, or other teaching materials [18]. After completing the didactic portion, learners may then engage in repetitive practice to develop task automaticity and efficiency.

Microlearning

Overview

Microlearning is an instructional approach that involves segmenting the curriculum into short bursts, or small bites, of learning [19]. In contrast to traditional training sessions with “massed” practice, microlearning sessions may involve spaced review and distributed practice, increasing on-task attention and decreasing mind wandering [20]. According to the “forgetting curve,” memory retention declines over time as learners tend to forget much of their learned material within hours or days [19]. Microlearning seeks to address this trend by introducing and re-introducing lessons in short bursts. Through distributed practice, microlearning promotes the transfer of information from short-term to long-term memory storage [19].

With the microlearning approach, learners experience low cognitive load since working memory does not become overstrained, and this maintains learning capacity [21]. In reducing mental fatigue, this strategy increases learning retention and efficiency [19]. While microlearning lessons are usually self-paced, learners tend to complete them faster given their high level of engagement [19].

Applications in Medical Education

In recent years, microlearning modules have become more readily available to learners with the emergence of

multimedia content that can be easily accessed via personal devices. In a Dutch non-randomized study involving medical and biomedical university students, investigators employed an open-source mobile application (or “app”) to teach circulation and respiration using microlearning and spaced review [22]. For a month before the exam, learners used the app to complete training modules with practice assessments that reviewed educational content and provided feedback. Intensive app users performed significantly better on the final exam compared to moderate users and non-users, though these results may also be correlated with increased time spent learning [23].

Applications in Dermoscopy Education

In dermoscopy education, a real-life example of microlearning can be found in a telementoring framework model called Project ECHO (Extension for Community Health Outcomes) [24]. As an effective alternative to on-site mentoring, tele-mentoring allows learners to process the cases with real-time guidance from dermoscopy experts [25]. In Project ECHO, teaching sessions occur on a monthly basis and pair a didactic micro-lecture with learner presentations of real-life challenging cases encountered during patient care. A before-and-after study among primary care providers demonstrated that ECHO attendance increased participants’ ability to interpret dermoscopic images of skin cancer [25].

Another example of microlearning in dermoscopy can be found in the educational webcasts posted by the International Dermoscopy Society (IDS). These webcasts include short YouTube videos of 5 to 10 minutes in length organized into disease-based learning (Level 1), morphology-based learning (Level 2), and context-based learning (Level 3) as well as case-based learning [26]. To facilitate conceptual understanding, these webcasts could be expanded by posting dermoscopic images with practice questions plus key points in a microlearning format on a weekly or monthly basis.

Since microlearning can be applied to drill certain topics or specific skills, educators may consider whether to implement “blocked” or “interleaved” practice. Many programs involve “blocked” practice in which the learner practices specific skills (eg A, B, C) one at a time in isolation (eg AAA BBB CCC) [27]. An alternative to “blocked” practice is “interleaved” practice in which learners practice multiple different skills in an intermixed order (eg ABC BCA CAB). In interleaved practice, the amount of practice devoted to a specific skill becomes spaced, or distributed, across the learning session [27].

By continuously exposing learners to multiple relevant topics, interleaved practice may be more effective in preparing learners for real-life applications. In dermoscopy

education, a microlearning module in which learners exclusively practice diagnosing seborrheic keratosis (SKs) would result in blocked practice, while one requiring a learner to distinguish between SKs, benign nevi, and melanomas, presented in a random order, would result in interleaved practice. In a before-and-after study for a dermoscopy training program, blocked practice for benign lesions resulted in high specificity for benign lesions but poor sensitivity for malignant lesions in that participants would frequently categorize melanomas as, for instance, SKs [28]. Sensitivity for malignant lesions subsequently improved with the adoption of interleaved practice [28].

By segmenting complex tasks into smaller units, microlearning represents a powerful teaching tool for dermoscopy education. It may enable an efficient transfer of expert-level pattern recognition skills to novices, especially when implemented through technology tools such as smartphone apps. In bridging the gap between formal and informal learning, the use of microlearning technology may enhance learner engagement and motivation as well as knowledge retention [29]. Microlearning modules may also be suitable for gamification in which game design principles are applied to enhance the learning experience and activate intrinsic reward pathways.

Perceptual Learning

Overview

Perceptual learning is a learning method that challenges the container model theory by promoting the idea of experience as fundamental to developing expertise [30]. In neuropsychology, perceptual learning refers to the changes that occur in neural circuitry as a result of experience, resulting in the development of sensory discrimination [31]. This phenomenon explains how we learn to discriminate between faces, speech sounds, and musical pitches. For visual discrimination training, this approach relies on repeated exposures to numerous stimuli (eg visual features) so that one learns to perceive subtle differences between the stimuli. The concept of perceptual learning may be applied to visual specialties in which the educator teaches key diagnostic features and then creates opportunities for learners to practice recognizing these features with feedback.

For medical image interpretation education, the two components of perceptual learning are discovery and fluency [6]. In the discovery phase, students learn to identify new information relevant to the diagnostic task by ignoring less relevant information and extracting the more salient points. Using inattentional selectivity, learners may process a large amount of information from a case. Fluency comes with practice and refers to the student ability to efficiently recognize the information needed for diagnostic tasks.

Applications in Medical Education

Through perceptual learning, learners receive exposure to real-life examples, engage in repetitive practice, and gradually learn to recognize important diagnostic features quickly and accurately. Perceptual learning has been applied to radiology and electrocardiogram (EKG) image interpretation training, where learners have demonstrated gains in accuracy and fluency [6,30]. More recently, perceptual learning has been applied to dermatology education, where learners classify clinical images of rashes and skin lesions by morphology, configuration, and distribution [32]. Through perceptual learning, learners demonstrated the ability to quickly and accurately identify skin lesion characteristics at a level comparable to that of expert dermatologists.

Applications in Dermoscopy Education

In a dermoscopy training program for primary care providers, educators applied a heuristic training approach that resembled the discovery phase of the perceptual learning approach [33]. In the heuristic strategy, learners are expected to devise their own heuristics, or mental shortcuts, for future decision-making based on their experiences. Following an introductory didactic training session on classical dermoscopic features, learners in the heuristic training arm were provided the opportunity to view a series of dermoscopic images with minimal guidance from instructors. Labeled with the diagnosis only, these images did not contain further annotation or description, and learners were expected to discover salient features on their own. On post-intervention assessments, learners in the heuristic training arm performed as well as learners who had received feedback on the salient features in those images.

Adaptive Learning

Overview

Adaptive learning is an educational approach that optimizes learning for the individual learner through innovative technology tools [6]. This approach features an adaptive algorithm that tailors the individual learning sequence according to their strengths and weaknesses. Adaptive algorithms resemble an automated form of the deliberate practice strategy commonly used to achieve expert performance in music and sports. In deliberate practice, a teacher evaluates student performance and recommends practice activities (training tasks) and practice objectives (training goals) based on the teacher prior experiences and the student needs [34]. Students follow teachers recommendations, practice with full concentration, and receive or self-generate immediate feedback [34].

In traditional medical education, pre-determined lecture or training schedules could not be easily adapted or modified to accommodate the individual student needs [35].

Students may have different starting points for a given topic, or they may learn at different paces based on their individual abilities and the instructional method being used. Adaptive approaches represent a solution to these problems: by responding to the learner response times and accuracy rates, adaptive algorithms can repeat content, or adapt content difficulty, to optimize the learning process [36].

Adaptive response time-based sequencing (ARTS) is an example of an adaptive learning approach that customizes the learning sequence based on performance data [37]. Once the algorithm has detected mastery of a specific concept according to objective learning criteria, it can retire that concept and shift to focus on the learner weaker areas. Learning criteria should correlate with a given level of proficiency and could involve a number of accurate responses provided within a specified amount of time, correlating with a degree of automaticity. Training is considered complete when all criteria are met.

Applications in Medical Education

Adaptive algorithms have been successfully applied in teaching transesophageal echocardiography (TEE) image interpretation. Like dermoscopic image interpretation, TEE interpretation involves recognition of diagnostic patterns. In one teaching method, an algorithm modified the sequence of and time intervals between different TEE cases to suit each learner needs [38]. It evaluated both response speed and accuracy to determine whether to retire or re-sequence a specific concept. This method proved effective in improving response time and accuracy and optimizing performance for TEE learners.

For electrocardiography (EKG) interpretation, adaptive learning has also been successful in promoting content mastery. Reading an EKG, like evaluating a skin lesion in dermoscopy, requires pattern recognition skills that novices are expected to obtain via experiential learning [30]. With ARTS, the pace of learning was adapted for each EKG learner based on response time and accuracy. As with the previous example, a concept was retired only if the learner achieved the target response time while maintaining accuracy. If both measures were not achieved, the concept was re-sequenced into the learning sequence.

Applications in Dermoscopy Education

For dermoscopy education, adaptive algorithms may gradually increase the difficulty of dermoscopic images based on learner performance to generate faster improvements in performance. Alternatively, if a learner repeatedly fails to recognize a specific dermoscopic feature, additional images containing the feature may be shown until the learner starts to “see” the feature. Since learners encounter new content according to a personalized training schedule, demotivation

and mental fatigue may be reduced [39]. Adaptive learning ensures that each student acquires the knowledge needed, in whatever sequence and at whatever pace, to reach their desired level of mastery. In addition, innovative technologies with user interface interactions may enable performance tracking and personalized modifications for efficient learning.

Conclusions

A summary of the instructional approaches explored in the first part of this review series is included in Table 1. In general, training programs that apply microlearning modules, perceptual learning cases, and/or adaptive learning algorithms may enable novices to acquire expert-level knowledge in an effective manner. Meanwhile, whole-task learning equips learners for real-life clinical situations using hypothetical clinical scenarios.

We envision a hypothetical dermoscopy training program that combines the strengths of each approach presented in this article. In this program, learning concepts, such as a specific dermoscopic diagnoses, would be organized as their own unit. Each unit may be prefaced by a real-world clinical scenario that promotes whole-task learning. Educational content on the dermoscopic diagnosis (eg clinical presentation, dermoscopic appearance) could then be presented via microlearning modules that deliver instruction in small segments to minimize extraneous cognitive load.

Each microlearning module may also include multiple example images of each diagnostic feature plus new cases for perceptual learning. These example images and cases could be hosted on a user-friendly application that contains elements of game design and provides immediate feedback to learners. Adaptive learning algorithms built into the application would either re-sequence or retire cases according

Table 1. Summary of the educational theories presented in the first part of this review series plus examples of existing or potential applications in dermoscopy education.

Educational Theory	Description	Application(s) in Dermoscopy Education
Container Model	<ul style="list-style-type: none"> Learners receive passive instruction and fill their mental “container” with as many facts and concepts as possible. Acquired knowledge is usually static and inflexible because it is isolated from its context. 	<p><i>Existing Applications</i></p> <ul style="list-style-type: none"> didactic lectures rules-based algorithms
Whole-Task Learning	<ul style="list-style-type: none"> Curriculum design is based on authentic clinical scenarios and comprises 4 components: (1) learning tasks, (2) supportive information, (3) just-in-time information, and (4) part-time practice. 	<p><i>Potential Application</i></p> <ul style="list-style-type: none"> curriculum design: structured as a series of clinical scenarios based on real-life cases
Micro-learning	<ul style="list-style-type: none"> Educational content is segmented into short bursts, or small bites, of learning that may be spaced apart. This approach is expected to enhance engagement, increase knowledge retention, and decrease mental fatigue. 	<p><i>Existing Application</i></p> <ul style="list-style-type: none"> Project ECHO, developed by dermatology faculty at MaineHealth
Perceptual Learning	<ul style="list-style-type: none"> For medical image interpretation, fine visual discrimination skills are developed through repeated exposures to numerous examples of important visual features. With feedback and practice, novices may learn to efficiently extract important features and ignore irrelevant ones. 	<p><i>Existing Applications</i></p> <ul style="list-style-type: none"> YouDermoscopy, created and developed by Meeter Congressi <p><i>Potential Applications</i></p> <ul style="list-style-type: none"> library of training cases: learners classify hundreds of images and receive feedback on performance
Adaptive Learning	<ul style="list-style-type: none"> Adaptive algorithms respond to the individual performance data and make personalized modifications to the training schedule. Each individual training schedule is tailored to his/her strengths and weaknesses in order to optimize learning outcomes. 	<p><i>Potential Applications</i></p> <ul style="list-style-type: none"> learning modules: learners complete assessments; adaptive algorithms retire specific learning concepts based on objective mastery criteria

ECHO = Extension for Community Healthcare Outcomes.

to learner performance, indicated by response time and accuracy. Upon completion of all microlearning modules for the unit, learners are offered the opportunity to revisit the clinical scenario from the beginning of that unit.

To evaluate the impact of these educational approaches on dermoscopic image interpretation skills, educators may assess learner performance at multiple time points using validated instruments that measure both fluency and accuracy in diagnosing lesions. Investigators may also perform prospective audits of clinical diagnoses versus histopathological diagnoses among participants in the training program.

With the container model, learners were taught to interpret images using a given set of diagnostic features and/or rule-based algorithms. However, learners often struggled with manipulating and applying acquired knowledge to new images. Compared to traditional methods, emerging approaches in image interpretation education are more interactive and learner-centered. These approaches may improve learning outcomes by grounding learning in real-life clinical scenarios (whole-task learning) or delivering instruction in short segments (microlearning). For dermoscopic training, perceptual learning and adaptive learning may be especially valuable in that they provide immediate feedback and adapt the pace of learning to learner performance, respectively. The second part of this series will continue exploring instructional strategies and methods in image interpretation education that could also support dermoscopy education.

References

1. Ternov NK, Vestergaard T, Hölmich LR, et al. Reliable test of clinicians' mastery in skin cancer diagnostics. *Arch Dermatol Res.* 2021;313(4):235-243. DOI: 10.1007/s00403-020-02097-8. PMID: 32596742.
2. Bereiter C, Scardamalia M. Beyond Bloom's taxonomy: rethinking knowledge for the knowledge age. In: Hargreaves A, Lieberman A, Fullan M, Hopkins D, eds. *International Handbook of Educational Change*. Vol 5. Dordrecht: Springer; 1998: 675-692.
3. Bowden D. The limits of containment: text-as-container in composition studies. *Coll Compos Commun.* 1993;44(3):364-379. DOI: 10.2307/358989.
4. Lakoff G, Johnson M. *Metaphors We Live By*. Chicago, IL, US: The University of Chicago Press; 2003.
5. Norman G, Bordage G, Page G, Keane D. How specific is case specificity? *Med Educ.* 2006;40(7):618-623. DOI: 10.1111/j.1365-2929.2006.02511.x. PMID: 16836533.
6. Kellman PJ. Adaptive and perceptual learning technologies in medical education and training. *Mil Med.* 2013;178(10): 98-106. DOI: 10.7205/MILMED-D-13-00218. PMID: 24084310.
7. Sweller J. Cognitive load theory. In: Mestre JP, Ross BH, eds. *The Psychology of Learning and Motivation: Cognition in Education*. Vol 55. San Diego, CA, US: Elsevier Academic Press; 2011:37-76.
8. Fraser KL, Ayres P, Sweller J. Cognitive load theory for the design of medical simulations. *Simul Healthc.* 2015;10(5):295-307. DOI: 10.1097/SIH.0000000000000097. PMID: 26154251.
9. Kahneman D. *Thinking, Fast and Slow*. New York, NY, US: Farrar, Straus and Giroux; 2011.
10. Gronchi G, Giovannelli F. Dual process theory of thought and default mode network: a possible neural foundation of fast thinking. *Front Psychol.* 2018;9:1237. DOI: 10.3389/fpsyg.2018.01237. PMID: 30065692. PMCID: PMC6056761.
11. Norman G, Young M, Brooks L. Non-analytical models of clinical reasoning: the role of experience. *Med Educ.* 2007;41(12): 1140-1145. DOI: 10.1111/j.1365-2923.2007.02914.x. PMID: 18004990.
12. Daniel M, Stojan J, Wolff M, et al. Applying four-component instructional design to develop a case presentation curriculum. *Perspect Med Educ.* 2018;7(4):276-280. DOI: 10.1007/s40037-018-0443-8. PMID: 29992438. PMCID: PMC6086819.
13. Castillo J-M, Park YS, Harris I, et al. A critical narrative review of transfer of basic science knowledge in health professions education. *Med Educ.* 2018;52(6):592-604. DOI: 10.1111/medu.13519. PMID: 29417600.
14. Pittenger AL, Olson-Kellogg B. Leveraging learning technologies for collaborative writing in an online pharmacotherapy course. *Distance Educ.* 2012;33(1):61-80. DOI: 10.1080/01587919.2012.667960
15. Bi M, Zhao Z, Yang J, Wang Y. Comparison of case-based learning and traditional method in teaching postgraduate students of medical oncology. *Med Teach.* 2019;41(10):1124-1128. DOI: 10.1080/0142159X.2019.1617414. PMID: 31215320.
16. Velmahos GC, Toutouzas KG, Sillin LF, et al. Cognitive task analysis for teaching technical skills in an inanimate surgical skills laboratory. *Am J Surg.* 2004;187(1):114-119. DOI: 10.1016/j.amjsurg.2002.12.005. PMID: 14706600.
17. Sherbino J, Dore KL, Wood TJ, et al. The relationship between response time and diagnostic accuracy. *Acad Med.* 2012;87(6):785-791. DOI: 10.1097/ACM.0b013e318253acbd. PMID: 22534592.
18. Janssen-Noordman AM, Merrienboer JJ, van der Vleuten CP, Scherpbier AJ. Design of integrated practice for learning professional competences. *Med Teach.* 2006;28(5):447-452. DOI: 10.1080/01421590600825276. PMID: 16973459.
19. Shail MS. Using micro-learning on mobile applications to increase knowledge retention and work performance: a review of literature. *Cureus.* 2019;11(8):e5307. DOI: 10.7759/cureus.5307. PMID: 31511813. PMCID: PMC6716752.
20. Metcalfe J, Xu J. People mind wander more during massed than spaced inductive learning. *J Exp Psychol Learn Mem Cogn.* 2016;42(6):978-984. DOI: 10.1037/xlm0000216. PMID: 26618908.
21. Raman M, McLaughlin K, Violato C, Rostom A, Allard JP, Coderre S. Teaching in small portions dispersed over time enhances long-term knowledge retention. *Med Teach.* 2010;32(3): 250-255. DOI: 10.3109/01421590903197019. PMID: 20218841.
22. Lameris AL, Hoenderop JG, Bindels RJ, Eijsvogels TM. The impact of formative testing on study behaviour and study performance of (bio)medical students: a smartphone application intervention study. *BMC Med Educ.* 2015;15:72. DOI: 10.1186/s12909-015-0351-0. PMID: 25889923. PMCID: PMC4404663.
23. Thijssen DHJ, Hopman MTE, van Wijngaarden MT, Hoenderop JGJ, Bindels RJM, Eijsvogels TMH. The impact of feedback during formative testing on study behaviour and performance of (bio)medical students: a randomised controlled study. *BMC Med Educ.* 2019;19(1):97. DOI: 10.1186/s12909-019-1534-x. PMID: 30943962. PMCID: PMC6446354.

24. Arora S, Thornton K, Murata G, et al. Outcomes of treatment for hepatitis C virus infection by primary care providers. *N Engl J Med*. 2011;364(23):2199-2207. DOI: 10.1056/NEJMoa1009370. PMID: 21631316. PMCID: PMC3820419.
25. Seiverling EV, Li D, Stevens K, Cyr P, Dorr G, Ahrns H. Distance learning and spaced review to complement dermoscopy training for primary care. *Dermatol Pract Concept*. 2021; 11(2):e2021030. DOI: 10.5826/dpc.1102a30. PMID: 33954013. PMCID: PMC8060017.
26. International Dermoscopy Society (IDS). Webcasts. International Dermoscopy Society. Available from <https://dermoscopy-ids.org/education-elearning/podcasts/>. Published 2021. Updated March 19, 2021. Accessed October 12, 2021.
27. Taylor K, Rohrer D. The effects of interleaved practice. *Appl Cogn Psychol*. 2010;24:837-848. DOI: 10.1002/acp.1598.
28. Ahrns HT, Butt M, Khalsa A, et al. Dermoscopy for family medicine residents: teaching benign neoplasms. Paper presented at: North American Primary Care Research Group Annual Meeting; November 20, 2017, 2017; Montreal, Quebec, Canada.
29. Buchem I, Hamelmann H. Microlearning: a strategy for ongoing professional development. *eLearning Papers*. 2010;21:1-15.
30. Krasne S, Stevens CD, Kellman PJ, Niemann JT. Mastering electrocardiogram interpretation skills through a perceptual and adaptive learning module. *AEM Educ Train*. 2020 May 5;5(2):e10454. DOI: 10.1002/aet2.10454. PMID: 33796803. PMCID: PMC7995930.
31. Kellman PJ. Perceptual learning. In: Pashler H, Gallistel R, eds. *Stevens' Handbook of Experimental Psychology: Learning, Motivation, and Emotion*. Vol 3. 3 ed.: John Wiley & Sons Inc; 2002:259-299.
32. Rimoin L, Altieri L, Craft N, Krasne S, Kellman PJ. Training pattern recognition of skin lesion morphology, configuration, and distribution. *J Am Acad Dermatol*. 2015;72(3):489-495. DOI: 10.1016/j.jaad.2014.11.016. PMID: 25592621.
33. Seiverling EV, Ahrns HT, Greene A, et al. Teaching benign skin lesions as a strategy to improve the triage amalgamated dermoscopic algorithm (TADA). *J Am Board Fam Med*. 2019;32(1): 96-102. DOI: 10.3122/jabfm.2019.01.180049. PMID: 3061 0147. PMCID: PMC8039813.
34. Ericsson KA. Acquisition and maintenance of medical expertise: a perspective from the expert-performance approach with deliberate practice. *Acad Med*. 2015;90(11):1471-1486. DOI: 10.1097/ACM.0000000000000939. PMID: 26375267.
35. Mettler E, Massey CM, Kellman PJ. A comparison of adaptive and fixed schedules of practice. *J Exp Psychol Gen*. 2016;145(7): 897-917. DOI: 10.1037/xge0000170. PMID: 27123574. PMCID: PMC6028005.
36. Mettler E, Massey C, Kellman P. Improving adaptive learning technology through the use of response times. *Proc Annu Conf Cogn Sci Soc*. 2011;33:6.
37. Mettler E, Kellman PJ. Adaptive response-time-based category sequencing in perceptual learning. *Vis Res*. 2014;99:111-123. DOI: 10.1016/j.visres.2013.12.009. PMID: 24380704. PMCID: PMC6124487.
38. Romito BT, Krasne S, Kellman PJ, Dhillon A. The impact of a perceptual and adaptive learning module on transoesophageal echocardiography interpretation by anaesthesiology residents. *Br J Anaesth*. 2016;117(4):477-481. *Br J Anaesth*. 2016 Oct;117(4):477-481. DOI: 10.1093/bja/aew295. PMID: 28077535.
39. Möckel T, Beste C, Wascher E. The effects of time on task in response selection: An ERP study of mental fatigue. *Sci Rep*. 2015;5(1):10113. DOI: 10.1038/srep10113. PMID: 26054837. PMCID: PMC4460573.