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Didactic biomodels in animal physiology learning: implementation in undergraduate veterinary medicine

Biomodelos didáticos no aprendizado da fisiologia animal: implementação em medicina veterinária de graduação

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ABSTRACT

Didactic biomodels have been used as a learning tool for physiology teaching, they are three-dimensional functional - artificial models that seek an approximation to the organisms function, and also to help its understanding. The objective of this study was to explore the student`s learning experience through the implementation of didactic biomodels in two universities located in Bogotá city, the subject was physiology in an undergraduate population of veterinary medicine for a whole academic year. This method consisted in using different tools such as structured surveys, Metacognition formats, teamwork and characterization of the models according to the biological system. Results in general were positive and indicated the value of didactic biomodels as a learning method and to knowledge acquisition, the students valued high marks in teamwork as a complement in solving problems, likewise, the models that aroused more interest were those carried out in unconventional species and the nervous system.

KEYWORDS: learning, tool, artificial models, metacognition, veterinary.

RESUMO

Os biomodelos didáticos têm sido usados como ferramenta de aprendizado para o ensino da fisiologia, são modelos funcionais tridimensionais - artificiais que buscam uma aproximação com o funcionamento dos organismos, e também para ajudar sua compreensão. O objetivo deste estudo foi explorar a experiência de aprendizado do estudante através da implementação de biomodelos didáticos em duas universidades localizadas na cidade de Bogotá. O assunto abordado foi fisiologia em uma população de graduandos de medicina veterinária durante um ano acadêmico. Este método consiste em utilizar diferentes ferramentas como pesquisas estruturadas, formatos de Metacognição, trabalho em equipe e caracterização dos modelos de acordo com o sistema biológico. Os resultados foram positivos e indicaram o valor dos biomodelos didáticos como método de aprendizagem e para aquisição de conhecimento. Os estudantes valorizaram notas altas no trabalho em equipe como complemento na solução de problemas, da mesma forma, os modelos que despertaram mais interesse foram os realizados em espécies não convencionais e no sistema nervoso.

PALAVRAS-CHAVE: aprendizagem, ferramenta, modelos artificiais, metacognição, medicina veterinária.

INTRODUCTION

Biomodels are defined as a tool to simulate a real life approach for anatomic study, function, disease simulation, and treatment testing, in literature we can find various forms of construction, ranging from the use of live animals to construction with all kinds of materials. The first three-dimensional biomodels date back to the eighteenth century, there approach of these structures where made by physician- anatomists and they constructed models in beeswax giving them the name of “Anatomical Waxes” (FORERO 2016), the purpose of these models was to explain and simulate the evolution and characteristics of the human specie in order to present them to apprentices and improve their knowledge.

In simple words, models are functional three-dimensional artificial constructions that seek an approximation to the function of an organism, they are built with educational purposes to study and understand the physiology of a specimen (FORERO 2016). This didactic method has been used in different universities around the world to improve the student´s learning (VILLAMIZAR & AQUINO 2016), they pretend to ease the transmission processes of basic science knowledge outside and inside the classroom (BERENGUER-ALBALADEJO 2016). Because of the educational system in Colombia and particularly in the universities where this study took place, some models are developed by the own interest of teachers and researchers, or students that are interested in some subject in specific, the models are usually built with not lasting materials plaster, plasticine, polyurethane foams, among others (Figures 1 and 2). But only since the 1990´s these models and simulators where brought to the attention to veterinary medicine to be used in teaching physiology and achieve a better understanding of this branch in medicine. In this study we will explore the biomodels built by undergraduate veterinary students built with their own materials and creativity, in order to represent an animals physiological processes.

Biomodels construction

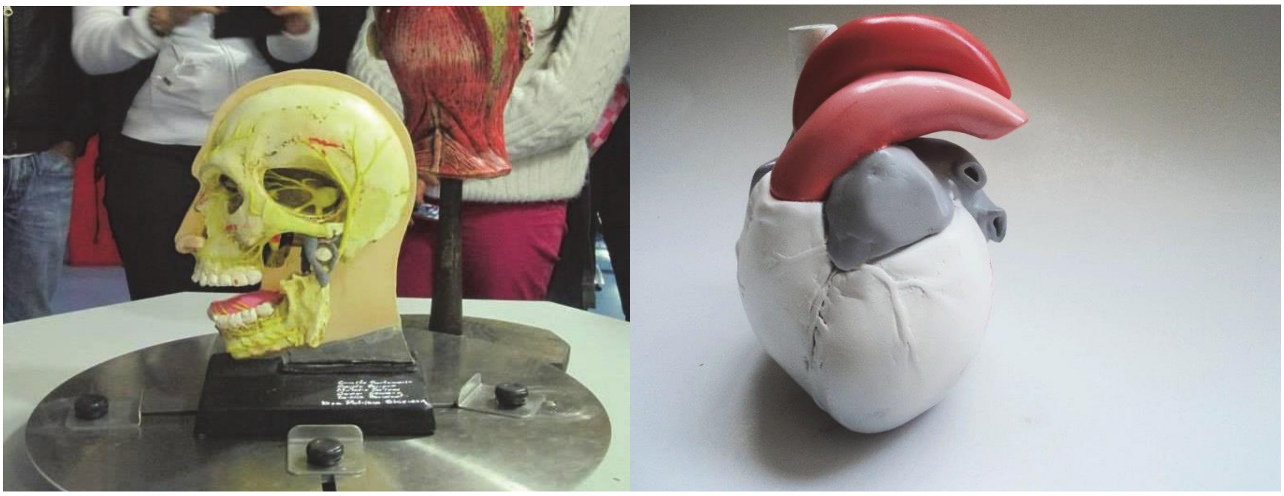

Figure 1. Scale models built by students to represent structures of the organism. (FORERO 2016).

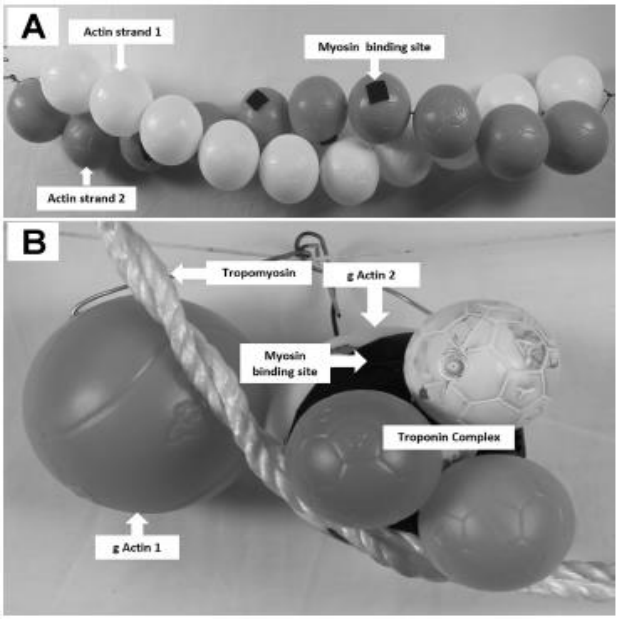

Figure 2. Didactic model that represents the muscle proteins in muscle contraction. (ANANDIT et al. 2018)

For a long period of time, we have used traditional teaching methods which consist in theoretical lectures followed by laboratory sessions in order to "put the theory into practice" (SUÁREZ SÁNCHEZ 2018). But now a days, it has been demonstrated that the use of these modles as a teaching method increases student`s primary knowledge (the ability to memorize concepts) and secondary understanding (the ability to understand concepts). The act of building scale biomodels has been implemented in order to improve the learning of science. Can this implementation be useful in a physiology course in an undergraduate level of veterinary medicine? In order to answer this question we must explore the student´s learning experience, since they are the creators of the biomodels and they are the only one's who can obtain all the benefits in their academic learning experience, on another hand, we are moving from traditional teaching to a constructivist teaching systems, where students are responsible for the creation and discovery of their own knowledge.

In the university's where the study took place, physiology class are consider a theoretical and practical course of five hours a week with groups of 25 to 30 students, the contents are taught by individual physiological systems and their applications in real life (for example diseases and treatments). Most of the laboratories are recorded in real time with the power lab equipment. Theoretical evaluations, seminars and applied workshops are taken in place as evaluation tools. We usually invite our students to consult basic physiology bibliographies such as Guyton, Lange, Boron, Saladin and Cunningham, as well as research articles in institutional databases, this also helps them to lay out theoretical foundations and functional components that the biomodel´s can and will need.

MATERIAL AND METHODS

The study was carried out in a population of Veterinary student´s in Bogota, Colombia from the university's of La Fundación Agraria de Colombia (Uniagraria) and Universidad de Ciencias Aplicadas y Ambientales (U.D.C.A), these students belonged to second, third and fourth semester, which had enrolled physiology clases during the two semesters in the course of 2022 (n = 120 students). Students where told that they had free will to pick the members to conform their work group, from which, 43 groups came about. The final class project was to create a didactic biomodel on any process or system in Physiology. Veterinary students gave an informed consent to carry out the study and authorize the use and publication of the results obtained in the study, also granting there permission to use their personal images.

In order to guide the students in this process, an informative class session was given, the objective was to contextualize the development of the didactic biomodels, this activity consisted in giving the historical background of the models, photos and videos of biomodels made in the past, and give the specific date in witch there models had to be exposed (at the end of the academic semester). The guidelines: It was emphasized that the model should be "functional" to represent any physiological process in a system, which in few words, it had to show a sequence of dynamic steps to expose a final function. The biomodel must be educational, this way it becomes a tool that allows students to explain a physiological topic to anyone without the need of using slides or another visual aid.

After the biomodels where built, exploring tools were implemented:

Structured survey

The method used was SOLTIS et al. (2015), this included the learning strengths described by HANSON (2006). Each student evaluated the contribution of this implementation in different topics related to physiology, these topics were; the domain of the subject, the development of critical and analytical thinking, the acquisition of problem-solving skills, interpersonal communication to understand ideas or concepts, the formation of work teams to facilitate learning, the acquisition of skills for managing roles within the group and familiarization with personal and group self-assessment. The contribution was graded from 1 to 5, 1 being the lowest score and 5 the highest score for each topic in this survey.

Metacognition test

Each working group was assigned a metacognition sheet developed by HANSON (2006) that allows self-assessment of the group performance. In this format, topics are provided with statements such as "did the whole group participat actively?" or "did the whole group prepar the exposition?", each group of students discussed each topic and gave a value from 0 to 5, 0 being the lowest score and 5 the higher score, at the end the final amount (maximum 50) provided the total performance rating.

Experiential feedback

At the end of the expositions of the biomodels, students were given an experiential question: Which was your experience in making physiological biomodels and did this impact your vocational training? The answers were given in hand writting and anonymous. In order to collect and organize the information, similar responses were quantified and organized into; general topics (the aplication of physiology in real life), subject domain (if the project was useful to reinforce the topics seen in class), knowledge (creat a higher understanding of physiology), research (promotes investigation), experience (increases practical experience) and learning methods (if it served as an additional technique in the learning process).

Characterization of the didactic biomodels

The biomodels built by the students in the physiology class, were classified in: "chosen animal" (pets, animals for consumption and non traditional species) and "physiological system" (Physiological theme of the model, that could of been based on the Nervous system, Cardiovascular system, respiratory system, Endocrine system, Reproductive system, Renal system, Digestive system, Muscles, Attached skin, or Eco-physiology).

RESULTS

Some didactic biomodels images are shown bellow (Figures 3, 4 and 5):

Figure 3. Students representing the “minor circulation” with one heart and two lungs made in resin and syringes connected to plastic tubes with red and blue liquid (arterial and venous blood), they are showing how blood travels from the heart to the lungs to be oxygenated in the pulmonary capillaries.

Figure 4. Students presenting the physiological process of lipid absorption in carnivores, this describes the action of pancreatic enzymes to break down triglycerides, the role of bile in fat emulsification, and the formation of chylomicrons.

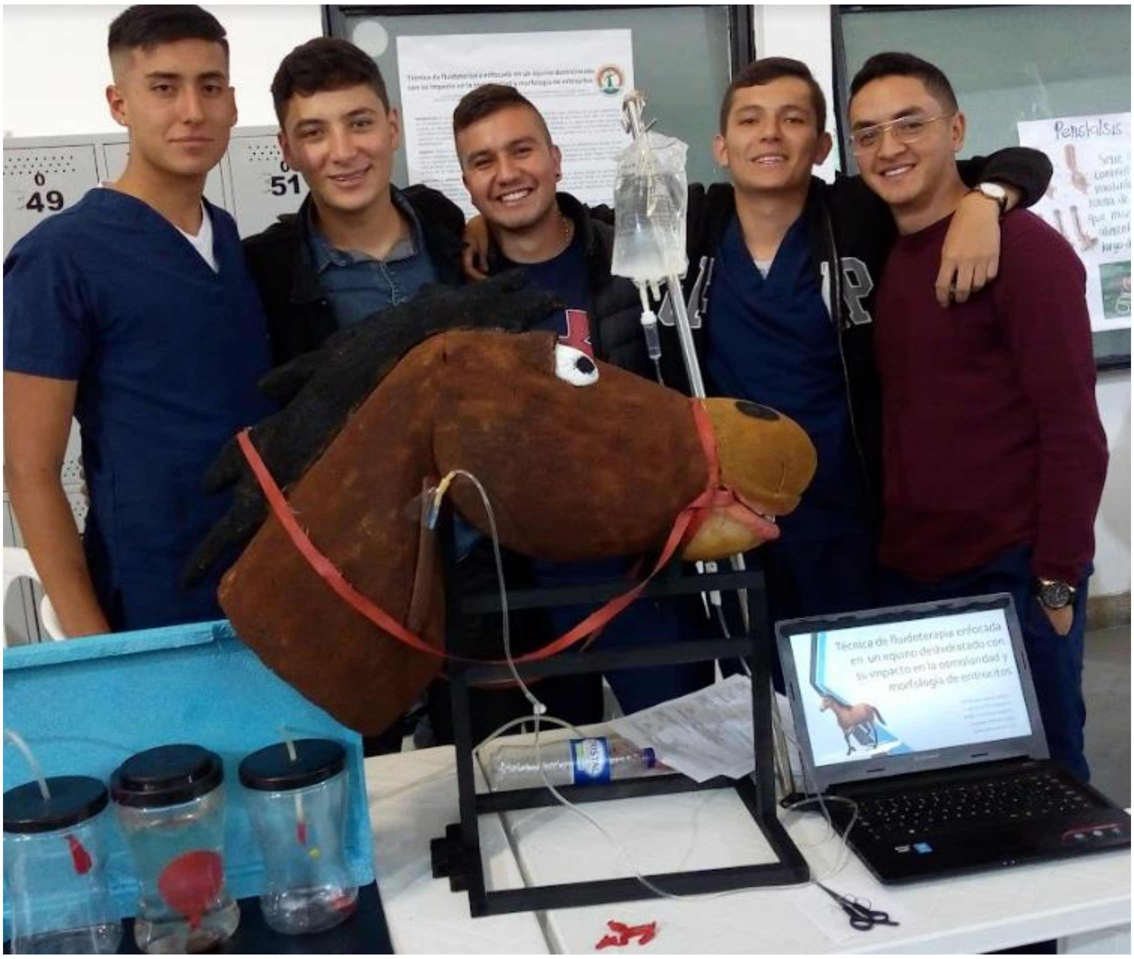

Figure 5. Students represented the physiological effect of the different tonic solutions on the red blood cells through intravenous hydration. In the bottles on the right, the change in cell shape was explained with balloons.

Structured survey

As shown in table 1 (n=88 students), the largest number of students gave a rating between 4 and 5 to the contribution in each topic, however, a high number of students gave a rating of 3/5 in the topic of "administration of roles within the group".

Table 1. The number of students who rated from 1 to 5 the contribution of each topic to their academic life. The largest number of students gave a rating between 4 and 5 to each topic.

Topics	1	2	3	4	5
Subject domain (terminology, methods, trends)			3	44	41
Development of critical and analytical thinking	1	1	1	49	36
Opportunities to gain problem-solving skills			2	51	35
Interpersonal communication to understand ideas or concepts		2	7	50	29
Gaining work team abilities	1	1	6	40	40
Skills for role acquisition or management of work teams	1	1	46	20	20
Familiarization with group personal self-assessment	2		4	40	42

Metacognition

In this exercise (n = 40 groups), the students gave a high rating to all the questions (Table 2).

Table 2. Qualification of the assessment of teamwork.

Item	Classification					Total participants	Rating Percentages				
	1	2	3	4	5		1	2	3	4	5
The whole group came prepared	0	0	2	10	28	40	0%	0%	5%	25%	70%
The whole group participated actively	0	0	0	4	36	40	0%	0%	0%	10%	90%
We all helped and supported each other	0	0	1	6	33	40	0%	0%	2.5%	15%	82.5%
Everyone asked questions when they didn't understand something	0	0	3	8	29	40	0%	0%	7.5%	20%	72.5%
We all provided clear explanations to their peers	0	0	1	10	29	40	0%	0%	2.5%	25%	72.5%
Everyone contributed ideas	0	0	1	7	32	40	0%	0%	2.5%	17.5%	80%
We all listened different ideas from our peers	0	0	3	4	33	40	0%	0%	7.5%	10%	82.5%
Everyone contributed to achieving the goal, no one was a dominant person	0	0	1	5	34	40	0%	0%	2.5%	12.5%	85%
Everyone understood the subject	0	0	0	4	36	40	0%	0%	0%	10%	90%
We all participated and achieved our assigned tasks	0	0	0	1	39	40	0%	0%	0%	2.5%	9705%

During this reaserch it is evident that students encountered difficulties in the functional part of the biomodel, specifically, implementing movement and dynamism to represent the interaction of biological processes. Also, there were classic coexistence problems in the work groups. Throughout the investigation it was found that some students did not scientifically deepen the processes in physiology and ended describing them in a general way, however, it was evident that this exercise helped them to consolidate their knowledge in comparison to other tools as traditional lectures or memory test.

Biomodels characterization

Each group of students (n= 43 groups) had the opportunity to choose their favorite animal or species, as it is shown in Table 3, most of the participants prefer to work with didactic biomodels based on “non-traditional” or wild life species. On the other hand, the most chosen physiological system was based on the nervous system, and the less liked topic was themuscular system.

Table 3. Selection of participants based on animal species and physiological system.

Selected animal or species	Participant groups	Percentages
Didactic models based on pets (Dog, cat, non-wild or slaughter birds, freshwater fish, small mammals)	5	11.62%
Didactic models based on animals for consumption (Cow, horse, pig, birds)	9	20.93%
Didactic models based on non-traditional species or wild life	29	67.44%
Total	43	100%
Physiological theme of the model		
Nervous system-based models	11	25.58%
Cardiovascular-based models	5	11.62%
Lung-based models	2	4.65%
Endocrine-based models	5	11.62%
Reproductive-based models	3	6.97%
Renal-based models	1	2.32%
Digestive-based models	8	18.60%
Muscle-based models	0	0%
Attached skin-based models	6	13.95%
Eco-physiology-based models	2	4.65%
Total	43	100%

Experiential feedback

According to the experience process in elaborating the didactic biomodel, each participant (n=120 students) answered the opened question based on the experience that this activity provided for their vocational training (Table 4). The most prevalent answers visualized the didactic biomodel as a learning tool for students that helped the knowledge acquisition.

Table 4. Student`s answers classified in general topics according to the experience in the building of the biomodels for academic training.

Item	Participants	Percentages
Real life comparison	17	14.16%
Subject domain	15	12.5%
Knowledge	34	28.33%
Research	10	8.33%
Experience	11	9.16%
Learning method tool	33	27.5%
Total	120	100%

DISCUSSION

Various ways of teaching physiology have been used over time; laboratory practices to learn about organs and system function (BORRÀS et al. 2012), the use of lectures, textbooks, commercial videotapes, real lab demonstrations, animal testing labs (the basic concept, focuses on providing the student with "real material" and "real experience") (SHORE et al. 2013), the lab based on computer software to simulate the behavior and physiological responses to different stimuli (BALAGUERA 2017), inquiry-based physiology labs characterized by learning through discovery (GALLFOR & HUERTA 2014), visual laboratories for the learning of professional ethics (ESCUDERO LIROLA et al. 2018) and Labtutor (step-by-step instructions, real-time records and data analysis) (SWIFT 2016). All these didactic tools are centered in memorization concepts, the understanding of basic concepts and real experience in order to improve the learning process. Based on the results of this study, the implementation of didactic biomodels, could be an evidence of the benefits of this tool (FERNÁNDEZ & MADRID 2010).

By exploring the educational experience of different authors, didactic biomodels that represent the different systems and processes in physiology, like in this study some have positive results, for example:

- By implementing a didactic model on renal physiology, most of the students agreed that the model was easy to understand, it improved their knowledge and many of them said that they would recommend the model's to their peers, in addition, a high number of students [63 of 76 students (83%)] would prefer to use the model instead of reading materials (RODRÍGUEZ & RUIZ 2020).

- When using a didactic model to exemplify the eye movements, all the students in the group felt that the model was very useful to understand the axes of the movements, some specific comments were "Very good", "I understood it very well", "It's very simple", "I never thought it would be so easy" and "Please use these models for other topics too". According to the researchers, the student's attention could be captured in a minute (GARAU 2017).

- As an attempt to explain the physiology of muscle contraction, a model of fibers was created from simple materials such as strings and balls, the three-dimensional nature of the models helped students to understand the structural aspects of skeletal muscle. 51.8% (n _ 83) of the students considered the use of models as "very useful", 42.2% found them "useful", while 4.8% of the students were neutral in their response. 1.2% of students found the models "confusing". There were no students for whom the use of models was "too confusing". According to the researcher, the students enjoyed these interventions, making the learning process both informative and enjoyable (ANANDIT et al. 2018).

- When a model was implemented to explain the processes of the cardiac cycle, students commented that it helped them to remember basic concepts, kept them awake, the session was interesting. According to the researchers SAJAL et al. 2018, this simple activity can be used to make the liveliest conference (SAJAL et al. 2018).

- By using a model based on the respiratory system, the understanding of respiratory mechanics increased by 70% compared to the previous extensive didactic teaching, some of their individual comments were "this is a good model to understand many physiological states" and "without this model I would never have understood the different characteristics of the respiratory system". According to the researcher, this model fosters the understanding of interactions and can improve the understanding of respiratory physiology

(VELÁSQUEZ et al. 2012).

Results obtained in this educational experience show consistency with the statements of different academic authors. This is why all attempts to improve teaching in the field of medicine are an issue that affects all the medical subjects from the academy, as said by GONZÁLEZ et al. 2015 *we continue to search for actions that lead to a new direction of work with fresh and encouraging panoramas for our students.* Medical education just can`t move away from this attempt, because it can be a space for the combination of teaching methods and interactive elements (FRIEDERICHS et al. 2014). Classes have often been criticized for being monotonous, students are only passive learners, it is to the fact, that textbooks seem to provide only limited understanding (SÁNCHEZ et al. 2014). However, even if different didactics are implemented, it is not possible to completely eliminate lectures, since they are useful to explain basic concepts (VILLAMIZAR & AQUINO 2016).

One big question that teachers share is: how to teach science in a meaningful way? (ORTEGA 2007) We always seek that our methods are the most complete and that can provide tools to learners, hoping that they will be able to use them, even throughout his professional life. It is difficult to find a definitive education method, but a promising possibility could include the active learning; a process to engage students in some activity and make them reflect about their ideas and how they are using them, this learning process does not prioritize the transmission of knowledge but it focuses on the active participation of students, this leads to developing skills such as, scientific process and complex thinking (RODENBAUGH et al. 2012). The present project was built on the idea of exploring if students were able to make a little change in their traditional study routine with the implementation of an activity that focused their attention on individual responsibility for building their knowledge. The creation of these biomodels was a complement within the curriculum of the course, the development of a tool for the students with the purpose of simulating a process in physiology and at the same time learning through discovery processes. These activities seek greater knowledge retention, a deeper understanding and a more positive attitude towards the subject that is intended to be taught (MAKUC SIERRALTA & LARRAÑAGA RUBIO 2015).

The center of this implementation was constructivism, the professors designs the activities, so the student takes control of his own learning, builds his own knowledge from different points of view and at his own pace (KAY & KIBBLE 2016), in addition, attempts to provide a more focused intervention where the student´s own experience was integrated at the same time that research skills are developed (AMOLINS et al. 2015). According to the results obtained in the structured survey, students gave high scores to the “learning and knowledge” items, this is positive, because this activity improves their assimilation process through an alternative tool compared to traditional teaching, also, students had a high willingness and enthusiasm to perform this activity. As professors, we were able to verify the interest and curiosity in the development of the biomodel, student´s became responsible for their learning and our role became working as a guide between them and the “knowledge empowerment”.

An important complement in biomodels development was collaborative learning; here the interaction, the exchange of ideas and knowledge between the members according to BLASCO et al. 2016, is associated with positive results such as student satisfaction, academic performance and professional behaviors. Metacognition, which means "thinking about what i am doing", includes self-management, self-for exampleulation, self-assessment and reflection on learning, according to LEÓN 2014 and the authors of this text share it, students realize that they are responsible for their own learning and what they need to evaluate (self-management and self-for exampleulation) from their own work team. Speaking about the working groups, students gave a very high score to questions such as; we all complemented the assigned tasks, everyone understood the material, the whole group participated, everyone contributed and no one assumed the role of leader, everyone contributed ideas and listened. They showed quite encouraging results due to the participation of everyone in the activity, something very good when it comes to promoting this competition, in addition, it shows that students realize the importance of developing problema solving skills. It is important to say that teamwork is always a path from which the final result benefits all working groups. On another hand, in the felled of medicine, it will be reflected in understanding the physiology of organisms and a better assimilation of future applied subjects of the curriculum, probably generating more meaningful learning.

From a practical point of view, biomodels have been used for a long time as educational tools since they can be more useful than two-dimensional images in learning and retaining physiology content, according to VALBUENA 2017, it is an excellent way to provide an inquiry-based, collaborative, and problem-solving activity that enhances learning, promotes curiosity, objectivity, and the use of scientific reasoning. According to LENIS et al. 2011**,** the models made by students themselves promote analytical, argumentative or innovation skills and additionally benefits the development of imagination, as well as foster creativity, innovation and entrepreneurship, an aspect that was evidenced in this educational experience too, especially when representing physiological processes in non - conventional or exotic species (there is not much information about them). RODENBAUGH et al. 2012, says that the building of physical models provides opportunities for the student to think about the information, get them involved in the learning process, develop a functional understanding of the material and using reasoning skills (DICARLO 2013), for example, when representing the nervous system (the system most preferred by students in this study) the coordination of all systems must be studied in the electrical and chemical synapse. These described qualities could be useful in physiology learning, if we can alternate the traditional teaching model (one-way information transmission), then implementation of didactic biomodels in physiology can open a door to continue finding pedagogical ways in our teaching practice.

In this educational experience there was no specific guideline on the type of material, the dynamic movement or the way of building the biomodels, practically the students had to build it from scratch to represent an already known biological phenomenon. As teachers we found great creativity on the part of our students, they used recyclable material from common objects such as syringes or bottles, old objects that were stored in their homes, school materials such as plasticine and balloons. In the part of the movement that was the most difficult, they implemented basic mechanical motors, gravity, movement of liquids by pressure with pumps or even they themselves moved the components with their hands. This is quite rewarding as it allows us to visualize a great diversity of ways of thinking and problem-solving abilities.

CONCLUSION

Students assimilation in the inclusion of a different learning tool shows hopeful results for professors, since it would allow students to acquire skills based on educational models outside the traditional ones and focus more on a constructivist paradigm. Students set great value on learning and teamwork, assigning very high grades and percentages in these areas, without excluding the other items that also generate quite positive impacts. This project could be an open door for other studies based on the inclusion of these tools and see the long-term results (even in different subjects). It is important to implement these didactical models in biological sciences to increase understanding and improve the long-term memory of our students. In this study, the creation of the biomodel was free thought according to the creativity of our learners, however, future studies could propose more specific or scientific guidelines (for example specific materials, specific movements or minimal biological processes) in order to improve the creation of this learning tool. We leave an open field for researching and evaluating these activities in order to find better learning ways.

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