



## VISUAL ANALOGIES IN DERMATOLOGY: IMPACT ON THE DIAGNOSTIC ACUMEN OF UNDERGRADUATE MEDICAL STUDENTS

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### Abstract:

**Background:** Visual analogies are much used in medical education; however, their effect on the development of clinical reasoning has yet to be investigated. In fields such as dermatology in which reasoning is predominantly based on the recognition of visual patterns, analogies may be even more useful. **Objectives:** To investigate the effects of the use of visual analogies on the accuracy of undergraduate medical students in diagnosing skin disorders. **Methods:** Sixty-four fourth-year medical students were divided into two groups to train in diagnosing skin diseases, either using visual analogies (study group) or from descriptions of elementary lesions (control group). The accuracy of the groups in diagnosing skin disorders was evaluated at 30 and 90 days after training, with their ability to create analogies also being tested at the 90-day evaluation. **Results:** Diagnostic accuracy improved in both groups when the students' performance before training was compared with their accuracy 30 days later (study group: 7.24±1.71 versus 8.76±1.83 respectively, p<0.001; control group: 7.42±2.02 versus 8.27±1.42, respectively, p<0.001). Results were similar 90 days after training. There was no statistically significant difference in diagnostic accuracy between the groups at 30 or 90 days following training (p=0.378). The study group performed better than the control group at making analogies (p<0.001), but there was no statistically significant correlation between diagnostic

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accuracy and the ability to make analogies ( $r = -0.15$ ;  $p = 0.437$ ). **Conclusion:** Diagnostic accuracy improved similarly in both groups. Other formats of visual analogies should be evaluated to clarify their role in developing diagnostic skills in dermatology.

**Keywords:** dermatology; learning; analogy; medical education

## 1. Introduction

Undergraduate medical students may fail to develop the skills required to correctly diagnose the most prevalent dermatological disorders.<sup>1</sup> The particular nature of diagnosis in dermatology, which is essentially based on visual cues, may contribute to this shortcoming.<sup>2</sup>

The visual perception of skin disorders appears to precede cognitive processing of the image, allowing the correct diagnosis to be reached quickly and intuitively. Therefore, recognizing visual patterns seems crucial.<sup>3,4</sup> This non-analytical processing does not demand a meticulous, systematic analysis of all the characteristics of skin diseases. With this form of retroactive reasoning, a hypothesis is made based on similarity with previous cases.<sup>5</sup> More analytical reasoning (analysis and cognitive interpretation of these images that reach the cerebral cortex rapidly) occurs later to confirm or rule out the diagnosis.<sup>5</sup>

Consequently, the more experienced clinician will reach a diagnosis and make the correct decisions faster.<sup>5,6</sup> Dermatologists diagnose faster and more accurately than primary care physicians, possibly due to the refinement of the mental filters associated with this non-analytical reasoning developed through repeated contact with many cases of the same disease and its different presentations.<sup>2,7</sup> Specialists can accurately identify different skin lesions without necessarily realizing how they reached a certain diagnosis. Conversely, the non-specialist physician or medical student, even after meticulously analyzing the lesions, is more likely to misdiagnose, since the perception of the characteristics involved in reaching a precise diagnosis is lost.<sup>8</sup> Notwithstanding, students using the same strategy as experienced physicians, generating hypotheses quickly in a non-analytical fashion, were found to have a greater likelihood of diagnostic errors due to their lack of clinical experience.<sup>9</sup>

The rapid mental processing derived from experience is based on certain perceptual aspects considered patterns or key characteristics that support diagnosis,<sup>8</sup> e.g. the predominant or typifying elementary lesion, its shape, color and anatomical site.<sup>4</sup> Combining these elements in tools designed to resolve problems quickly (heuristic) helps the diagnosis of skin disorders (e.g. *asymmetry*, *border*, *color*, *diameter* and *evolving* used to diagnose melanoma).<sup>10</sup>

Cognitive science endorses perceptual learning in highly visual disciplines, suggesting that interventions can increase diagnostic acumen over the long- and short-term, effectively teaching students to recognize patterns.<sup>11</sup>

Despite advances in knowledge and understanding, few studies have evaluated strategies aimed at developing and improving the cognitive elements underlying clinical reasoning in dermatology. Visual analogies are based on the human ability to classify objects from similarities observed when seeking images similar to a certain reference figure.<sup>1,12</sup> Thus, inexperienced individuals were shown to accurately classify neoplastic skin disorders using personal criteria only.<sup>12</sup> Likewise, undergraduate medical students and lay individuals accurately diagnosed skin disorders following training with software that stimulated participants to recognize lesions based on similarities.<sup>13</sup>

Some skin diseases are popularly known by the name of objects/natural events to which they have been compared (e.g. condyloma acuminatum/"cock's comb," pityriasis versicolor/"white patches," plantar wart/"fisheye wart").<sup>14</sup> Indeed, analogies could be used as a learning strategy to accurately diagnose a skin disorder or analogical target.<sup>6,15</sup> The significance of the target is based on knowledge of a familiar situation represented here by objects/natural events<sup>15,16</sup> (the analogical source or even meaningful signs) that, according to Ausubel's<sup>17</sup> meaningful learning theory, generates an anchor to which the new knowledge is attached. An analogy code<sup>18</sup> is thus created between target and source, allowing students to identify the most relevant shared characteristics,<sup>6,15</sup> and consequently diagnosing skin disorders.

Although visual analogies between objects and skin lesions are very simply processed, without involving predictive or explanatory inferences, they can provide insight and be potentially useful in learning.<sup>16,19,20</sup> Nevertheless, visual analogies are underutilized as a teaching strategy,<sup>16,19</sup> perhaps due to erroneous ideas that non-analytical reasoning rather than a lack of clinical experience leads to diagnostic errors.<sup>8,9</sup> Under certain circumstances, exhaustive detailing of data from patients can even reduce accuracy in diagnosing skin disorders.<sup>8</sup>

Since visual analogies were expected to increase the diagnostic acumen of medical students in dermatology despite their inexperience, this study compared training based on visual analogies with the more traditional teaching strategy based on written descriptions of elementary skin lesions.

## 2. Methods

The internal review board of the José do Rosário Vellano University (UNIFENAS) approved the protocol of this controlled experimental study under reference 2,377,765. The participating students provided written informed consent.

All 4<sup>th</sup> year undergraduate medical students at UNIFENAS were invited to participate. The 8-semester problem-based learning curriculum addresses dermatology in the seventh semester, including lectures, laboratory work and training in simulated and outpatient settings. Consequently, 4<sup>th</sup>-year students are familiar with diagnosing skin disorders but are not yet experts, hence the ideal candidates for this study.

The participants were assigned to one of two groups using alternate allocation, and were trained to diagnose skin disorders, either by comparing them to objects/natural events (study group) or by reviewing descriptions of elementary skin lesions (control group). Participants were asked to diagnose 20 skin disorders from color images at baseline, and 30 and 90 days after training. In all three 15-minute tests, typical, albeit different, images of the same diseases were used.

Of the 20 skin disorders, 15 had been part of the previous semester's syllabus; hence familiar to the students (familiar diseases) and 5 had not (unfamiliar diseases) (Figure 1). The degree of difficulty was estimated based on a pilot study with undergraduate medical students from the same university who did not participate in this study. The diagnosis was considered easy when the accuracy in the pilot study was  $\geq 50\%$  and difficult when  $< 50\%$  (Table 1).

**Table 1:** Box showing the diseases presented during the study

Diseases unfamiliar to students		Diseases familiar to students	
Lesion number	Name	Lesion number	Name
1	Angiofibroma	2	<b>Squamous cell carcinoma</b>
4	Pitted keratolysis	3	<b>Keratoacanthoma</b>
5	Cylindroma	6	Condyloma acuminatum
9	Lymphostatic verrucosis	7	Cornu cutaneum
16	Conjunctival nevus	8	Striae
		10	<b>Erythema multiforme</b>
		11	<b>Soft fibroma</b>
		12	<b>Dimorphic leprosy</b>
		13	<b>Ichthyosis</b>
		14	Melanoma
		15	Blue nevus
		17	<b>Bullous pemphigoid</b>
		18	Psoriasis
		19	Keloid
		20	<b>Filiform wart</b>

**Note:** The diseases classified as difficult are highlighted in bold.

Difficulty was not defined for the unfamiliar diseases, since accuracy in the pilot study was close to zero. Photographs of objects/natural events resembling images of the 20 skin disorders were selected.

In the study group, training consisted of: examining printed color images of typical presentations of the same diseases diagnosed in the baseline test and printed color images of objects/natural events that resembled these disorders, correlating the event with the corresponding skin disorder, describing the characteristics of the object associated with the image, and providing the most likely diagnosis for each disorder. The order of the diseases differed from the order of the objects. Only one event was to be associated with each disorder. For the control group, training consisted of: looking at printed color images of the skin disorders diagnosed in the baseline test; reading various

names of groups of elementary skin lesions; providing the name of the group of elementary lesions corresponding to each of the skin disorders; describing the typical characteristics of the elementary lesions for each disorder according to the group selected; and giving the most likely diagnosis for each skin disorder. For both groups, diseases considered easy were alternated with those considered difficult. The same folder of color images was used for both groups.

The training was given simultaneously in different rooms, one for each group, over a 50-minute period. Slides of each skin disorder analyzed, with their respective diagnosis, were shown to all the participants. For the study group, objects of comparison were also provided, while the control group was given the name of the group of skin disorders. No other information was provided.

The 30- and 90-day tests were identical for both groups and consisted of diagnosing the same twenty skin disorders presented in the training phase based on images of their typical presentation. The images were not those shown during training and the order was different. At the 90-day test, participants were also asked to name an object/natural event that resembled each skin disorder. Most of the images used were amplified to conceal the site of the lesions.

Three evaluators blinded to group assignment analyzed diagnostic accuracy and the participants' ability to make analogies at 90 days post-training. Discrepancies between evaluators were resolved by consensus following the debate.

Accuracy was classified as: *correct* (1 point) (complete diagnosis, e.g. condyloma acuminatum); *partially correct* (0.5 points) (incomplete diagnosis, e.g. condyloma; accurate description, e.g. growth caused by HPV; or popular name, e.g. cock's comb); or *incorrect* (0 points).

Two scoring systems were used to evaluate participants' ability to make analogies. The first served to assess the ability of students in the study group to memorize objects. Answers were classified as: *correct* (1 point) when the object was that shown during training (e.g. blackberry for angiofibroma); *partially correct* (0.5) when the analogy was feasible but not that shown during training (e.g. a bunch of grapes rather than blackberry for angiofibroma); or *incorrect* (0). In the second system, used to evaluate the ability of the students in both groups to make analogies, the answers were classified as: *correct* (1) when the analogy was considered compatible with the disease or *incorrect* (0) if not.

## 2. Data analysis

The principal endpoint was *diagnostic accuracy*, defined as the sum of the scores for each skin disorder. Mean scores were calculated per test and per group. Repeated measures analysis of variance (ANOVA) was performed, with diagnostic accuracy being the outcome variable and the group the exposure variable, at baseline, 30 and 90 days. Two-way ANOVA was conducted to evaluate a possible interaction between diagnostic difficulty and familiarity with the lesion in the association between the outcome and

exposure variables. Outliers were determined based on the analysis of residuals, with the highest and lowest values being discarded.

Pearson's coefficient was used to analyze correlations between diagnostic accuracy and the students' ability to make visual analogies. Cohen's d was calculated to measure the effect size of the impact of training on diagnostic accuracy. P-values <0.05 were considered significant.

### 3. Results

Of 77 students invited to participate, 64 (83.1%) agreed and were included. Four participants, two in each group, were excluded from the subsequent analyses, since they did not conclude the study. Two outliers, one in each group, were also excluded following exploratory analysis of residuals. Therefore, 58 participants were included in the final analysis, 30 in the study group and 28 in the control group.

The groups were similar in relation to sex ( $p=0.362$ ), age ( $p=0.851$ ) and baseline diagnostic accuracy ( $p=0.698$ ) (Table 2).

**Table 2:** Baseline characteristics of the participants in the two study groups

Characteristics	Study group Visual analogies (n=33)	Control group Elementary lesions (n=31)	Overall sample (n=64)
Age; mean $\pm$ SD	24.9 $\pm$ 3.5	24.7 $\pm$ 4.8	24.8 $\pm$ 4.2
Females, n (%)	21 (63.6)	23 (74.2)	44 (68.8)
Diagnostic accuracy; mean $\pm$ SD	7.42 $\pm$ 2.02	7.24 $\pm$ 1.71	7.39 $\pm$ 1.83

**Note:** SD: standard deviation; Diagnostic accuracy scores ranged from 0 to 20.

An association was found between the phase of the study and the accuracy scores in both groups ( $p<0.001$ ) (Table 3). Mean accuracy scores in the study group were significantly higher at 30 days (7.42 $\pm$ 2.02; Cohen's d 0.49) and 90 days (8.84 $\pm$ 1.44 versus 7.42 $\pm$ 2.02; Cohen's d 0.81) compared to baseline. Results were similar for the control group: 7.24 $\pm$ 1.71 at baseline versus 8.76 $\pm$ 1.83 at 30 days (Cohen's d 0.86) and 9.07 $\pm$ 1.69 at 90 days (Cohen's d 1.08). Accuracy was similar in the two groups at all phases of the study ( $p=0.378$ ).

**Table 3:** Mean overall scores for the diagnosis of dermatological diseases analyzed by the participants in the two study groups at the different stages of the study

Study phases <sup>a</sup>	Study group <sup>b</sup> Visual analogies (n= 30)	Control group <sup>b</sup> Elementary lesions (n=28)	Overall sample (n=58)
Baseline	7.42 $\pm$ 2.02	7.24 $\pm$ 1.71	7.39 $\pm$ 1.83
30 days after training	8.27 $\pm$ 1.42	8.76 $\pm$ 1.83	8.45 $\pm$ 1.56
90 days after training	8.84 $\pm$ 1.44	9.07 $\pm$ 1.69	8.79 $\pm$ 1.32

<sup>a</sup>  $p<0.001$  throughout the study phases. <sup>b</sup>  $p=0.378$  when comparing the two groups.

**Note:** Values are expressed as means  $\pm$  standard deviations; Diagnostic accuracy scores ranged from 0 to 20.

Four outliers, two in each group, were removed from the diagnostic difficulty analysis, with 56 participants being included, 29 in the study group and 27 in the control group (Table 4). The effect of training on diagnostic accuracy was only significant for diseases considered easy in each individual group ( $p < 0.001$ ). Likewise, no association was found between the group and diagnostic accuracy when diagnostic difficulty was taken into consideration ( $p = 0.899$  for easy diseases and  $p = 0.642$  for difficult diseases).

**Table 4:** Mean accuracy scores for the diagnosis of the dermatological diseases considered easy or difficult and analyzed by the participants of the two study groups

Study phase <sup>a</sup>	Degree of difficulty	Study group <sup>b</sup> Visual analogies (n= 29)	Control group <sup>b</sup> Elementary lesions (n=27)	Overall sample (n=56)
Baseline	Easy	5.13 ± 1.33	5.12 ± 0.94	5.13 ± 1.15
	Difficult	2.42 ± 1.14	2.03 ± 1.16	2.15 ± 1.05
30 days	Easy	5.73 ± 0.85	5.72 ± 0.92	5.72 ± 0.92
	Difficult	2.31 ± 0.79	2.84 ± 1.36	2.43 ± 0.93
90 days	Easy	6.19 ± 0.65	6.14 ± 0.60	6.14 ± 0.60
	Difficult	2.26 ± 0.90	2.47 ± 1.34	2.19 ± 0.89
a: When comparing the study phases: Easy: $p < 0.01$ ; Difficult: $p = 0.116$ .				
b: When comparing the two groups: Easy: $p = 0.899$ ; Difficult: $p = 0.642$ .				

For the set of seven dermatological diseases considered easy, possible scores ranged from a minimum of 0 (the worst score possible) to a maximum of 7 (the best score possible). For the set of eight diseases considered difficult, the minimum score possible was 0 and the maximum score possible was 8.

Performance was very poor for the five disorders considered unfamiliar (angiofibroma, pitted keratolysis, cylindroma, lymphostatic verrucosis and conjunctival nevus), with a median score of zero in both groups at baseline and 30 days, and of 0.5 at 90 days. For the more familiar diseases, results were similar to those reported for the overall scores.

At 90 days, the study group performed better at making analogies between skin disorders and objects/natural events than the control group, irrespective of sex (study group:  $11.27 \pm 2.72$  versus  $11.45 \pm 2.61$  for males and females, respectively; control group:  $8.63 \pm 3.29$  versus  $8.67 \pm 3.09$ ;  $p < 0.001$ ). Participants in the study group remembered more objects used in training than would be expected by mere chance: study group:  $8.86 \pm 2.54$  versus  $8.48 \pm 2.31$  for males and females, respectively; control group:  $5.94 \pm 2.29$  versus  $5.50 \pm 2.21$ ;  $p < 0.01$ . Nevertheless, no correlation was found between the scores for the association disease/objects and participants' diagnostic accuracy ( $r = -0.15$ ;  $p = 0.437$ ).

#### 4. Discussion

This study compared the effect of training using visual analogies versus descriptions of elementary skin lesions on the diagnostic accuracy of undergraduate medical students and found that both strategies resulted in a similar and significant increase in accuracy,

even 90 days after training. Participants in the study group were trained to focus on the characteristics predictive of diagnosis when comparing the skin lesions to an object, without having to take into account all the clinical characteristics present. Because dermatology reasoning depends largely on recognizing visual patterns, training with visual analogies was expected to result in a better performance than that achieved through the description of elementary lesions.

A previous study evaluated two strategies in the diagnosis of skin lesions: (1) “*post-verbal visualization*” (diagnosis based exclusively on comprehensive verbal descriptions of photographs followed by a diagnosis of the same disorder after seeing the corresponding photograph); and (2) “*visualization*” (diagnosis after seeing images of the diseases but without any verbal description). For experienced participants, diagnostic acumen with photographs was better than that of participants exposed to post-verbal visualization or exclusively verbal descriptions. For less experienced participants, diagnostic acumen was poorer under all conditions. Therefore, visualization may result in better diagnostic acumen in more experienced individuals precisely because they have skills that allow them to identify the most pertinent characteristics.<sup>8</sup> Although that study involved physicians rather than undergraduate medical students, there are similarities with the present study, with one group undergoing an exclusively visual strategy (study group) and the other descriptions, albeit here not verbal, of elementary skin lesions (control group). Furthermore, participants of the study group were trained to extract the most relevant characteristics with which to diagnose skin disorders by comparing images with objects in a process resembling the perception used by specialists. Nevertheless, in this study, the use of visual analogies did not prove better than the description of elementary skin lesions insofar as students’ diagnostic skills were concerned.

One possible explanation for this may lie in the superficiality of the analogy used, which consisted of simply comparing appearances between the object/natural event and the skin disorder. Deeper analogies that compare function, for example, establish a more significant association between different domains, enabling the student to recover and transfer learning more easily.<sup>21</sup> Perhaps if, instead of merely encouraging students to make visual analogies, they were also stimulated to apply a deeper form of reasoning, the results could be different. To illustrate this point, keratoacanthoma is a skin lesion that resembles a pomegranate; however, its course has also been compared to a volcano. Volcanoes can be active when in eruption, inactive when dormant, or extinct. The biological cycle of the keratoacanthoma is similar, with rapid growth over some months, tending to regress spontaneously thereafter and even disappear, leaving only a scar.<sup>22</sup> However, there are few skin diseases such as the keratoacanthoma that can be compared using analogies of their structure or function. Because of the extensive amount of visual information in dermatology, superficial analogies are relevant, not only in teaching but also when describing, naming and retrieving information.<sup>19</sup>

This is not to say that superficial analogies cannot generate insights into the cognitive structure. Indeed, the finding that the students in this study group performed better when associating diseases with comparable objects in the 90-day test and recalled



some of the objects used in training supports this. It also suggests that they were able to transfer the existing common principle in their recognition of the pattern, i.e. the characteristics that are most relevant when comparing the object (analogical source) and the skin disease (analogical target);<sup>21</sup> however, there was no interactive association regarding the correct diagnosis of the disease, i.e. when analyzing the image, the students remembered the object that resembled the disease but did not remember its name.

The names are the symbols and the images are the meanings of these symbols. Learning names and symbols is referred to as representation learning, one of Ausubel's<sup>17</sup> types of meaningful learning, considered the most basic form of learning and the one on which all others depend.<sup>23</sup> Therefore, the analogy was apparently made, but the symbols of the images analyzed were lacking. This suggests that the study group was actually better at diagnosing than the results would indicate, particularly considering that some skin disorders are known by the name of the comparable object. Why, however, did the students make the correct analogy but were unable to name the skin disorder? There may be a gap in this representation learning. The students may not have been exposed to the names of the diseases for long enough for an association to be made between the names and the cognitive content associated with them, i.e. the images they represent. Therefore, no association was made between names and symbols.

The effects of both training strategies on diagnostic accuracy were positive only when diagnoses were easy, familiar. This short training period may have been insufficient to allow knowledge related to unfamiliar or more complex skin lesions to be learned and retained. In medical education, and particularly in dermatology, repetition and review of a given subject from different perspectives appears to be important for knowledge to be retained.<sup>24</sup>

This is the first study conducted with undergraduate medical students in which the effect on the diagnostic accuracy of using visual analogies in dermatology training is analyzed. The present findings show that this relatively simple strategy can be used to help students develop initial diagnostic skills in dermatology, without any need for more complex associations, while learning to diagnose unfamiliar or inherently more difficult diseases requires more than analogies or descriptions. However, diagnostic accuracy was not considered satisfactory in either group despite the positive effect found with both teaching strategies. Limitations of this study include the fact that it was conducted over a short period of time, in a single teaching institute, involving a single undergraduate level and evaluating only one form of visual analogy (objects, accidents of nature).

In conclusion, accuracy in diagnosing skin disorders improved in both groups. Additional studies on the use of visual analogies in other formats, using deeper analogies or in association with other strategies are required to improve comprehension of their role in the development of clinical reasoning.

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### **Conflicts of interest statement**

The authors declare that there is no conflict of interest.

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### **References**

1. Aldridge RB, Glodzik D, Ballerini L, Fisher RB, Rees JL. Utility of non-rule-based visual matching as a strategy to allow novices to achieve skin lesion diagnosis. *Acta Derm Venereol.* 2011;91(3):279-283.
2. Norman GR, Rosenthal D, Brooks LR, Allen SW, Muzzin LJ. The development of expertise in dermatology. *Arch Dermatol.* 1989;125(8):1063-1068.
3. Norman GR, Coblenz CL, Brooks LR, Babcock CJ. Expertise in visual diagnosis: a review of the literature. *Acad Med.* 1992;67(10 Suppl):S78-S83.
4. Lowenstein EJ, Sidlow R. Cognitive and visual diagnostic errors in dermatology: part 1. *Br J Dermatol.* 2018;179(6):1263-1269.
5. Kulatunga-Moruzi C, Brooks LR, Norman GR. Coordination of analytic and similarity-based processing strategies and expertise in dermatological diagnosis. *Teach Learn Med.* 2001;13(2):110-116.

6. Sternberg RJ. *Psicologia cognitiva*. [Cognitive psychology]. 5<sup>th</sup> ed. São Paulo: Cengage Learning; 2016.
7. Clark RA, Rietschel RL. The cost of initiating appropriate therapy for skin diseases: a comparison of dermatologists and family physicians. *J Am Acad Dermatol*. 1983;9(5):787-796.
8. Kulatunga-Moruzi C, Brooks LR, Norman GR. Using comprehensive feature lists to bias medical diagnosis. *J Exp Psychol Learn Mem Cogn*. 2004;30(3):563-572.
9. Eva KW. What every teacher needs to know about clinical reasoning. *Med Educ*. 2005;39(1):98-106.
10. Harrington E, Clyne B, Wesseling N, et al. Diagnosing malignant melanoma in ambulatory care: a systematic review of clinical prediction rules. *BMJ Open*. 2017;7:e014096.
11. Guégan S, Steichen O, Soria A. Literature review of perceptual learning modules in medical education: what can we conclude regarding dermatology? *Ann Dermatol Venereol*. 2021;148(1):16-22.
12. Brown NH, Robertson KM, Bisset YC, Rees JL. Using a structured image database, how well can novices assign skin lesion images to the correct diagnostic grouping? *J Invest Dermatol*. 2009;129(10):2509-2512.
13. Aldridge RB, Maxwell SS, Rees JL. Dermatology undergraduate skin cancer training: a disconnect between recommendations, clinical exposure and competence. *BMC Med Educ*. 2012;12:27.
14. Vallarelli AF, Silva VMCF, Souza EM. Dermatologia comparativa. [Comparative dermatology]. *An Bras Dermatol*. 1999;74(1):75-76.
15. Gentner D, Holyoak KJ. Reasoning and learning by analogy. *Am Psychol*. 1997;52(1):32-34.
16. Frieden IJ, Dolev JC. Medical analogies: their role in teaching dermatology to medical professionals and patients. *J Am Acad Dermatol*. 2005;53(5):863-866.
17. Ausubel DP. *Aquisição e retenção de conhecimentos: uma perspectiva cognitiva*. [Acquisition and retention of knowledge: a cognitive perspective]. Porto: Paralelo; 2003.
18. Santos SCS, Téran AF. Aprendizagem significativa, modelos mentais e analogias no contexto construtivista: uma aproximação possível para a educação em ciências. [Meaningful learning, mental models and analogies in the constructivist context: a possible approach to science education]. In: Santos SCS, Téran AF. *Educação em Ciências na Amazônia: múltiplos olhares*. [Science Education in the Amazon: multiple perspectives]. Manaus: Editora UEA; 2010:203.
19. Pena GP, Andrade-Filho JS. Analogies in medicine: valuable for learning, reasoning, remembering and naming. *Adv Health Sci Educ Theory Pract*. 2010;15(4):609-619.
20. Gentner D, Markman AB. Structure mapping in analogy and similarity. *Am Psychol*. 1997;52(1):45-56.
21. Blanchette I, Dunbar K. How analogies are generated: the roles of structural and superficial similarity. *Mem Cognit*. 2000;28(1):108-124.

22. Andrade Filho JS. Analogias em medicina - Parte I. [Analogies in Medicine - Part I]. *Rev Méd Minas Gerais*. 2008;18(3):220-224.
23. Moreira MA. *A teoria da aprendizagem significativa de Ausubel: teorias da aprendizagem*. [Ausubel's theory of meaningful learning: theories of learning]. São Paulo: EPU; 1999.
24. Friedlander MJ, Andrews L, Armstrong EG, et al. What can medical education learn from the neurobiology of learning? *Acad Med*. 2011;86(4):415-420.

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