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AMÍCIO PINA DE CASTRO

QUEBRA-CABEÇA INTEGRANDO SINAPSE, CONTRAÇÃO MUSCULAR E SISTEMA NERVOSO AUTÔNOMO: EFEITO NO APRENDIZADO E NA PERCEPÇÃO DOS ALUNOS

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Trabalho de Conclusão de Curso apresentado à Faculdade de Odontologia de Piracicaba da Universidade Estadual de Campinas como parte dos requisitos exigidos para obtenção do título de Cirurgião Dentista.

Undergraduate final work presented to the Piracicaba Dental School of the University of Campinas in partial fulfillment of the requirements for the degree of Dental Surgeon

Orientadora: Profa. Dra. Fernanda Klein Marcondes

Co-orientadora: Lais Tono Cardoso

ESTE EXEMPLAR CORRESPONDE À VERSÃO FINAL DO TRABALHO DE CONCLUSÃO DE CURSO APRESENTADO PELO ALUNO AMÍCIO PINA DE CASTRO E ORIENTADO PELA PROFA. DRA. FERNANDA KLEIN MARCONDES.

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RESUMO

O objetivo do presente trabalho foi descrever o jogo educativo “Integrando Sinapse, Contração Muscular e Sistema Nervoso Autonômico”, desenvolvido para auxiliar os alunos a compreenderem e integrarem conceitos relacionados à fisiologia das sinapses, contração muscular e sistema nervoso autônomo, analisar seu efeito na aprendizagem e avaliar a percepção dos alunos sobre o jogo educativo. Estudantes de Odontologia, Farmácia e Medicina, de três instituições de ensino superior, participaram de atividades com este jogo educativo, após aulas teóricas sobre os temas acima citados. Os alunos de Odontologia e Farmácia realizaram pré e pós-teste, respectivamente, antes e após a atividade com o jogo educativo, e foram convidados a responder a uma pergunta, usando uma escala do tipo Likert, se achavam que a atividade com o jogo era útil para a aprendizagem (1 = não útil para a aprendizagem; 5 = necessário para a aprendizagem). Os alunos de Medicina somente responderam a pergunta sobre a utilidade do jogo para seu aprendizado. As notas obtidas no pós-teste foram significativamente maiores que as notas obtidas no pré-teste realizado por alunos dos cursos de Odontologia e Farmácia ($p < 0,05$). As médias de pontuação indicadas em respostas à questão sobre a utilidade do jogo para o aprendizado foram de $4,41 \pm 0,06$, $4,93 \pm 0,07$ e $4,28 \pm 0,13$, respectivamente, para estudantes de Odontologia, Farmácia e Medicina. O jogo educativo aumentou a aprendizagem dos estudantes de graduação de acordo com a percepção dos mesmos e as notas obtidas nos testes.

Palavras-chave: Ensino. Aprendizagem. Jogo educacional. Fisiologia.

ABSTRACT

The aim of this present work was to describe the educational game “Integrating Synapse, Muscle Contraction and Autonomic Nervous System” that was developed to help students in understanding and integrating concepts related to physiology of synapses, muscle contraction and autonomic nervous system, to analyze its effect on learning and evaluate students' perceptions about the educational game. Dentistry, Pharmacy and Medicine students from three higher education institutions participated in the activity with this educational game, after theoretical classes with the topics mentioned above. Dentistry and Pharmacy students performed pre and post-test, respectively, before and after the educational game activity, and were asked to answer a question using a Likert-type scale, if they thought the activity with the game was useful for learning (1 = not useful for learning; 5 = necessary for learning). Medical students only answered the question about the usefulness of the game for their learning. Dentistry and Pharmacy students had higher scores in post-tests than pre-tests ($p < 0.05$). The average points indicated in answers to the question about the usefulness of the game for learning were 4.41 ± 0.06, 4.93 ± 0.07 and 4.28 ± 0.13, respectively, for Dentistry, Pharmacy and Medicine students. The educational game increased the learning of undergraduate students according to their perception and score tests.

Keywords: Teaching. Learning. Educational game. Physiology.

SUMÁRIO

1 INTRODUÇÃO

O avanço do conhecimento científico, o acesso à informação por meio de dispositivos eletrônicos e a democratização do acesso à internet impõem desafios cada vez maiores a todos que atuam e se dedicam à educação. Nos ambientes escolares é necessário que os aprendizes mudem de sua condição passiva de expectadores e receptores de informações para uma posição ativa (Almeida, 2003). Além disso, é necessário que a escola promova a atualização de seus professores e solucione os problemas referentes à dificuldade no aprendizado, falta de disciplina, distrações oferecidas pelos diversos meios de comunicação com diversas fontes de informação e pouca motivação dos professores e alunos (Berbel, 2011). Para responder a estes desafios, tem-se buscado implementar práticas, em sala de aula, que promovam maior participação do aluno e o desenvolvimento de sua autonomia e pensamento crítico, em todos os níveis de ensino (Silva e Sales, 2017).

No ambiente universitário, falta de motivação e engajamento dos estudantes estão entre os maiores problemas da educação mundial (Lee 2011), além da insegurança com relação ao conhecimento sobre o conteúdo ministrado (Reis et al., 2013), prejudicando desempenho e capacidade na resolução de problemas (Berbel, 2011). Esta situação pode ser alterada por mudanças no processo de ensino-aprendizagem para permitir maior autonomia dos estudantes, favorecendo a formação de profissionais críticos, reflexivos e com maior facilidade na tomada de decisões. (West et al, 2000; Mitre et al, 2008; Cezar et al, 2010; Berbel, 2011; Pinto et al, 2012; Rocha, Lemos, 2014; Trindade et al, 2014).

Metodologias ativas de ensino têm sido reconhecidas como estratégias que aumentam a motivação, engajamento e o aprendizado dos estudantes, em diferentes níveis educacionais, principalmente no campo da saúde, onde existe uma necessidade de transformação curricular para que o saber propriamente dito seja mais valorizado do que a aquisição do saber em si, com o intuito de formar profissionais mais capacitados e com melhores preparados para a tomada de decisões (Mitre et al, 2008; Marin et al. 2010; Head, Arber, 2013; Randi, Carvalho, 2013; Miller, Metz, 2014)

Neste contexto, na Faculdade de Odontologia de Piracicaba (FOP – UNICAMP), têm sido utilizadas como metodologias ativas: jogos educacionais (Marcondes et al., 2015; Luchi et al., 2017), aulas dialogadas, trabalhos em grupo, dramatização, portfólio (Montrezor et al., 2016), nas disciplinas Biociências I e II, ministradas no primeiro ano do curso de Graduação em Odontologia. Avaliar a percepção dos alunos sobre os impactos destas metodologias sobre o seu aprendizado, e comparar o desempenho dos alunos nas avaliações

antes e após a implantação das metodologias, são mecanismos importantes para avaliação da hipótese de que as metodologias ativas promoveriam aumento do aprendizado, e também para o aprimoramento destas metodologias.

Segundo diferentes autores, os jogos educacionais aumentam o interesse e retenção de conhecimento, além de estimular a habilidade para resolução de problemas (Tarouco et al, 2004; Barclay et al, 2011; Schneider, Jimenez, 2012; Luchi et al. 2019). Dados obtidos por nosso grupo de pesquisa mostraram que jogos educacionais aumentaram o aprendizado de alunos universitários sobre fisiologia cardíaca (Marcondes et al., 2015; Cardozo et al., 2016), potencial de ação (Luchi et al., 2017) e sistema muscular (Luchi et al. 2019).

O objetivo deste trabalho foi analisar o efeito de um quebra cabeça desenvolvido para auxiliar os alunos a compreenderem e integrarem conceitos de Fisiologia da sinapse, contração muscular e sistema nervoso autônomo, sobre o aprendizado e avaliar a percepção dos alunos sobre este jogo educacional.

2 ARTIGO: INTEGRATING SYNAPSE, MUSCLE CONTRACTION, AND AUTONOMIC NERVOUS SYSTEM PUZZLE: EFFECT ON STUDENT LEARNING AND PERCEPTION

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Lais Tono Cardozo[1], Amicio Pina de Castro[1], Alexsandro Ferreira Guimarães[2], Lucila Ludmila Paula Gutierrez[2], Luís Henrique Montrezor[3], Fernanda Klein Marcondes[1]

[1]Department of Physiological Sciences, Piracicaba Dental School, University of Campinas - UNICAMP, Piracicaba, SP, Brazil.

[2]Department of Basic Health Sciences, Federal University of Health Sciences of Porto Alegre-UFCSPA, Porto Alegre, Rio Grande do Sul, Brazil.

[3] Department of Biological Sciences and Health-Biotechnology and Medicine, University of Araraquara-UNIARA, Araraquara, São Paulo, Brazil.

*Cardozo LT and Castro AP contributed equally to this work.

Correspondence to:
Dr. Fernanda Klein Marcondes
Department of Physiological Sciences, FOP-UNICAMP
Av. Limeira, 901, 13414-903 - Piracicaba - SP
Phone: 55 19 21065380
ferklein@unicamp.br

Short title: Synapse, muscle and ANS game: learning and perception

Abstract

The aim of the present work was to describe the educational game "Integrating Synapse, Muscle Contraction, and Autonomic Nervous System" that was developed to assist students in understanding and integrating concepts related to the physiology of synapses, muscular contraction, and the autonomic nervous system, to analyze its effect on learning and the students´ perception about the educational game. Dentistry, Pharmacy and Medicine students participated in activity with this educational game. Dentistry and Pharmacy students performed pre and post-tests respectively after lectures and after the activity with the educational game. The mean scores obtained in the post-test were significantly higher than the mean scores for the pre-test ($p < 0.05$). These students and also Medicine undergraduate students were invited to answer a question, using a Likert-type scale, if they thought the activity with the game was useful for learning (1 = not useful for learning; 5 = necessary for learning). The mean of scores indicated were 4.41 ± 0.06, 4.93 ± 0.07 and 4.28 ± 0.13 respectively for Dental, Pharmacy and Medicine students. The educational game increased learning of undergraduate students according with their perception.

Snapshot

We described the educational game “Integrating Synapse, Muscle Contraction, and Autonomic Nervous System”, analyzed its effect on students´ learning and perception. Scores in tests performed after the game activity were higher than in pre-test, performed after lectures. Students answered if the activity with the game was useful for learning (1 = not useful; 5 = necessary for learning). The mean of answers were higher than 4.40. The game increased learning according with students´ perception.

Keywords: teaching, learning, educational game, physiology

Introduction

Physiology is a basic discipline in all courses of the health area and is considered difficult by students, since it requires that they understand different concepts and integrate them with knowledge acquired in other disciplines, in order to relate the morphological characteristics and functions of different organs and systems of the human body (18). In most institutions, traditional Physiology classes still involve a large number of lectures, which can include videos and animations as complementary resources, together with a test after delivery of all the content (15).

In Brazilian universities, Physiology courses are offered in the first and second semesters, in Dentistry undergraduate courses or in the second, third and fourth semesters, in other undergraduate health careers´courses. The physiology of synapses, muscular contraction, and the autonomic nervous system are contents delivered in these courses, taught in separate classes frequently. It is necessary to help the students to assimilate this knowledge, so that they are able to actually understand the normal bodily functions and apply this knowledge in clinical situations in the future (18).

For first-year students, the difficulty in assimilating these contents is even more evident, as they are added to the difficulties related to transitioning from high school to higher education, moving to a new city, taking on new responsibilities, forming a new circle of friends, and organizing their time in accordance with the University routine (17). In addition, a misunderstanding that these students often bring from high school is that everything in science has already been discovered; they do not realize that knowledge is always evolving

and that much of it is still not found in textbooks, which requires them to learn to continuously research using other resources.

Concerning the content mentioned above, students have difficulty in understanding the different effects of neurotransmitters in the muscle tissue, the roles of receptor subtypes in physiological responses in the different tissues, the contrary and complementary actions of the sympathetic and parasympathetic nervous systems, factors that alter the physiology of synapses, diseases (such as depression and myasthenia gravis) related to these changes, and the mechanisms of action of medications used for these diseases. Therefore, the contents must be taught slowly, gradually increasing the level of complexity.

At different levels of the educational system, changes in teaching strategies have been implemented in order to make the teaching-learning process more student-centered. However, due to their experience in primary education and high school, students often arrive at university used to traditional teaching methods, involving lectures, repetition of exercises, and memorization of content (20).

Therefore, complementing or replacing traditional theoretical lectures with active teaching strategies can be useful, as the latter enable students to participate actively in the teaching-learning process. This approach favors autonomy, arouses curiosity, increases the interest and participation of the students in classes, and enables them to assimilate basic and clinical concepts at increasing levels of complexity, hence promoting meaningful learning (3, 13, 20).

Among active teaching strategies, educational games can assist learning by increasing the students' interest and knowledge retention, stimulating problem-solving and decision-making abilities, and promoting greater interaction among the students (2, 14, 22, 24, 26). In previous studies, our research group observed that educational games could increase student learning about heart physiology (6, 14) and action potential (11).

In order to assist students in understanding, assimilating and integrating concepts related to the physiology of synapses, muscular contraction, and the autonomic nervous system, the educational game "Integrating Synapse, Muscle Contraction, and Autonomic Nervous System" was developed at the Piracicaba Dental School of University of Campinas, Piracicaba – SP, Brazil, and has been used in Dentistry course.

The aim of the present work was to describe this educational game, evaluate its effect on learning, and assess the students' opinions of its utility, in undergraduate courses.

Material and Methods

This study was approved by the Ethics Committees of Piracicaba Dental School (FOP) of the University of Campinas and Federal University of Health Sciences of Porto Alegre (UFCSPA), and was authorized by the Teaching Committee of University of Araraquara (UNIARA). Fifty-eight students from the Dentistry undergraduate course of the FOP, fifteen students from Pharmacy course of UFCSPA and forty-two students from Medicine course of UNIARA participated in the study. These students were enrolled in the Bioscience I (FOP), Physiology I (UFCSPA) and Physiology and Biophysics III (UNIARA) disciplines, in the first semester of 2017, 2019 and 2019, respectively.

In Dentistry course of FOP, the integrated Bioscience I discipline is offered in the first semester, consisting of the subjects Anatomy, Biochemistry, Histology, and Physiology. At UFCSPA, Physiology I discipline is offered in the third semester when the Pharmacy students are also enrolled in Biochemistry, Molecular Biology and Basic Microbiology disciplines. At UNIARA, Physiology and Biophysics III discipline is offered in the third semester in Medicine course along with Psychology, Biochemistry, Molecular Biology, Epidemiology, Semiology, Family Health Program, Biostatistics, Morphology and Anatomy. The contents of Physiology and Biophysics III discipline are the nervous, endocrine and renal systems. In Physiology and Biophysics I and II disciplines the contents presented to the students were hidroelectrolytic balance; reproductive physiology and the cardiovascular, digestive, and respiratory systems.

The activity with the educational game and the tests constituted part of the disciplines, so all the students participated in these activities. In Dentistry course, in order to ensure autonomy and reduce the vulnerability of students in the decision to participate in the study (25), the request to use the data for the research was made to the students at the beginning of the following semester, after disclosure of the final grades of the Bioscience I discipline at. Invitation to participate in the research was made outside of class hours, at a specific scheduled time. On that day, the students were also asked to answer questions concerning their opinion about the use of the educational game. The students of Pharmacy course were invited to participate at the beginning of the discipline Physiology I. In Medicine course, the invitation of students was done in the middle of the third semester after the lectures on synapses, muscle contraction and autonomic nervous system.

Description of the educational game

The game was based on a puzzle that required the organization, in a table, of tokens indicating neurons, receptors, neurotransmitters, and effects on target organs (Figure 1). This was followed by group discussion of questions on the topics studied.

The A3 size table contained the names of the nervous system divisions (the somatic nervous system and the sympathetic and parasympathetic divisions of the autonomic nervous system). It was divided into four columns, indicating synapses, neurotransmitters, receptors, effector organ, and effect (Figure 1A).

The tokens (Figure 1B) that completed the table represented neurons, neurotransmitters (noradrenaline and acetylcholine), adrenergic receptors (alpha and beta), cholinergic receptors (nicotinic and muscarinic), tissues (vascular smooth muscle, smooth muscle of the gastrointestinal system, and skeletal muscle), and the effects (contraction and relaxation).

Nervous System	Synapses / Neurotransmitters / Receptors	Effector Organ	Effect
Somatic			
Sympathetic			
Sympathetic			
Parasympathetic			

Figure 1 – A

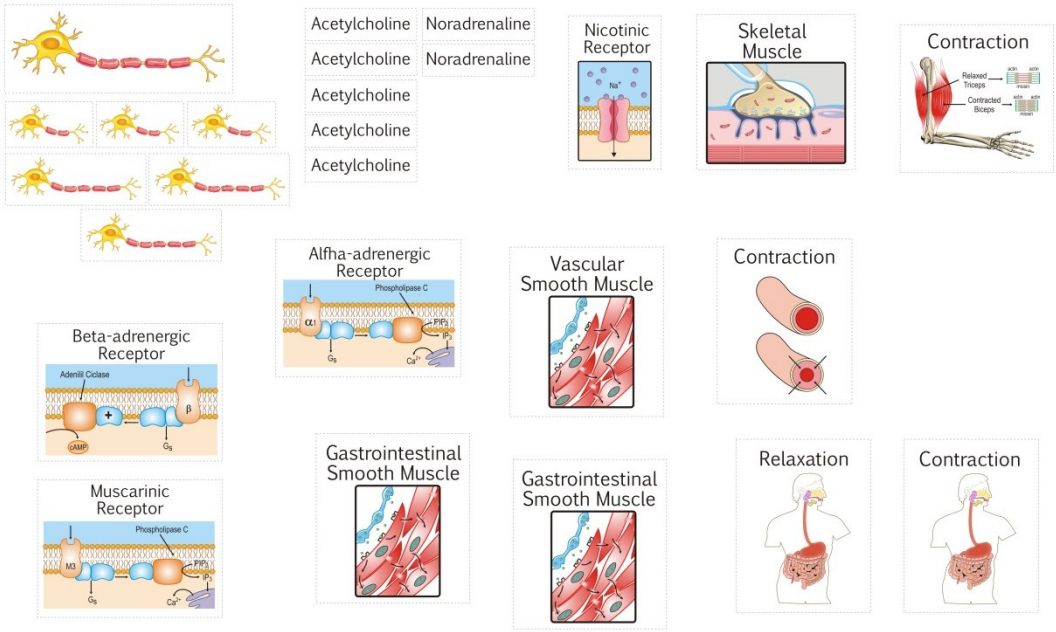

Figure 1 - B

Figure 2 presents the assembled puzzle. The table and tokens were printed in color on 120g/m2 white paper and were laminated.

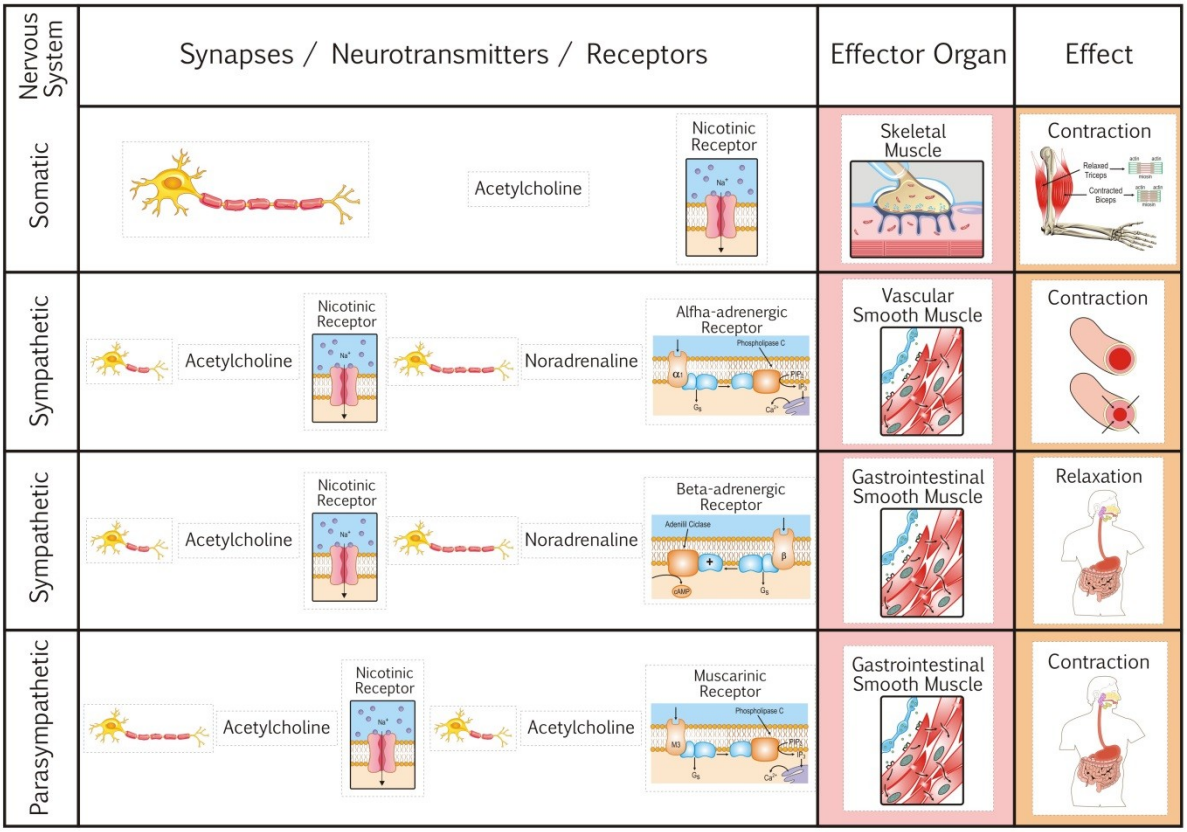

Figure 2

Description of the activity

During the Bioscience I (FOP) and Physiology I (UFCSPA) disciplines, the students attended one theoretical class about synapses, two classes about muscle contraction, and one class about the autonomic nervous system. During the Physiology and Biophysics III (UNIARA) discipline, the students attended four lectures about synapses, two lectures about muscle contraction, and four lectures about autonomic nervous system. During all these classes, the lecturer asked questions, so that the students could reflect on the theme being discussed.

In a later lesson, the activity with the educational game was performed in the three courses.

At the beginning of the activity, the students were divided into groups with 5-6 members. Each group was given a game and was instructed to fill in the table with the tokens in the correct way. When the group finished filling the table, they called a monitor or the lecturer to assess whether the placement of the tokens was correct. If there was any mistake, the students were told that they should review the placement of the pieces, but did not receive any indication of what the mistakes were. The aim was to stimulate discussion among the students, so that they could identify the errors themselves.

During filling the table, the students should be able to remember and apply their knowledge about the different receptors for neurotransmitters in the body, the different effects of the neurotransmitters, depending on the receptor subtype activated, and the different types of synapses in the somatic and autonomic nervous system divisions.

After the table had been filled correctly, the students were given questions to answer in groups, about the topics addressed in the table (Table 1). The group members discussed the questions and, as soon as they had finished elaborating the answers, called the lecturer or a monitor, to whom they orally explained their answer. In order to ensure that all the students actually participated in the discussion and in elaboration of the correct answers to the questions, each group was given one question at a time. The next question was only delivered after a satisfactory answer had been provided to the previous one. In this way the discussion is stimulated among the students who are focused on the same question.

Evaluation of the effect of the educational game on student learning

After the theoretical lectures about synapses, muscle contraction, and the autonomic nervous system. In Dentistry course, the students were instructed to study for a test. Immediately before the activity with the game, a pre-test was applied, composed of multiple choice and open-ended questions (Table 2). In Pharmacy, the students also performed the same pre-test, however they were not previously informed that they would pass a test.

Immediately after the activity with the game, the Pharmacy students answered a post-test, which was also composed of multiple choice and open-ended questions, although the questions were different from those used in the pre-test, but covered the same contents (Table 2). Dental students answered the same post-test, four days after the activity with the educational game. All pre-test and post-test questions had the same value: 2.0 points.

Learning has not been evaluated in the Medicine course because there was no time enough for the application of pre and post-tests.

Table 1. Questions used in the activity with the educational game.

	Question
1	In the assembled puzzle, it can be seen that the same neurotransmitter triggers opposing actions in muscle tissue. Describe this situation in the puzzle and explain why it occurs.
2	In the assembled puzzle, compare the morphologies of the synapses of a neuron with skeletal muscle, and of a neuron with smooth muscle. Describe the observed morphological differences and discuss how these morphological characteristics are related to differences in synaptic transmission.
3	Relate the organization of the contractile proteins in the skeletal and smooth muscles to the direction of contraction and the function of these muscle types in the organs in which they are found.
4	To hunt animals, indigenous people can use a blowpipe to shoot darts poisoned with curare, a substance obtained from plants, which binds to nicotinic acetylcholine (ACh) receptors, preventing ACh binding and resulting in no response in the cell. It is, therefore, an antagonist of these receptors. Animals affected in this way are immobilized and easily captured. Considering what you have learned about the physiology of skeletal muscle contraction, explain how curare produces this effect.
5	Nicotine is a nicotinic receptor agonist, because it activates this receptor, mimicking the action of ACh. A non-smoker who chews a nicotine gum can present an increase in heart rate, which is a function controlled by sympathetic neurons. If the postganglionic sympathetic neurons secrete noradrenaline, explain how nicotine, in low concentration, can increase the frequency of heartbeats.
6	In an experiment about synaptic transmission, a synapse was maintained in a medium equivalent to the extracellular fluid, but without calcium ions. An action potential was triggered in the presynaptic neuron and reached the axon terminal. However, the usual post-synaptic cell response did not occur. To what conclusion could the researchers arrive, based on these results? Discuss.
7	In another experiment, muscle cells were maintained in plates with nutrient medium without calcium, at 37 °C, with oxygenation. Norepinephrine was added, the effects were evaluated, and the tissues were then washed. Afterwards, acetylcholine was added and the effects were evaluated. In the plates with smooth muscle cells, there was no muscle contraction in either situation. Explain this result.
8	In skeletal muscle cell plates, muscle contraction was only observed in response to the addition of acetylcholine. Explain this result.

Table 2. Questions used in the pre- and post-tests.

Pre-test	Post-test
1) Number, in correct order, the sequence of events of a chemical synapse, from the activation of the presynaptic neuron to the completion of the neurotransmitter effect (2.0). ( ) Opening of voltage-dependent calcium channels; ( ) Calcium influx; ( ) Approach and anchoring of vesicles from the synaptic terminal; ( ) Presynaptic cells depolarization; ( ) Activation of the SNARE complex by calcium; ( ) End of the neurotransmitter effect; ( ) Fusion of the vesicles with the plasma membrane; ( ) Release of the neurotransmitter in the synaptic cleft (exocytosis); ( ) Interaction with the receptor in the postsynaptic cell.	**1) Choose the alternative that represents the correct sequence of events of a chemical synapse, from the activation of the presynaptic neuron to the completion of the neurotransmitter effect (2.0).** 1. Opening of voltage-dependent calcium channels; 2. Calcium influx; 3. Approach and anchoring of vesicles from the synaptic terminal; 4. Presynaptic cells depolarization; 5. Activation of the SNARE complex by calcium; 6. End of the neurotransmitter effect; 7. Fusion of the vesicles with the plasma membrane; 8. Release of the neurotransmitter in the synaptic cleft (exocytosis); 9. Interaction with the receptor in the postsynaptic cell. a) 1, 4, 2, 3, 5, 7, 8, 9, 6 b) 1, 4, 2, 5, 3, 7, 8, 9, 6 c) 4, 1, 2, 5, 3, 7, 8, 9, 6 d) 2, 1, 4, 5, 3, 7, 8, 9, 6 e) 4, 1, 2, 3, 5, 7, 8, 9, 6
2) The autonomic nervous system (ANS) controls the functions of our organs, through its sympathetic and parasympathetic divisions. Mark true (T) or false (F) for the statements below (2.0): ( ) Preganglionic fibers of the sympathetic and parasympathetic nervous systems release acetylcholine (ACh), which binds to nicotinic cholinergic receptors in the autonomic ganglia. ( ) Preganglionic fibers of the sympathetic and parasympathetic nervous systems release noradrenaline, which binds to nicotinic cholinergic receptors in the autonomic ganglia. ( ) Most postganglionic sympathetic fibers release noradrenaline, which binds to muscarinic cholinergic receptors in target organs. ( ) The postganglionic sympathetic fibers release acetylcholine, which binds to muscarinic cholinergic receptors in the synapse with the target organ. ( ) Since the ANS presents basal release of its chemical mediators, the fact that most of our organs receive dual innervation (sympathetic and parasympathetic) is important for the effective control of functions. For example, after a scare, in order to return the heart rate to baseline levels, the inhibition of the sympathetic system, simultaneously with the activation of the parasympathetic system, results in a greater and faster effect than if only the parasympathetic system was activated in order to reduce the activity of the heart's pacemaker cells.	**2) Nicotine is an agonist of nicotinic receptors, i.e., it activates these receptors, mimicking the action of acetylcholine (ACh). One of the side effects of the use of nicotine gum, in treatments to "quit smoking", is increase of the heart rate. This side effect occurs because (2.0):** a) Nicotine activates acetylcholine receptors in the parasympathetic postganglionic neuron, which releases ACh in the heart; b) Nicotine activates noradrenaline receptors in the sympathetic postganglionic neuron, which releases noradrenaline in the heart; c) Nicotine activates norepinephrine receptors in cardiac cells; d) Nicotine activates acetylcholine receptors in the sympathetic postganglionic neuron, which releases noradrenaline in the heart; e) Nicotine activates noradrenaline receptors in the parasympathetic postganglionic neuron, which releases ACh in the heart.

3) Sertraline hydrochloride is a medication used in the treatment of depression and its mechanism of action is by inhibition of serotonin reuptake. This inhibition causes (2.0):

a) Reduction of the availability of the neurotransmitter serotonin in the synaptic cleft;

b) Reduction of the amount of serotonin receptors in the postganglionic neuron;

c) Increase of the availability of the neurotransmitter serotonin in the synaptic cleft;

d) Difficulty of the presynaptic vesicles to move towards the membrane in the preganglionic neuron.

3) Pargyline belongs to the class of MAO (monoamine oxidase) inhibitor medications. It is used to treat depression, as it inhibits the enzyme that metabolizes amines, after its reuptake by neurons in the central nervous system. Depression is related to the reduction of serotonin synthesis. Based on the physiology of synapses, pargyline can reduce the symptoms of depression because it (2.0):

a) Reduces the availability of serotonin in the synaptic cleft;
b) Reduces the amount of serotonin receptors in the postsynaptic neuron;
c) Increases the amount of serotonin receptors in the postsynaptic neuron;
d) Increases the chance of serotonin binding to its receptors in the postsynaptic neuron, since its action increases the time that serotonin is present in the synaptic cleft;
e) Hinders or prevents the action of the SNARE complex for serotonin release by the presynaptic neuron.

4) In an experiment on synaptic transmission, a synapse between a neuron and a skeletal muscle cell was kept in a medium equivalent to the extracellular fluid, but without calcium ions. An electrical stimulation was applied to one presynaptic neuron, but the usual response of the postsynaptic cell did not occur (2.0).

a) What would be this usual response?
b) Considering the physiology of chemical synapses, discuss what conclusion the researchers reached, based on the result obtained.

4) In an experiment, skeletal muscle cells were maintained in nutrient medium plates without calcium, at a temperature of 37 °C, with oxygenation. Noradrenaline was added, the effects were assessed, and the cells were then washed. Subsequently, acetylcholine was added and the effects were evaluated. Muscle contraction was only observed in response to the addition of acetylcholine. Explain the results obtained (2.0).

5) Explain briefly how the botulinum toxin interferes in synaptic transmission. Based on this mechanism of action, explain briefly how it acts in aesthetic treatments to reduce expression lines (wrinkles) (2.0).

5) In myasthenia gravis, the body produces antibodies against the cholinergic receptors present in the skeletal muscles, which results in severe muscle weakness. One of the treatments used for this pathology is the administration of acetylcholinesterase inhibitors. Explain how acetylcholinesterase reduces the symptoms of myasthenia gravis (2.0).

Evaluation of the students' opinions

The students were also invited to answer a question about their opinion regarding the use of the educational game, indicating, using a Likert-type scale, if they thought the activity with the game was useful for learning (1 = not useful for learning; 5 = necessary for learning), with justification of their answers.

In Dentistry course, the students answered this question at the end of the Physiology discipline, after the final grades had been disclosed. In Pharmacy and Medicine

courses, the students answered this question immediately after the activity with the educational game.

Statistical analysis

The scores from the pre- and post-tests were compared using the Student's t-test for paired samples, with a significance level of 5%. Analysis of the opinions provided using the Likert-type scale are presented as means ± standard error of mean (SE).

Results

Of the 88 Dentistry students who were enrolled in the Bioscience I discipline, 61 agreed to participate in the study. Of these, 3 were excluded because they missed the class in which one of the two tests was applied. Hence, the total number of participants was 58. Of the 15 Pharmacy students enrolled in the Physiology I discipline, all of them agreed to participate and answered both pre and post tests.

In both courses, the mean scores obtained in the post-test were significantly higher than the mean scores for the pre-test ($p < 0.05$) (Table 3). No comparison between the courses was done because the aim of this study was not compare the courses.

Table 3. Scores for the pre- and post-tests (before and after the activity with the educational game).

Course	N	Pre-test score	Post-test score
Dentistry	58	5.58 ± 0.32	6.76 ± 0.29*
Pharmacy	15	4.23 ± 0.49	6.33 ± 0.68*

Values are means ± SEM. Pre-test was applied after lectures about synapses, muscle contraction, and the autonomic nervous system and before the activity with the educational game. The post-test was applied immediately (Pharmacy) or four days (Dentistry) after the activity with the game. All the pre-test and post-test questions had the same value (2.0 points). * Significant difference relative to the pre-test, within the same group ($p < 0.05$).

Considering the perception of students about the educational game, the average Likert-type scale answer, concerning whether the activity with the puzzle was useful for

learning, was 4.41 ± 0.06, 4.93 ± 0.07 and 4.28 ± 0.13 respectively for Dental, Pharmacy and Medicine students.

The justifications provided by the Dental students for their opinions about the educational game included the following: “Helped in understanding and assimilating the content”; “Assisted in fixing the content provided in the lectures”; “Assisted in guiding studies”; “Encouraged students to study”; and “Is a more interactive learning method”.

Pharmacy students justifications included the following: “Is a ludic activity in which I could visualize and understand the contents”, “It was possible to correct informations in a ludic way”, “Helped me to construct a logic sequence of thinking”, “It was helpful because we pay attention, and are not worried if we make mistakes”, “It was easier to understand the mechanisms with pictures”.

According to Medicine students, the educational game “was useful to better remember and understand the subjects studied”, “was useful for group discussion, solving doubts that still existed and making learning easier to visualize”, “the playful form of the game made the learning of the contents easier”, “ the game was useful for my learning because its didactics allows a visualization of how the process occurs, which is essential for my understanding”.

Discussion

The results obtained in this study indicated that the use of the educational game “Integrating Synapse, Muscle Contraction, and Autonomic Nervous System” increased the Dental and Pharmacy students’ learning about these themes. And considering their perception about the educational game, for these students and also for Medicine students, the game was useful for learning. These results were in accordance with the findings of other studies concerning the effects of educational games on learning (5, 6, 11, 12, 26).

The students considered that the game was useful for learning, as also reported in other studies involving educational games (7, 11, 12, 14, 16) and other active methods such as attempting to discover the hidden keywords of a scientific paper (8), performing an online game (4), and using a jigsaw technique to elucidate clinical problems (19).

In addition to enabling students to participate actively in the teaching-learning process, educational games also increase interaction among the students and their engagement with the content studied, making the class more fun and stimulating critical and reflective thinking (2, 12, 14). Another advantage of using educational games is that during the activity,

there is immediate feedback for the student and the lecturer. The student can perceive where his/her difficulties and doubts lie, and resolve them; for the lecturer, this feedback provides information about the students' understanding of the content, so that he/she can decide how to continue the classes (1).

Assessing students' perceptions and opinions is important, because it provides evidence that the teaching tool actually helps in learning, enabling further improvement of the strategy used. However, it is essential to evaluate learning, in order to know whether the method being used is actually effective (10). Research performed in the classroom can suffer from certain restrictions that often cannot be controlled by the teacher, such as the scheduling of the course, the physical space, and the presence of monitors together with the teacher during classes. However, it is possible to develop a design to evaluate the effectiveness of an educational strategy, taking into consideration the actual conditions of the classroom.

There are different ways to assess learning, such as using the performance evaluation of control and experimental groups (6, 11, 21), pre-and post-tests (2, 8, 9), and analysis of poor grades or drop-out rates (27). In this study, pre-and post-tests were used as a method of assessment, due to the scheduling of classes and the fact that the contents were delivered separately, in classes with different numbers of students, which made it impossible to divide the students into control and experimental groups. Furthermore, the method uses little time, does not disturb the dynamics of classes, and provides information about a student's performance before and after application of the strategy evaluated (8, 9). However, care must be taken when preparing questions for the two tests, since if they were exactly the same, the students could answer correctly or incorrectly, due to remembering the answer already provided in the pre-test (8). In this study, care was taken to develop questions for the post-test that addressed the same contents as the pre-test questions, but were not exactly the same, hence decreasing the memory effect.

In the present study, the post-tests were applied immediately after the activity with the educational game and four days after this activity because the schedules of Dentistry and Pharmacy courses were different. Both the short-term and mid-term evaluations showed that the activity with the educational game improved the learning of students when compared to their knowledge after lectures, evaluated in the pre-test.

In previous studies, our research group developed two other educational games, one about the cardiac cycle (14) and another about membrane potential and action potential (11). In these two studies, the students were divided into control and game groups. The control group attended a traditional theoretical lecture, while the game group participated in

the activity with the educational game. Afterwards, comparison was made of the scores achieved by the two groups in a test. In both studies, improved performance in the tests on the themes discussed was observed for the students of the game group, compared to the control group, in addition to positive assessments made by the students concerning the use of these games (6, 11). The results of the present study corroborated the beneficial effects on learning and the positive assessments of the students observed in the earlier studies. The educational games "Cardiac Cycle Puzzle" and "Understanding the Action Potential" are used as teaching tools in classes on these subjects, with the students learning the content during the activities with the games (6, 11). Differently, in this study, the purpose of the game "Integrating Synapse, Muscle Contraction, and Autonomic Nervous System" was to promote active participation and integration of the students' previous knowledge. When filling in the table for this game, the students should remember and apply contents learned in previous lessons, such as the diversity of receptors for neurotransmitters in the body, the different effects of the neurotransmitters, depending on the subtype of receptor activated, and the different types of synapses of the somatic and autonomic nervous systems. When discussing the questions provided after filling in the table, they should integrate this knowledge, reflecting on and applying what they had learned.

This educational game could be adapted and used in other classes, gradually increasing its complexity, in order to integrate the contents related to cardiovascular and endocrine physiology. In the undergraduate Dentistry course of FOP-UNICAMP, in the first semester, the students take the Bioscience I discipline, which addresses the topics of muscle contraction, synapses, and the autonomic nervous system. In the Bioscience II discipline, the physiology of the cardiac muscle is studied within the cardiovascular physiology unit, in the second semester of the course, together with study of the endocrine system.

The use of the game at other times of the course enables students to remember concepts that were learned previously, as well as to add new information. This process is important for learning, since new memories become stabilized, after an initial significant learning, in a process called memory reconsolidation (23). In everyday life, the reactivation of memory is a crucial process of the learning experience, which occurs because we are constantly experiencing situations related to previous learning. In Physiology classes, for example, the students need to remember the anatomical or histological structures of an organ, in order to properly understand its function. At this point, the students need to retrieve previous knowledge of anatomy and histology, adding new information about the function of specific organs to an existing memory (23). Therefore, the students learn the contents and

remember these contents at future times, integrating them with new knowledge, hence being able to solve problem situations that have increasing degrees of complexity.

In conclusion, the results of this study indicated that the use of the educational game "Integrating Synapse, Muscle Contraction, and Autonomic Nervous System" helped in the learning about the themes, allowing the integration of contents and interaction among the students. The game received a positive evaluation of the students and could be adapted for use with other topics. The results showed that it was possible to develop a low-cost material that could be applied to a range of themes and at different times during Physiology disciplines.

Acknowledgments

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Grants

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Figure legends

Figure 1. Table (A) and tokens (B) of the educational game "Integrating Synapse, Muscle Contraction, and Autonomic Nervous System".

Figure 2. Table and pieces composing the educational game "Integrating Synapse, Muscle Contraction, and Autonomic Nervous System".

3 CONCLUSÃO

Os dados aqui apresentados indicam que a diversificação dos métodos utilizados favorece o aprendizado e a motivação do aluno, provavelmente porque atende à diversidade de modalidades sensoriais de aprendizagem (Fleming e Bauma, 2006) que encontramos em uma turma de alunos. Vale também destacar que a avaliação discente possibilitou o aprimoramento das metodologias aqui descritas para os anos seguintes (Marcondes et al, 2015).

Desta forma concluímos que o uso do jogo educacional como metodologia ativa aplicada em diversas áreas de ensino, contribui muito para o melhor aprendizado dos alunos, durante toda a formação, sendo uma ferramenta útil para ajudar na retenção de vários conteúdos a serem estudados nos anos posteriores.

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ANEXOS

Anexo 1 – Verificação de originalidade e prevenção de plágio *(com exclusão das referências bibliográficas constantes nas páginas 26 a 28, 31 e 32).*

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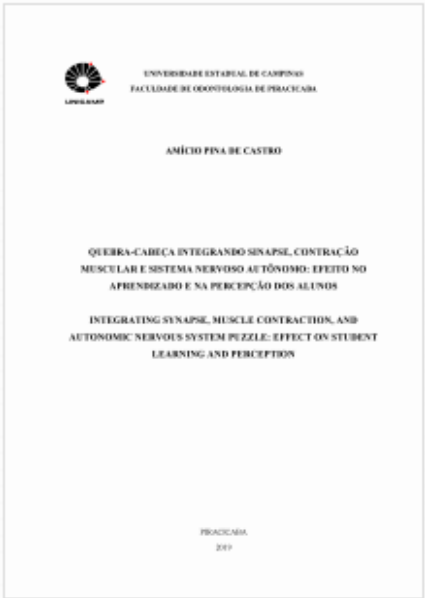

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QUEBRA-CABEÇA INTEGRANDO SINAPSE, CONTRAÇÃO MUSCULAR E SISTEMA NERVOSO AUTÔNOMO: EFEITO NO APRENDIZADO E NA PERCEPÇÃO DOS ALUNOS

INTEGRATING SYNAPSE, MUSCLE CONTRACTION, AND AUTONOMIC NERVOUS SYSTEM PUZZLE: EFFECT ON STUDENT LEARNING AND PERCEPTION

PIRACICABA
2019

QUEBRA-CABEÇA INTEGRANDO SINAPSE, CONTRAÇÃO MUSCULAR E SISTEMA NERVOSO AUTÔNOMO: EFEITO NO APRENDIZADO E NA PERCEPÇÃO DOS ALUNOS

RELATÓRIO DE ORIGINALIDADE

15%	5%	11%	6%
ÍNDICE DE SEMELHANÇA	FONTES DA INTERNET	PUBLICAÇÕES	DOCUMENTOS DOS ALUNOS

FONTES PRIMÁRIAS

1	Kelly Cristina Gaviao Luchi, Luís Henrique Montrezor, Fernanda K. Marcondes. "Effect of an educational game on university students' learning about action potentials", Advances in Physiology Education, 2017 Publicação	2%
2	"Educação no século XXI: volume 2", GN1 Genesis Network, 2018 Publicação	2%
3	Submitted to Universidade Estadual de Campinas Documento do Aluno	2%
4	Lais Tono Cardozo, Aline Soares Miranda, Maria José Costa Sampaio Moura, Fernanda Klein Marcondes. "Effect of a puzzle on the process of students' learning about cardiac physiology", Advances in Physiology Education, 2016	2%

Anexo 2 –Comprovante de aprovação pelo Comitê de Ética em Pesquisa

COMITÊ DE ÉTICA EM PESQUISA
FACULDADE DE ODONTOLOGIA DE PIRACICABA
UNIVERSIDADE ESTADUAL DE CAMPINAS

CERTIFICADO

O Comitê de Ética em Pesquisa da FOP-UNICAMP certifica que o projeto de pesquisa "Avaliação discente sobre o uso de metodologias ativas no ensino de fisiologia", CAAE 42980515.0.0000.5418, dos pesquisadores Fernanda Klein Marcondes, Kelly Cristina Gavião, Michelle Franz Montan Braga Leite, Aline Soares Miranda, Talita Costa, Lyvia Regina Rafaela Gonçalves Hamparian, Fernanda Bidoli, Amicio Pina De Castro, Rodrigo Duarte De Souza, Pamella Teles Pessoa, Adrianne Palanch, Erica Maria Granjeiro, Lucila Ludmila Paula Gutierrez, Lais Tono Cardozo, Barbara Almeida e Debora Costa Ruiz, satisfaz as exigências das resoluções específicas sobre ética em pesquisa com seres humanos do Conselho Nacional de Saúde – Ministério da Saúde e foi aprovado por este comitê em sua versão original 01/04/2015 e na última versão emendada em 25/09/2019.

The Research Ethics Committee of the Piracicaba Dental School of the University of Campinas (FOP-UNICAMP) certifies that research project "Student´s evaluation about the use of active metodologies in physiology teaching", CAAE 42980515.0.0000.5418, of the researcher's Fernanda Klein Marcondes, Kelly Cristina Gavião, Michelle Franz Montan Braga Leite, Aline Soares Miranda, Talita Costa, Lyvia Regina Rafaela Gonçalves Hamparian, Fernanda Bidoli, Amicio Pina De Castro, Rodrigo Duarte De Souza, Pamella Teles Pessoa, Adrianne Palanch, Erica Maria Granjeiro, Lucila Ludmila Paula Gutierrez, Lais Tono Cardozo, Barbara Almeida and Debora Costa Ruiz meets the requirements of the specific resolutions on ethics in research with human beings of the National Health Council - Ministry of Health, and was approved by this committee on 04th of April of 2015 (original version) and 25nd of September of 2019 (last amended version).

Profa. Fernanda Miori Pascon
Vice Coordenador
CEP/FOP/UNICAMP

Prof. Jacks Jorge Junior
Coordenador
CEP/FOP/UNICAMP

Nota: O título do protocolo e a lista de autores aparecem como fornecidos pelos pesquisadores, sem qualquer edição.
Notice: The title and the list of researchers of the project appears as provided by the authors, without editing.

Anexo 3 – Comprovante de Bolsa de Iniciação Científica

FAPESP SAGe

VISUALIZAÇÃO DE DESPACHO

Processo	2017/25690-0
Linha de Fomento	Programas Regulares / Bolsas / No País / Iniciação Científica - Fluxo Contínuo
Situação	Encerrado
Vigência	01/03/2018 a 28/02/2019
Beneficiário	Amicio Pina de Castro
Responsável	Fernanda Klein Marcondes
Vínculo Institucional do Processo	Faculdade de Odontologia de Piracicaba/FOP/UNICAMP

Folha de Despacho

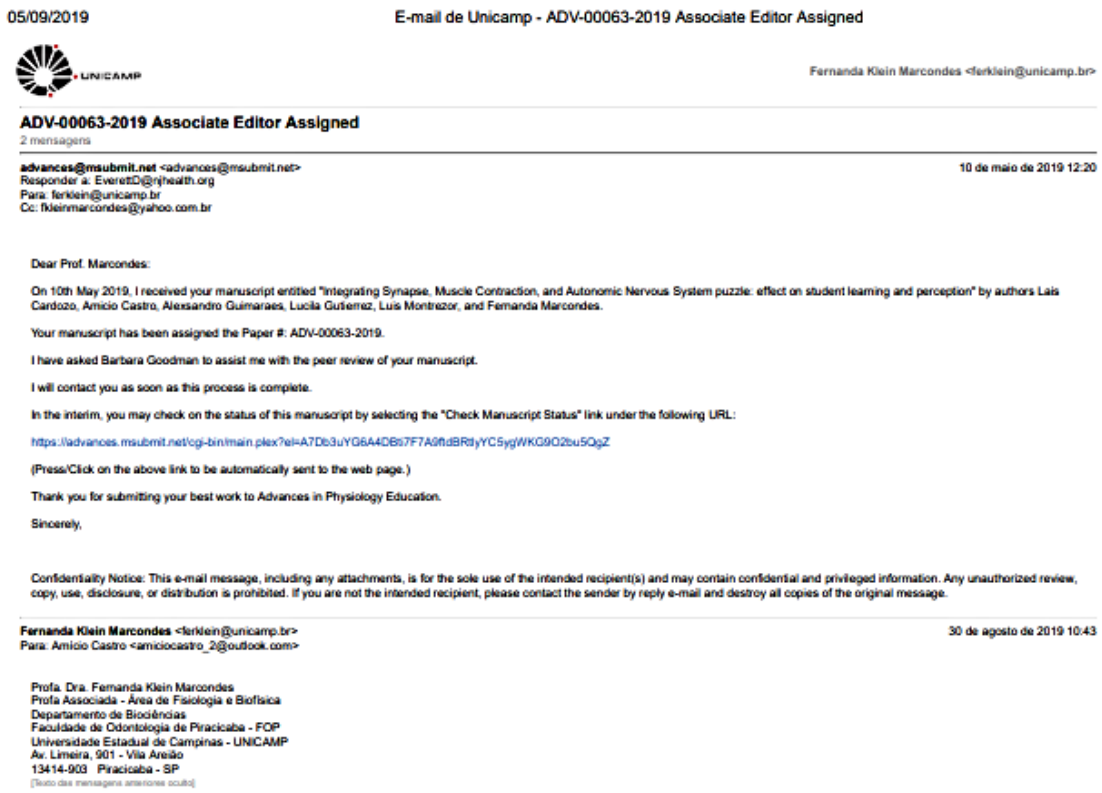
Datas do Despacho

Emitido em :	08/08/2019

Objetos de análise

Objeto de análise	Data de Submissão	Resultado
Relatório Científico 2	09/05/2019	Aprovado

Anexo 4 – Comprovante de submissão do Artigo



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Para: ferklein@unicamp.br
Cc: fkleinmarcondes@yahoo.com.br

Dear Prof. Marcondes:

On 10th May 2019, I received your manuscript entitled "Integrating Synapse, Muscle Contraction, and Autonomic Nervous System puzzle: effect on student learning and perception" by authors Lais Cardozo, Amicio Castro, Alexsandro Guimaraes, Lucila Gutierrez, Luis Montrezor, and Fernanda Marcondes.

Your manuscript has been assigned the Paper #: ADV-00063-2019.

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Sincerely,

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Fernanda Klein Marcondes <ferklein@unicamp.br> 30 de agosto de 2019 10:43
Para: Amicio Castro <amiciocastro_2@outlook.com>

Profa. Dra. Fernanda Klein Marcondes
Profa Associada - Área de Fisiologia e Biofísica
Departamento de Biociências
Faculdade de Odontologia de Piracicaba - FOP
Universidade Estadual de Campinas - UNICAMP
Av. Limeira, 901 - Vila Areião
13414-903 Piracicaba - SP
[Texto das mensagens anteriores ocultos]