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Construction of anatomical models as a didactive tool for Neurophysiology classes at undergraduate level

Construção de modelos anatômicos como uma ferramenta didática para aulas de Neurofisiologia em nível de graduação

Construcción de modelos anatómicos como herramienta didáctica para las clases de Neurofisiología en la licenciatura

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Abstract
A wide range of studies has shown the need for professors to review some of their pedagogical practices, primarily when the content being taught is complex and abstract. With this in mind, the current research aims to develop a new and more effective approach to teaching neural physiology. The chosen methodology was a practical activity in which 1st-year students of Nursing and Pharmacy had to assemble a model of nerve cells. The students were given general guidelines but were free to decide on the materials to build the model. Our results showed that students produced high-quality and accurate models, including details of morphophysiological structures of neurons. Thus, the construction of models is an interesting didactic tool in lessons about complex and abstract topics such as neurophysiology. The use of models motivated students and increased their interest in the content covered by the lecturer.
Keywords: Morphophysiology; Neurons; Active methodology; Health; Teaching.

Resumo
Uma vasta gama de estudos demonstrou a necessidade de que os professores revejam algumas das suas práticas pedagógicas, principalmente quando o conteúdo a ser ensinado é complexo e abstrato. Com isto em mente, a investigação atual visa desenvolver uma nova abordagem mais eficaz ao ensino sobre fisiologia neural. A metodologia escolhida foi uma atividade prática em que os estudantes do 1º ano de Enfermagem e Farmácia tiveram de montar um modelo de células nervosas. Os estudantes receberam orientações gerais, mas foram livres para decidir sobre os materiais para construir os modelos neurais. Os nossos resultados mostraram que os estudantes produziram modelos de alta qualidade e precisos, incluindo detalhes das estruturas morfofisiológicas dos neurónios. Assim, a construção de modelos é uma ferramenta didática interessante nas aulas sobre tópicos complexos e abstratos, tais como a neurofisiologia. A utilização de modelos motivou os estudantes e aumentou o seu interesse nos conteúdos abordados pelo professor.
Palavras-chave: Morfofisiologia; Neurónios; Metodologia ativa; Saúde; Ensino.

Resumen
Una amplia gama de estudios ha demostrado la necesidad de que los profesores revisen algunas de sus prácticas de enseñanza, especialmente cuando el contenido a enseñar es complejo y abstracto. Teniendo esto en cuenta, la investigación actual pretende desarrollar un nuevo enfoque más eficaz para la enseñanza de la fisiología neuronal. La metodología elegida fue una actividad práctica en la que los alumnos de 1º de Enfermería y Farmacia tuvieron que montar un modelo de células nerviosas. Los estudiantes recibieron directrices generales, pero fueron libres de decidir los materiales para construir los modelos neuronales. Nuestros resultados mostraron que los estudiantes produjeron modelos de gran calidad y precisión, incluyendo detalles de las estructuras morfofisiológicas de las neuronas. Así, la construcción de modelos es una interesante herramienta didáctica en las clases sobre temas complejos y abstractos como la neurofisiología. El uso de modelos motivó a los alumnos y aumentó su interés por los contenidos tratados por el profesor.
Palabras clave: Morfofisiología; Neuronas; Metodología activa; Salud; Enseñanza.

1. Introduction

Anatomy and physiology are required components of the curriculum of several undergraduate health science courses. Learning morphophysiology is fundamental to students' understanding of life, cells, tissues, organ systems and organisms, their functions, and related dysfunctions in the human body.(Dekker & Wolff, n.d.) A major challenge for university teachers of these disciplines has been to make anatomical and physiological concepts enjoyable to students, primarily because this content must be applied in an integrated and contextualized manner.

Knowledge of morphophysiology is of fundamental importance in the training of health professionals, as it provides essential information about the structures, functioning and physiology of the human body. It is also noteworthy that, usually, health professionals work with organic dysfunctions, so it is necessary to have specific knowledge of the body structures and their functioning so that the professionals achieve a better compression of the organism as a whole.

Despite their importance, subjects related to morphophysiology are considered to be very complex, abstract, detailed and challenging to understand by students training to become health professionals. These difficulties make students feel confused, disinterested and unmotivated. Professors of anatomy and physiology must be aware of the problems their students face when learning those topics and consider new ways of teaching, especially considering that traditional lectures and textbook reading are stressful for students. According to Granjeiro,(Granjeiro, 2019) current pedagogical practices should be reevaluated and updated, given that students today have a profile that is increasingly dynamic and computerized. Thus, it becomes necessary to use methodologies that attract students' attention and allow more integrative and effective teaching. In Brazil, teaching and learning morphophysiology is particularly challenging given the shortage of appropriate didactic resources, such as anatomical, cellular, biochemical and physical-chemical models, which would help professors and increase students' knowledge acquisition.

Significantly, adequate pedagogical methods can reduce the number of students who drop out of courses and guide students in their future practical experiences. University professors in health science courses have been seeking new teaching methods to better deal with students' lack of knowledge and interest in lectures. Those new methods are also expected to better compete with students' excessive interest in the fast information flow on the internet and their search to become creative and critical professionals.(Granjeiro, 2019; *View of Effects of ILearning Media on Student Learning Motivation*, n.d.) So, it is of fundamental importance to search for methods that facilitate students' learning.(Aini et al., 2019)

One type of methodology that has become more popular amongst university professors is active methodologies. Such methods place students in the center of the teaching and learning processes, helping them engage with the content more autonomously.(Leite1, 2018; Ribeiro Sobral et al., 2012) These pedagogical strategies can improve students' communication skills, creativity, and interest in research, leading to professionals who are more autonomous, critical, and reflective.(Basnet et al., 2013)

It is essential to highlight that, regardless of the pedagogical method chosen by the professor, the primary purpose of teaching should be to optimize students' learning and training.(Rodrigues et al., 2021) Thus, professors must ensure the organization and adequacy of the courses to meet students' diverse professional interests.(*ZABALZA, Miguel A. O Ensino*

Universitário: Seu Cenário e Seus Protagonistas. Porto Alegre: Artmed, 2004, 239 p. - PDF Download Grátis, n.d.) This is done by reviewing pedagogical practices that may be leading to students' lack of motivation, dropping out of courses and poor learning.

Thus, the current research aimed to develop a practical activity that facilitated the learning of neurophysiology by undergraduate students. The exercise involved students building morphological models of neurons, as well as describing, in the built model, the processes of neuronal communication. In other words, the current study aimed to exemplify professors' use of active didactic tools, which increase students' learning and reduce the stressful effects caused by reading and observing lectures. In addition, our study aimed to introduce professors to the possibility of teaching Physiology using group work and dialogue to increase students' social skills.

2. Methodology

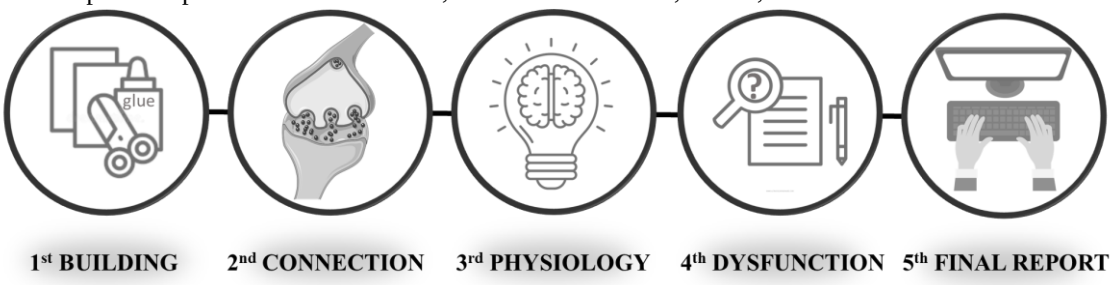
The study was conducted at the Department of Biological Sciences at the State University of Feira de Santana (UEFS/DCBIO), located at Avenida Transnordestina, s/n - Novo Horizonte CEP 44036-900 - Feira de Santana – Bahia. This educational institution offers several undergraduate courses, including health courses, such as Medicine, Nutrition, Pharmacy, Dentistry, Biology, Psychology and Physical Education. All these courses have the subjects of Human Anatomy and Physiology as mandatory curriculum components. The current research happened in the 1st semester of 2019 and involved 70 second-year students of the Pharmacy and Nursing courses who were enrolled in Human Physiology offered by the Department of Physiological Sciences.

The participating students were divided into two theoretical classes (Nursing class and Pharmacy class: one class for each course with 35 students) and six practical classes (Nursing class and Pharmacy class: three classes for each course with 12 students). Before the experimental category, students attended three extended classroom lectures over a week — two-hour per class, in which they were taught basic information about the anatomy and physiology of neurons, such as their morphological structures. The practical classes were held in three face-to-face meetings lasting two hours each. Before attending those practical classes, students received a training plan containing the classes' objectives, method, examination and references. This was done so students were informed that *i)* they would be building anatomical models to facilitate their understanding of neurophysiology; *ii)* they should read the educational material found in the reference list; *iii)* they should bring whatever tools and building material they thought necessary, and *iv)* those models would be assessed and graded.

As previously mentioned, to carry out the proposed practical activities, students were instructed to choose and bring didactic materials of their preference. They were asked to use maximum creativity when selecting these materials since they would be building models of neuronal cells containing organelles, synaptic vesicles, neuron extension, plasma membrane, protein channels, ions etc.

During the practical classes, students were asked to organize themselves into groups of no more than four students each, who should work together to deliver the build neurological model. In addition, each group was asked to use books, computers, tablets and mobile phones to research the morphological structures of neurons. The practical activity was divided into five phases, as in Figure 1.

Figure 1: Synthesis of the methodological path followed in practice assembling and connecting neurons performed by students of the Nursing and Pharmacy courses 1/2019 of UEFS. **1st Phase** – *Building*: in this phase, students were presented with neuron cell diagrams to guide the model's building. Afterwards, the groups started to build the morphological neuron structures. Since each group brought their own building materials, we observed various choices, such as strings, fabrics, stones, buttons, Styrofoam, electric wires, wires, glue, scissors, paints, cardboards, EVA, and others. **2nd Phase** – *Connection:* Students had to connect the anatomical models to create a chain of neurons in this phase. **3rd Phase** – Physiology: in this phase, each group used the chain of neurons built to explain the passage of the neuronal stimulus through the chain. In this phase, students also used their model to simulate the electrical synapse and the ions and neurotransmitters in the process. **4th Phase –** *Dysfunction*: in this phase, students were instructed to research and explain how a particular pathology could bring about a disturbance in neuronal neurophysiology and all the possible treatments for that disturbance. **5th Phase –** *Final Report*: in this last phase, the groups wrote a scientific report composed of an introduction, material and method, results, discussion and references.



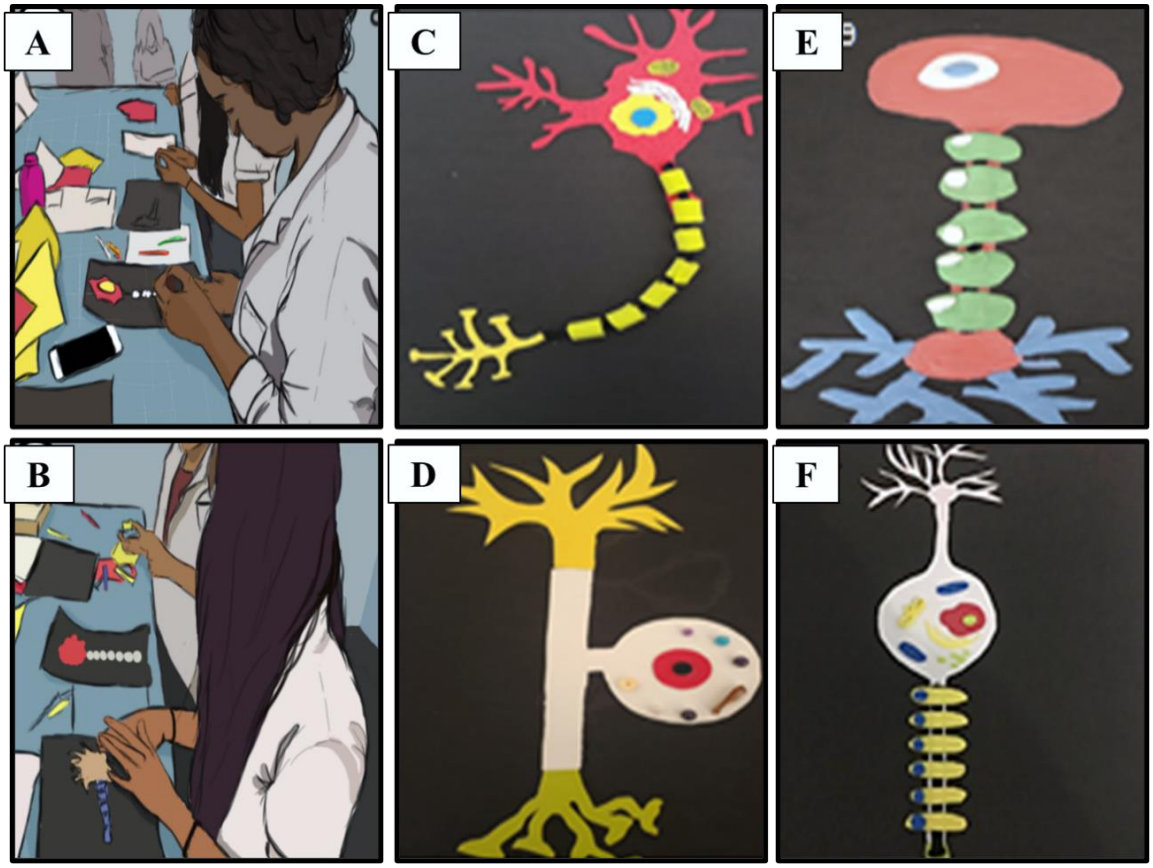
Source: Authors.

3. Results

During the practical classes, we observed high levels of interaction, organization and autonomy of the students (Figure 2: A and B – *Supplementary material 1*). We observed that students built four different models, as recommended by the morphological classifications found in their textbooks (multipolar; unipolar; pseudounipolar, and bipolar, represented in the Figure 1 by the letters C, D, E, and F, respectively).

As exemplified in Figure 1, it is clear that students build very creative and didactic models. For instance, some groups included the different regions of the neuron's body in the model to represent the details of cellular organelles, the dendrite and axon extensions. In the axons, it was possible to notice the fundamental structures for synaptic communication, for example, myelin sheath and Ranvier's node, which were used to explain neuronal physiology. The students were also attentive to the chemical part of neurons representing ions, ion channels, synaptic vesicles, neurotransmitters and synaptic slits.

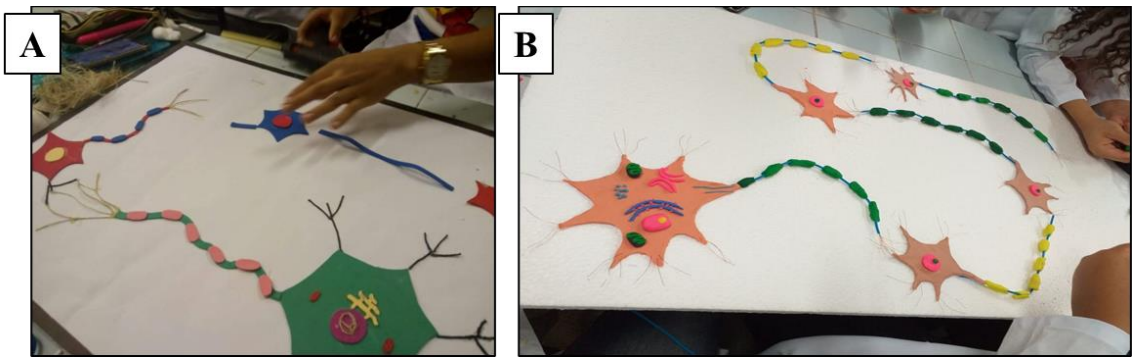
Figure 2: Illustration of the model prepared by students of the discipline of neurophysiology on the morphophysiological structure of neurons.



A) and B) the students building the neurological cells using different materials; C) represent a multipolar neurological cell; D) represent a neurological unipolar cell; E) represent a neurological pseudounipolar cell; and F) represent a neurological bipolar. Original phots in *Supplementary Material 1*. Source: Authors.

Students brought a huge diversity of materials to customize their models. This shows interaction between the members of the groups and thorough planning. One group built their model using EVA, which is a type of rubber composed of a high technology mixture of Ethyl, Vinyl and Acetate. This is a non-toxic material well known among artisans and artists. The neurons made by EVA were rich in details, colors and creativity, as shown in Figure 2. Another group tried to represent the neurons in a three-dimensional image (Figure 2A) and other groups used Styrofoam, clay and electrical wires (Figure 2B). The model built with Styrofoam was very detailed and accurate in its representation of cell organelles, which were made using modeling clay in different colors (Figure 2B).

Figure 3: Model prepared by students of the discipline of neurophysiology on the morphophysiological three-dimensional structure of neurons.



A) neurons in 3D; **B)** 3D montage of the connection between neurons. Source: Authors.

In 2nd phase, the groups assembled axodendritic connections (axon termination of one neuron and dendrite of another neuron); axosomatic connections (axon termination of one neuron and the cell body of another neuron) and axo-axon connections (axon termination of one neuron and the axon of another neuron), which were used in the 3rd and 4th phases.

In the 3rd and 4th phases, students were instructed to use their models to explain the physiology of the neurons. We observed that the explanations were of high accuracy in terms of morphology and functions of neurons, including the functioning of electrical synapses (input and output ions) and chemical synapse (neurotransmitters), which shows that students learned the content well.

In the 4th phase, we observed that students conducted thorough research on neuronal dysfunctions. They explained their findings using their models and altering their structures. For example, one group modified the model to represent changes in the myelin sheath due to specific pathologies. Another group was able to explain depression by altering the model's chemical communication between neurons.

In the last phase of the study, students presented 16 scientific articles (eight written by the students of the nursing class and eight written by the students of the pharmacy course). In the articles, students reported satisfaction with the practical activities, having found them fascinating. They also noted that the suitable class allowed a better understanding of such a complex content, including aspects related to the functioning of cellular organelles, neuronal electrophysiology and possible dysfunctions that can bring severe consequences to the organism's homeostasis. This knowledge is of extreme importance for future performance nursing and pharmacy professionals.

This descriptive research sought to observe, record and describe the didactic method suggested by the patient and executed by the students. Thus, the results observed during the execution of the practice class entitled "Assembling and Connecting Neurons" will be described. According to Marconi (2001), generally, in quantitative research of descriptive type, the design chosen by the researcher does not allow the data to be used for hypothesis tests. However, hypotheses can be formulated as a posteriori since the study's objective is only to describe the fact. Thus, the idea of this study was to improve student learning using a didactic method. To this end, the construction of neurons gave students a better understanding of the content administered in both practical and theoretical classes. It was not intended to buy grades, much less to show students' learning quantitatively; this study intends to describe what was observed about the teaching and learning process when students were engaged in this activity as follows in the description of the results, discussion, and final considerations.(Marconi & Lakatos, 2003)

4. Discussion

Nowadays, students have a more dynamic profile than in the past. This makes it essential to adopt methodologies that attract students' attention and make learning more integrated and effective.(Granjeiro, 2019) Professors should seek new teaching and learning formats that correspond to contemporary society's perspectives and overcome the daily challenges in favors of quality higher education. Professors must rethink their pedagogical practice and focus on actively including students in the teaching-learning process. Our research suggests that teaching is more effective when students participate in classes and become more engaged and excited with student-student interaction. Thus, the role of the professor goes beyond just teaching classes.

At UEFS, these two topics are usually taught independently by different professors. This makes it harder for students to comprehend and integrate the disciplines, hindering their training as health professionals. Thus, a good alternative for studying physiology is practical activities, which allow the integrated teaching of organic systems' physical and chemical aspects less abstractly.

In Brazil, integrating theory and practice in human physiology courses is challenging since most public universities do not offer appropriate conditions for developing practical activities.(Rodrigues et al., 2021) *In vivo*, animal models offer good practice for students. However, to minimize unnecessary animal suffering, Brazilian laws do not allow the use of such models in the class. Thus, alternative models should be researched and developed, such as those used in the current research.(Rodrigues et al., 2021)

Given the difficulties encountered in performing practical physiology activities, the professor must reinvent his pedagogical practices so that they can mediate and facilitate the assimilation of contents by students. In this perspective, Stabio et al.(Stabio et al., 2018) recommend that students should build their own anatomical models to better understand concepts of neuroanatomy and neurophysiology. Their research showed that when students used wires, wool, paint, and other low-cost resources to create 3D models, their understanding of neuroanatomy and neurophysiology increased.(dos Santos et al., 2021; Stabio et al., 2018)

Students' construction of anatomical models is an excellent option for learning physiology because they allow the high activation of various sensory pathways (vision, hearing, and touch) and neural regions, which facilitates learning.(“Anatomical Society Virtual Winter Meeting,” 2021) Moreover, constructing models allows students to better assimilate morphological structures and their respective functions.(Breakspear et al., 2010)

In this study, we observed that when students build their own models of neurons, they have the opportunity to integrate theory and practice and better understand neural communication and its physical and chemical components, which are topics typically considered too complex and abstract. The students reported that practical classes helped them learn about neuroanatomy and neurophysiology compared to theoretical lectures and textbooks.

During the practical activities, we observed that students were highly interested and curious about the topics. This differs from their behaviour in theoretical classes, which displays a lack of interest and motivation. Thus, using practical activities, such as the construction of models, helped the teaching process by increasing students’ motivation to learn neurophysiology. According to Gurses et al,(Gurses et al., 2015) one of the conditions for meaningful learning to happen is a predisposition to learn.(Gurses et al., 2015) That is, education must be accompanied by an affective experience that arouses interest in learning.(Tian et al., 2020) Thus, professors should always be attentive to the signs of demotivation and disinterest from students since these behaviours harm the teaching and learning process. Examples of such behaviors are tiredness, demotivation, lack of participation, comments, or questioning. Similarly, classes should be planned and engaging, motivating and attention-grabbing.(Greene et al., n.d.; Hill et al., 2019) According to Mayer,(Mayer, 2020) emotion allows activation of neural regions involved in processing memory formation, which is fundamental in the learning process.

For learning to happen effectively and lastingly, it must awaken some emotion or meaning in the learner. The greater the interest and motivation for a particular subject or theme, the greater the absorption and ease in acquiring this knowledge.(Tyng et al., 2017) On the other hand, when a fact generates strong anguish or emotional burden, temporary failures in attention and concentration can be caused, preventing the development of new learning.(Fraser & McLaughlin, 2019; Ikkai & Curtis, 2011) Therefore, it is up to the professor to prepare creative and participatory classes to awaken students' interest in learning. Using innovative teaching methods provides opportunities for active participation in the teaching and learning process.

A good option of an active method for teaching human physiology was described by Granjeiro,(Granjeiro, 2019) when students conducted their own research about homeostatic conditions, taking measurements of blood pressure, heart rate and temperature. This active methodology provided students with opportunities to relate the theoretical contents learned in the classroom to those applied in practical activities, making the learning process more meaningful and participatory. Teaching through research motivates students to develop an investigative attitude, which can create opportunities to acquire knowledge in a conceptually consistent way and develop essential skills and autonomy. In the 4th phase of the current research, students had to research different neurological dysfunctions. We observed that students were highly interested in learning about such topics and actively engaged in researching and reading academic papers. Thus, the study of dysfunctions can be an excellent starting point for the study of the normal functioning of the neural system. Learning about physiological dysfunctions is essential because these students will work with patients who show several types of dysfunctions. Therefore, connecting the content being taught with students' future practice is a crucial way to arouse interest in comprehending important content about physiology.

In the practical classes observed in our research, students showed much interest in researching the physiological dysfunctions that affect neurons. We could also see that interest was displayed in the text of the scientific articles written by the groups. The writing of useful reports in the format of scientific papers is an essential didactic tool to familiarize students with scientific language and understanding of research. In addition, the scientific texts written in practical classes can be submitted by students to scientific conferences and published in journals.

Thus, this study presents an innovative, feasible, and low-cost didactic possibility to be used in anatomy and physiology classes. Through manual and playful activities, a greater interest of undergraduate students was observed in learning about neurophysiology, including a more significant number of questions, answers and comments made by students compared to their behavior in theoretical classes. The practical activities allowed students to participate in the courses on neural morphophysiology in a more active, participative, critical, reflexive, and autonomous way.

5. Final Considerations

It was possible to observe during a practical class that the construction of didactic models allowed a moment of much learning because during the activity of neuron building was observed the interest, participation, and dedication of the students in the context of neurophysiology were more significant than during the theoretical classes. Thus, it is considered that the students were more engaged in constructing not only morphological neurons but also in the practical learning of each structure, which allowed the teaching of neurophysiology without significant stress. It was also possible to notice that the students presented selfless behavior and mutual collaboration, which allowed the teachers to visualize a creative and less stressful class. Finally, it is reasonable to infer that artistic activities during human physiology classes were influential in teaching and learning since this discipline has content that involves many molecular issues that hinder teachers' learning process. Thus, this pedagogical method is considered an active, engaging, feasible, and essential tool in constructing a class rich in knowledge without so much stress leading to understanding.

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