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EXPERIENCE REPORT

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Analogies applied to learning the non-laboratory morphofunctional muscular system: an experience report

Analogias aplicadas à aprendizagem do sistema muscular no laboratório morfofuncional: um relato de experiência

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ABSTRACT

Introduction: The strategies applied in the classroom have been changing through time, especially when it comes to medical education. It is a challenging task for teachers and monitors to promote the teaching of anatomy inside medical education, since anatomy is seen as a mechanical content and hard to understand by the students. Therefore, this study aims to report the use of analogies as an anatomy teaching strategy in a medical college in countryside of Pará, Brazil.

Experience report: The innovating analogy strategy was applied by teachers and monitors to 56 1st -semester medical students. The aim of this study was to include analogies in morphofunctional classes that would help students to understand the muscle system anatomy by comparing daily objects with parts of the human body. Four analogies were selected: microscopic muscle structure (fibers, fascicle, muscle); macroscopic muscle structure (muscle belly, aponeurosis); transversus abdominis muscle; scalene muscles.

Discussion: Few studies use analogies for teaching in health science and none have been focused on teaching anatomy. Existing studies show that low-budget resources, such as analogies, are efficient for teaching/learning process.

Conclusion: The experience proved to be an excellent alternative to the students' teaching-learning, considering that they achieved the learning goals in the experience. The content, which could be boring, was learned in a ludic and interactive way and so the active knowledge construction was easier. The analogy strategy can increase student interest in classes and content retention is improved and it contributes to individual academic formation.

Keywords: Association learning; Medical education; Anatomy; Problem-Based Learning; Monitoring.

RESUMO

Introdução: *As estratégias utilizadas dentro de sala de aula têm se modificado com o passar do tempo, em especial no âmbito da educação médica. Promover o ensino da anatomia dentro do curso de Medicina é uma tarefa desafiadora para os docentes e discentes monitores, tendo em vista que ela é dita como um conteúdo mecânico e de difícil assimilação pelos alunos. Dessa forma, este trabalho visa relatar o uso de analogias como estratégia de ensino para anatomia em uma faculdade de Medicina do interior do Pará.*

Relato de experiência: *A estratégia inovadora foi idealizada e aplicada por docentes e discentes monitores aos 56 estudantes do primeiro semestre do curso de Medicina. A proposta do trabalho foi incluir nas aulas analogias que auxiliassem a compreensão da anatomia do sistema muscular no laboratório morfofuncional, comparando estruturas do corpo humano com objetos do cotidiano. Desenvolveram-se quatro analogias: estrutura muscular microscópica (fibras, fascículo, músculo), estrutura muscular macroscópica (ventre muscular e aponeurose), músculo transverso do abdômen e músculos escalenos.*

Discussão: *Poucos estudos utilizam as analogias para ensino na saúde e não há nenhum até então voltado para o ensino de anatomia. Os estudos existentes mostram que recursos de baixo orçamento, como as analogias, são eficientes para o ensino/aprendizagem.*

Conclusão: *A experiência demonstrou ser excelente alternativa para o ensino-aprendizagem dos discentes, haja vista que eles atingiram os objetivos de aprendizagem. O conteúdo, que poderia ser monótono, foi trabalhado de forma lúdica e interativa, o que facilitou a construção ativa do conhecimento. A estratégia de analogias pode aumentar o interesse do aluno dentro de sala de aula e a fixação do assunto, contribuindo assim para a formação acadêmica do indivíduo.*

Palavras-chave: *Aprendizagem por Associação; Educação Médica; Anatomia; Aprendizagem Baseada em Problemas; Monitoria.*

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INTRODUCTION

The teaching of medicine in Brazil has undergone changes since 2014 with the publication of the new National Curriculum Guidelines for the course (DCNs, *Diretrizes Curriculares Nacionais*)[1], which propose that colleges and universities carry out teaching with active methodologies based on interdisciplinarity, aiming to train professionals with a social vision and capable of having humanistic actions towards their patients[2]. In active teaching, the student leaves the posture of receiver, where the teacher is the holder of knowledge, to become the protagonist of their learning, in which the teacher is a facilitator and mediator of the process[3].

In this context, the teaching of anatomy, in particular, is considered by medical students to be a content that must be memorized and is difficult to assimilate, being monotonous and mechanical, which generates student demotivation[4,5]. Because anatomical studies are based on memorization through repetition, it is difficult to consolidate long-term memory, which corroborates the report of difficult learning of this discipline[6,3]. Aiming at the students' participation and effective learning, new strategies have been used for the teaching/learning of anatomy, and so, a tool that can be used in educational practice is the analogy[4-8].

Analogies can be understood as comparisons with a high level of relational similarity and little structural similarity[9] between two domains: the source (what is already known) and the target (a concept that one wants to explain)[10,11]. To create the analogy, it is necessary to base it on the individuals' previous knowledge[12], which will serve as an anchor for the new knowledge; that is, the source needs to be a known object or concept, preferably from everyday life[13]. Analogical reasoning is important in the process of learning with analogies, since it involves different areas of the prefrontal cortex and brain circuits, which use new information and allow interactions with existing associations, i.e., the new information is assimilated based on what was already known[14,15]. Thus, the content that sometimes seems to be difficult for students to assimilate, when seen associated with an analogy, can become concrete and understandable.

An example of an analogy is the umbrella and the role of melanocytes, skin cells that produce the pigment melanin, which in turn protects the nuclei of cells against the sun. In this case, we have the umbrella, which is a palpable object present in everyone's daily life, being compared to the function of a cell, visible only under a microscope, which would facilitate histological learning. Analogies, however, can generate some inconsistencies, because they will never be fully true. Thinking about the example of the umbrella, although the function is compared with melanocytes, the structure should not be compared. Melanocytes are not bendable, for example, like umbrellas. Also, if the source object is not well known, no parameter will be generated for comparison[16].

To overcome the limitations of analogies, a solution would be for students to create their analogies themselves. Thus, they would be able to organize what they know about a studied phenomenon or structure. The passive observation of a comparison already presented is replaced by an active learning process[17]. The analysis of analogies should be a process accompanied by the teacher, who has the role of encouraging the identification of correspondences, as well as the limitations in the relationship of two objects or concepts.

This article reports on the innovative initiative of teachers and monitors who included analogies in the morphofunctional teaching of the muscular system, with emphasis on anatomy, comparing structures of the human body with everyday objects in the students' life, aiming at promoting greater excitement, assiduity and retention of the content among the students. The diversification in the way fundamental contents are approached is in line with the medical course DCNs. Moreover, pedagogical strategies tend to foster active learning, due to the interactive construction of knowledge, thus demonstrating the benefits of the applicability of active methodologies[17].

EXPERIENCE REPORT

The present study used analogies as a teaching-learning resource, throughout the month of June 2022. This experience was applied at the Morphofunctional Laboratory (LMF) of Universidade Federal do Pará – UFPA, Altamira Campus in the Trans-Amazonian region to the 56 medical students attending the first semester during the practices of the axis Conception, Development and Life Cycles of the Human Being (CFSH)[1]. At this University, teaching is distributed in three axes, which work together, linking theory to practice.

The LMF is present in the CFSH axis, in which classes are theoretical-practical and take place in laboratories instead of classrooms[18]. In this space, the student has at their disposal computers, microscopes, synthetic parts of the human body and histological slides, where the study is directed through scripts, which exist to meet the new DCN. The scripts ensure that the teaching-learning process happens autonomously, as the student is free to seek the content at their own pace, in the way that most favors individual learning[5].

To carry out the activity, the materials prepared by the team of teachers and monitors were analogies that alluded to the structure and/or functionality of the muscular system, that is, structures of the muscular organization to be related to everyday objects that resembled each other in structure and function. The team previously prepared an analogy reasoning

and determined learning objectives that students should ideally achieve. These analogies were organized in images without captions, printed on A4 sheets, with phrases that referred to the topic that would be learned during the meeting.

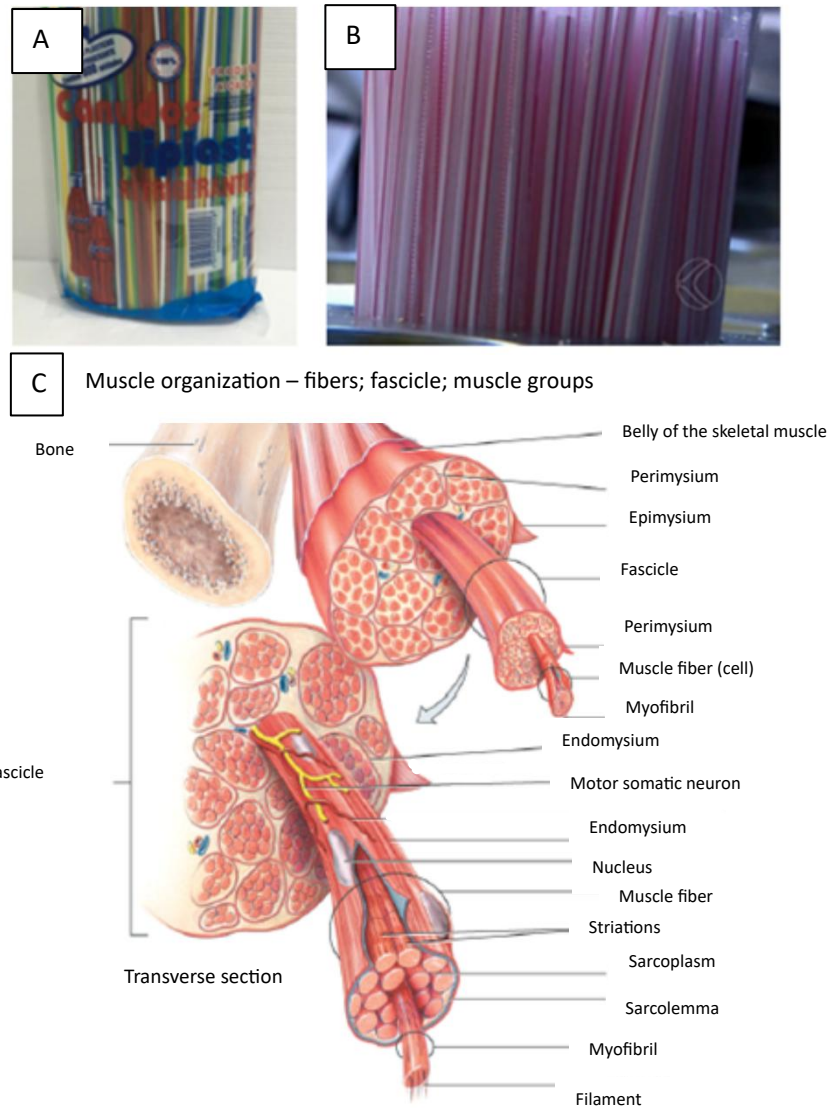
Analogies

To prepare the material, the monitors got together and selected four images described below to be related to their respective sentences:

Image of a pack of striped plastic straws to be associated with muscle organization: fibers, fascicle and muscle. The fibers are muscle cells formed by myofibrils, consisting of actin and myosin filaments. Each muscle fiber is covered by a membrane called the endomysium. A group of fibers is covered by a membrane called perimysium and is called fascicle[19]. The set of fascicles is called muscle, which is covered by the membrane called epimysium. In this image, students were expected to associate each straw with a muscle fiber; the bag that covers each straw with the endomysium; the set of straws with the fascicle; and the larger bag that contains all the straws with the perimysium. By continuing the reasoning freely, the students could understand that the joining of several packets of straws (fascicles) would form a muscle (Figure 1).

Image of a trampoline to be associated with the macroscopic organization of the muscular structure: muscle belly and aponeurosis. The muscle belly is the contractile part, which has muscle fibers, while aponeuroses are large, flattened portions of connective tissue that connect muscles to bones or

Figure 1. Image and sentence that presented to the students the analogy about muscle structure - fibers, fascicle and muscle (A e B) and organization of skeletal muscle and its connective tissue linings (C).



Source: https://www.plasty.com.br/image/cache/catalog/Pl%C3%A1sticos/CANUDOS/CANUDO%20800-1000x920.jpeg, adapted (A); https://s2-g1.glbimg.com/jDzuNFdk0CMSPf4QbKshmCnyNRY=/0x0:618x473/984x0/smart/filters:strip_icc()/i.s3.glbimg.com/v1/AUTH_59edd422c0c84a879bd37670ae4f538a/internal_photos/bs/2019/C/b/c0CDdJRBO7c5usbx8hAA/capturar.jpg, adapted (B) ; Tortora and Derrickson, 2016[20] (C).

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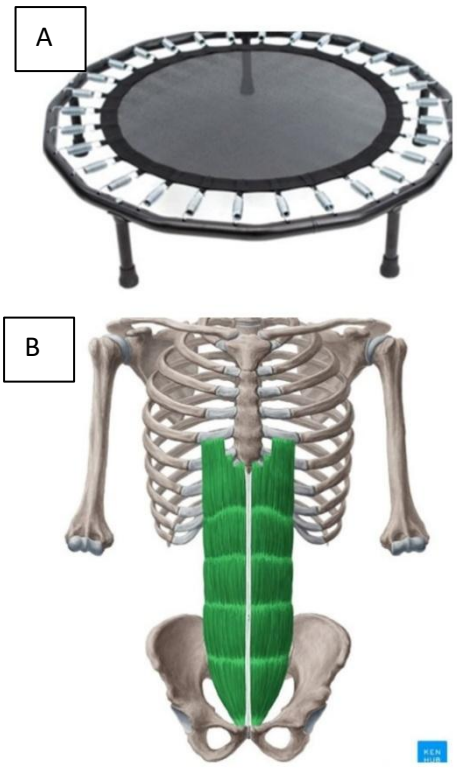
other muscles[20]. In this image, the students were expected to relate the trampoline tissue to the aponeurosis, the springs to the muscles, and the iron base to the bones (Figure 2).

Image of the Rio Bonito dam (ES) to be associated with the transversus abdominis muscle. It is a deep plane muscle that forms the anterior wall of the abdomen together with three other muscles. Its fibers are transverse with the exception of the lower fibers, which are oblique. It originates from the internal surfaces of the seventh to the twelfth costal cartilages, thoracolumbar aponeurosis, iliac crest and connective tissue located deep in the lateral third of the inguinal ligament; Its insertion is located in the linea alba with aponeurosis of the internal oblique muscle of the abdomen, pubic crest and pectineal line of the pubis through the inguinal sickle. This arrangement of the fibers is essential to compress the abdominal contents and increase intra-abdominal pressure, thus retaining the viscera present in the abdomen[21]. With this analogy, the intention was for the students to understand the containment function of the abdominal organs performed by the transverse muscle, just as the dam contains the water of the river (Figure 3).

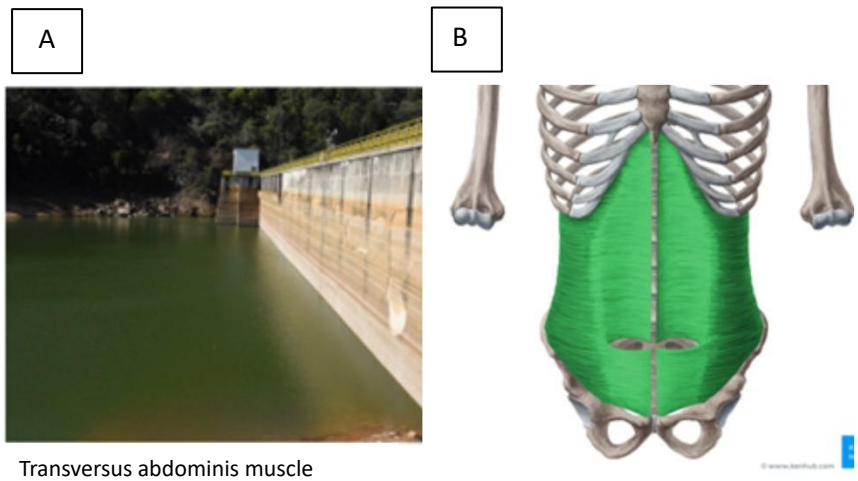
Image of cranes representing the scalene muscles. Located in the anterolateral region of the neck, they consist of a set of muscles: anterior scalene, middle scalene and posterior scalene. Although these muscles exhibit different origins, their insertions are in the first ribs, so they promote the lateral tilting movement of the neck and are accessories of breathing, participating in forced inspiration. In it, the ribs are elevated, which generates an increase in the size of the rib cage and a decrease in intrathoracic pressure, facilitating the entry of air. For this analogy, the students were expected to relate the lifting of the container by the crane with the function of the scalene muscles to raise the ribs when they contract together and the proximal insertion is fixed and only the distal insertion is mobile, with the container being compared with the ribs and the wire of the crane that pulls the objects with the scalene muscles (Figure 4).

Figure 2. Image that presented to the students the analogy about macroscopic muscle organization: Muscle belly and aponeurosis (A) and skeletal muscle organization (B).



Source: https://imgs.extra.com.br/1510648573/1xg.jpg?imwidth=1000, adapted (A); Kenhub GmbH, 2023 (B).

Figure 3. Image and sentence that presented to the students the analogy of the transversus abdominis muscle (A) and muscle organization of the anterolateral wall of the abdomen (B).



Transversus abdominis muscle

Source: https://www.pomeranafm.com.br/wp-content/uploads/2016/09/Represa-Rio-Bonito-Governo-do-Estado-Copia-1-1-1000x500.jpg, adapted (A); Kenhub GmbH, 2023 (B).

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Analogy application

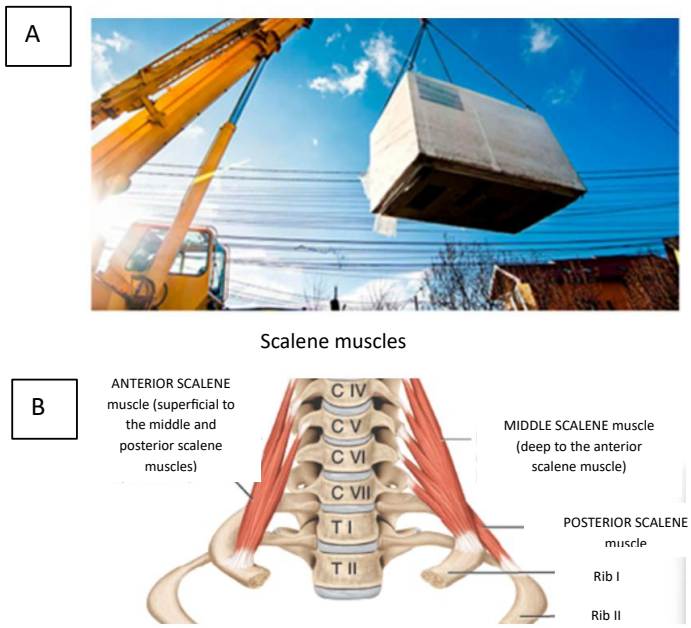
During the practice, the class was divided into small groups, each with a printed copy and with the instructions to relate the written sentence to the image, making analogies based on the theoretical knowledge generated after studying in the laboratory with computers, books and synthetic parts. Although there was a previous idealization about analogies and learning objectives, students were free to develop their reasoning as long as they reached an understanding of the topic. The groups had an average of three hours to complete the activity and then presented the prepared associations to the class. After the presentation, the monitors and teachers checked whether the analogies of each group differed from each other, and it was identified that the answers they developed differed little from each other (Chart 1).

Based on the record of the students' answers, we can observe that most students achieved the expected result, i.e., that what was thought of before the application of the methodology. The students learned correct concepts and exposed their thinking about anatomical structures and functions. However, some students analyzed the analogies in the wrong way, which also generated a valid discussion during the activity. We obtained, for example, the analogy made by the students that each red stripe on the straws would be a muscle fiber and the entire straw would be a fascicle. In this case, the endomysium is non-existent, since the bag that covers a unit of straw would represent the perimysium.

Still from this perspective, other students evolved in their analyses beyond what was expected for the activity. For example, regarding the analogy of the dam and the transversus abdominis muscle, one group related the opening of the dam's gates to voiding and fecal function, in which the transversus abdominis participates as an auxiliary. This moment of feedback was also of paramount importance for the students to discuss which comparisons would be more reliable to the structures already chosen and applied. At the end of the semester, there was a meeting with the teachers and the group of monitors and it was thought of other objects that could be related to anatomical structures of the muscular system, such as the lens of a camera that can be compared to the circular muscles (sphincters, orbicularis oculi and orbicularis oris) and the "baby jumper" toy that can be compared to the levator ani muscle group.

The other components of the locomotor system (bones and joints) were worked with other teaching strategies, and this report is only an excerpt of the entire semester. However, we suggest some analogies that can be applied, such as a comparison between the children's turntable and the spheroidal synovial joints such as the glenohumeral joint, since the object resembles the head of the humerus in a cylindrical shape and

Figure 4. Image and sentence that presented to the students the analogy about the scalene muscles and their respiratory function (A) and anterior view of the relationship of the scalene muscles with the rib cage (B)



Source: https://www.arclocacoes.com.br/images/menu/munck.jpg, adapted (A); Tortora and Derrickson, 2016[20] (B).

Table 1. Presentation of the results found after the study of analogies by the students.

Presented analogy	Obtained reasoning
Straws and muscle organization	• Straws: muscle fibers; • Set of straws: fascicles; • Bag containing 1 straw: endomysium; • Bag containing all straws: epimysium. • Each white or red stripe on the straw: muscle fibers; • One straw: fascicle; • Bag that contains one straw: perimysium.
Trampoline muscle organization	• Trampoline: aponeurosis; • Springs: muscles; • Metal bed support structure: bone; • Springs: muscle belly; • Spring ends: aponeurosis origin and insertion; • Trampoline and metal structure: bones.
River dam and transversus abdominis muscle	• Barrier: muscle; • Water: internal organs; • Dam wall: muscle; • Dam: transverse abdominal.
Container and scalene muscles	• Container: ribs; • Steel Cable: Tendon; • Crane: scalene muscle; • Truck: spine/muscle origin. • Crane rod: cervical spine; • Steel cable: scalene muscles; • Container: ribs/chest.

Source: Prepared by the authors.

the loop is compared to the hollow-shaped glenoid cavity, presenting a movement similar to that of circumduction[22]. When teaching the classification of bones regarding the shape, the short bone can be compared with a die, where the three dimensions have similar measurements (length, width and thickness). Long bones resemble a cane, because they have a length greater than their width and thickness, and flat bones resemble a pot lid, where the thickness is smaller than the other dimensions, width and length, and may have protruding bone accidents (such as the pot lid)[21].

It is important to highlight the fact that some students in the first semester are unable to finish on time some activities proposed by the day script, since many are still adapting to the method; therefore, it is beneficial to use short, simple and well-directed activities for these students in the first semester, such as analogies, as they help to better fulfill the objectives that comprise the entire script to be worked on and facilitate learning.

DISCUSSION

The study of anatomy is essential in health courses, especially in the medical area[22]. To learn extensive contents, such as human anatomy, and generate greater interest in the subject, the use of active methodologies is beneficial when compared to the traditional methodology. By placing the student as the protagonist of their learning and instigating them to be curious, independent and active in the construction of their knowledge, facilitating the understanding and retention of the studied topic, we obtain good results[23,2]. The need arises to increasingly seek new forms of teaching for the LMF, which teaches basic subjects, such as anatomy and histology, for example[8].

Active methodologies allow several ways of approaching issues within the medical school, with a common objective, which is the need to raise questions-problems, which trigger the student to search for explanatory factors and to suppose solutions to the problem[25]. Among these methodologies are analogies, which aim to make learning more fluid and autonomous by correlating a structure with something from everyday life [26]. In addition to motivation, it is important that the student find meaning in their studies and that the contents be connected to their reality[27]. In our study, we found students motivated in their tasks and committed to learning, since the analogies referred to everyday objects, giving meaning to the teaching strategy.

Agra *et al*.[28] (2023), who used a didactic model of a non-biological eye made of Styrofoam for medical residency students to train in strabismus surgery techniques, observed that students were interested in the practical study, mainly first-year ones, as well as in our study. Unlike our study, the authors applied a test before and after the activity with the non-biological eye model and obtained an increase in the mean grade of all residents after the activity. The didactic model described is an interesting alternative for the teaching of anatomy, since it is a visual structure and is built by the students themselves.

Parallel to this, developing strategies for teaching anatomy, where the individual needs previous knowledge, reflecting on the comparison and discussing with classmates their perspectives on the questions-problems presented to them, generates the development of critical reasoning, communication skills and an active being in problem solving[29], thus contributing to professional training and the profile of physicians recommended by the DCNs[1]. In this context, Araújo *et al*. [30] (2014) proposed for the teaching of anatomy the didactic strategy of creating anatomical models by students after lectures. Small groups of 5 to 6 students should use recyclable materials, modeling clay, Styrofoam and paint to create models that represented anatomical structures. The result was that the students got involved and excited about their studies and correctly made anatomical models.

Queiroz *et al.*[4] (2021) brought in their study the discussion of the advantages for monitors, teachers, and students of the LMF an approach with analogies in the teaching of human histology. The researchers encouraged the "brainstorming" based on comparisons of cells with everyday objects to instigate imagination, autonomy and critical thinking in class. They observed that traditional teaching tends to inhibit students due to excessive demand for memorizing names and that with the use of analogies, students actively participated. In our study, we also had the effective participation of students committed to analyzing the analogies, who did not hesitate to present their ideas to the class.

Another resource that can be used in anatomy classes is technology, which is increasingly present in human life, such as 3D anatomical parts, anatomical tables, and virtual reality glasses[31]. These tools have shown a promising and beneficial future for teaching, as they facilitate students' understanding and learning, since they are ludic and attractive ways for students to study anatomy, as well as analogies[32]. On the other hand, the instruments mentioned have a high cost for educational institutions, especially for public universities that depend on financial transfers for this modernization and computerization, while the application of analogies is almost free of costs[32,33]. To understand which resource is best for learning anatomy, technological resources or analogies, more studies must be carried out.

At the time of the writing of this manuscript, we did not find scientific studies on the application of analogies in the LMF for the teaching of anatomy, only for the teaching of histology,

as in the study by Queiroz et. al. (2021) [4]. What was found is the study by Mascarenhas *et al.*[34] (2018), which used the comparison of the human body functions with the structure of a building, in the architecture and urbanism course. In this study, students were encouraged to list similarities and differences between the human body and a vertical building and, as a result, the analogies highlighted were: hair as the roof of the building, skin as the external cladding of the building and vision/eyes would be similar to windows/openings[34].

There is also another method of analogies that uses hand movements as related to the structures of the human body, which is called "*hand as foot*". The example found in the literature is with the hands joined, with one of the fists in a pincer grip being encompassed by the contralateral hand and which resemble the structures of the uterus, cervix and vagina and thus, when moved, they make an analogy to uterine prolapse, thus facilitating the memorization of the degrees of prolapse by students[35]. The other reference is to the hands joined by the thumbs in an "L" shape, one mirroring the other with the palatine bone, an important structure that cannot be seen directly. With the hands, it is possible to promote an analogy with the bone, where the fingers are the bone processes, representing the anatomical structure of the palatine bone clearly expressed, helping in the teaching-learning process of anatomy[36].

It is important to develop studies that demonstrate the self-learning character of the LMF, which is a great challenge for the teacher, who must achieve the educational objective in the laboratory environment without, however, interfering in the student's final production and in the connection of learning with tutoring[37]. A greater challenge stands out when dealing with students in the first semester, who since basic education have been taught in the traditional methodology and when entering undergraduate school, they need to adapt to the new teaching model, where they leave the role of receiver to be an active individual in the construction of their knowledge, a process that requires time for the construction of skills and competencies[38].

The students in the first semester had their interest and attention stimulated, since the analogies encourage the students' imagination and creativity to find the similarity of the image offered with the analogy of skeletal muscle and its function in the body. This type of teaching instigated students to join their previous academic knowledge of muscle anatomy and physiology with something from everyday life, which made the teaching and learning process fluid, dynamic and easy to memorize. It is important to highlight the role of mediators, i.e., the monitors and teachers, who helped not to generate failures during the comparisons, clearing up doubts and mediating the final presentation.

The activity with analogies at the LMF promoted discussion between teachers, students and monitors about other anatomical structures that could be compared with something from our daily lives, generating ways to retain the content and contributing to the construction of more dynamic knowledge within the classroom. Encouraging curiosity and working on the skills and competencies established by the curriculum in the medical school enhances the student's learning by stimulating them with images and/or key questions that help them assimilate the content being studied due to the association of academic knowledge with everyday situations[30].

We emphasize that the use of analogies for medical education is not yet extensive in Brazil and there is much to be explored within this teaching methodology. Therefore, we suggest that future studies use more analogies applied in higher education, preferably with qualitative and quantitative data, which enable the analysis of the results with statistics to assess the significance of the results. It is important that further studies highlight the effectiveness and impasses of the methodology in the teaching-learning process within medical education.

FINAL CONSIDERATIONS

The teaching strategy with analogies was productive, as it developed relevant characteristics for student learning, such as autonomous study, memorization, teamwork, interpretive and organizational skills. There were divergences between the results presented by students, especially in analogies 1 and 4, thus demonstrating greater difficulty for students to make the comparison. However, even with the presented impasses, the analogies achieved the proposed study objectives.

The discussion about what was or was not similar in the comparison of anatomical structures with objects, the solution of doubts about the subject during the class and the active role of the students in the construction of knowledge demonstrated the benefit of the strategy for the topic. The use of analogies can be carried out in other axes of medical education, favoring the critical and reflective positioning of the student on the contents in a contextualized way as required by the integrated course curriculum.

Analogies can allow long contents to be presented in a ludic context, together with theoretical lectures on the subject to be studied at the LMF. However, this activity must be evaluated and improved throughout the process, as well as have new complementary pedagogical strategies added aiming to facilitate the understanding of anatomical concepts.

AUTHOR CONTRIBUTIONS

Gabriele Lima de Lucena and Luiza Penha Pinheiro participated in the writing, formatting, correction and organization of the

manuscript. Elielton Barreto Gomes and Conceny Ribeiro Dutra participated in the writing, formatting and correction of the manuscript. Ândria do Socorro Gusmão de Carvalho participated in the writing of the manuscript. Tinara Leila de Souza Aarão participated in the writing, correction and organization of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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DATA AVAILABILITY

Research data is available in the body of the document.

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