How We Teach: Classroom and Laboratory Research Projects

Effect of a puzzle on the process of students’ learning about cardiac physiology

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Cardozo LT, Miranda AS, Moura MJCS, Marcondes FK. Effect of a puzzle on the process of students’ learning about cardiac physiology. Adv Physiol Educ 40: 425–431, 2016; doi:10.1152/advan.00043.2016.—The aim of the present study was to evaluate the effects of using a puzzle to learn about cardiac physiology. Students were divided into control and game groups. In class 1, the control group had a 2-h theoretical class about cardiac physiology, including a detailed description of the phases of the cardiac cycle, whereas the game group had a 50-min theoretical class without the description of the cardiac cycle. In class 2, the control group did an assessment exercise before an activity with the cardiac puzzle and the game group answered questions after the above-mentioned activity. While solving the puzzle, the students had to describe the cardiac cycle by relating the concepts of heart morphology and physiology. To evaluate short-term learning, the number of wrong answers and grades in the assessment exercise were compared between the control and game groups. To evaluate medium-term learning, we compared the grades obtained by students of the control and game groups in questions about cardiac physiology that formed part of the academic exam. In the assessment exercise, the game group presented a lower number of errors and higher score compared with the control group. In the academic exam, applied after both groups had used the puzzle, there was no difference in the scores obtained by the control and game groups in questions about cardiac physiology. These results showed a positive effect of the puzzle on students’ learning about cardiac physiology compared with those not using the puzzle.

ALL STUDENTS in health science courses must understand the morphofunctional characteristics of the circulatory system and physiology of the cardiac cycle to understand the physiopathological changes occurring in the heart and vessels. This is necessary to enable them to integrate clinical and basic science concepts (4, 17, 24) so that they are able to provide the population with guidance and diagnose and treat cardiovascular diseases adequately (1).

These topics are often approached in the subjects during the first year of health science undergraduate courses. Freshmen students go through a period of changes that may include moving from their home city, making new friends, adapting to new schedules, financial issues, distance from their familiar environment, and worries about their professional future. These factors might generate fear and anguish, leading to academic stress that might hinder their learning abilities (31).

In addition to academic stress, teaching methodologies also influence the students’ learning process. When the teaching-learning process is focused on students, they become responsible for their own learning (18, 21) and actively engage in the construction of their knowledge, developing critical and reflexive skills (7, 12, 30, 32, 35, 46). Active methodologies are interactive processes of knowledge, analyses, studies, research, and individual or collective decisions (10, 21). In the perception of students, active learning strategies facilitate learning, increase satisfaction in studying, and allow them to have fun while learning (9, 14, 19, 33, 34).

Among the active teaching-learning methodologies, educational games may be mentioned; these are defined as competitive activities, simulations, or noncompetitive exercises with prescribed rules and procedures (2, 22). A “game” is a generic term that provides challenges and situations with the integration of contents and learning activities including boards, letters, and skilled activities (11).

Different types of educational games have been used for training in health care courses, such as crossword puzzles (5), games using LEGO pieces (44), game boards (15, 42), the construction and manipulation of skeletal muscle models (36), and puzzles and card games (6, 26, 37, 42). Educational games increase students’ interest in the topic being studied and develop their problem-solving and teamwork skills (6, 39, 43).

However, there are few studies on the effect of educational games on learning, and the results are varied. Barclay et al. (6) observed an improvement in learning, demonstrated by a significant increase in the grades obtained in tests applied after the use of card games in the teaching of cardiology and infectious diseases in an undergraduate course in pharmacy. On the other hand, McCarroll et al. (28) observed no significant difference in the scores obtained by students who used and those who did not use a game about the identification of skeletal muscles, although the students positively evaluated the use of the game.

Puzzles are a type of educational game. According to Michalewicz and Michalewicz (29), puzzles should follow some criteria: generality, simplicity, a Eureka factor, and an entertainment factor. Generality is related to the strategies that the solvers should develop and that will help them to solve other problems in the future. Considering simplicity, an educational puzzle should be simple and easy to remember, and, in this way, its solution and the content addressed will be easily remembered afterward. Another important feature of educational puzzles is called the Eureka factor: a puzzle has pieces that fit together, each piece fits into only one place, and those who are solving the problem often use intuition to start their search for the solution, which usually leads them astray. Eventually, there is a a hit (Eureka!). This time, it is accom-
companied by a sense of relief; the frustration students felt during the error clears, and they feel a sense of reward for solving the puzzle. This provides students with immediate feedback about their mistakes and successes. The last criterion is the entertainment factor: puzzles should be fun and challenging; otherwise, it is easy to lose interest in them. Entertainment is a result of simplicity, frustration, the Eureka factor, and an interesting creation. However, it is not necessary for a single game to comprise all these criteria.

The coordinator of this study used a cardiac cycle puzzle as an active learning method for teaching dental students about the cardiac cycle in physiology classes (25). This puzzle has been described in a previous publication (26). It has been shared with physiology teachers in a teaching workshop in Brazil (27) and has been used to teach classes in biology, medicine, pharmacy, odontology, and nursing courses (26, 27). Analysis of the perception of students from different health career courses about this game showed that they considered the puzzle a useful learning tool (26). Although the students found that they understood the subjects better when using the puzzle, this does not mean that the game really had an effect on their learning. Therefore, the aim of the present study was to evaluate the effect of the use of this puzzle on the process of undergraduate dental students learning about cardiac physiology by measuring their performance in knowledge assessment tests.

MATERIALS AND METHODS

This study was conducted at the Piracicaba Dental School of the University of Campinas in Piracicaba, SP, Brazil, after approval of the Research Ethics Commission of the Piracicaba Dental School-University of Campinas (Protocol 34/2015). All 67 students (age: 18–25 yr) taking the subject Biosciences II were invited to participate in the study by signing the Informed Consent Form. When enrolling in the undergraduate program, students are randomly divided into groups A and B by the academic system. Based on this division, they attend practical lessons in laboratories capable of accommodating up to 40 people at different times. For the present study, groups A and B were designated as the control and game groups by drawing names. The control group and were informed that there would be an assessment in the next class. After 4 days, in the game group’s next class (class 2), the teacher held a discussion with the control group on the students’ doubts about the characteristics of heart cells and the cardiac cycle. After the discussion, students did an assessment exercise consisting of open and multiple-choice questions.

The game group had a 50-min theoretical class (class 1) about the same topics addressed in the class attended by the control group without the description of the phases of the cardiac cycle. In this lecture, the teacher did not show the relations between the special characteristics of cardiac cells and the cardiac cycle. Students were instructed to study the topics in the textbook indicated to the control group and were informed that there would be an assessment in the next class. After 4 days, in the game group’s next class (class 2), before the test, students carried out the activity with the cardiac cycle puzzle that was conducted as follows.

Briefly, students in groups of four to five participants received the puzzle containing pictures of the cardiac cycle phases, illustrating the pathways of arterial and venous blood in the heart as well as contraction and relaxation of the atria and ventricles (26). First, students were asked to identify the correct sequence of the figures representing the stages of the cardiac cycle. The puzzle also contains a table that has five columns and six rows, indicating the phases of cardiac cycle, atrial state, ventricular state, state of the atrioventricular valves, and state of the pulmonary and aortic valves, as well as chips that indicate the names of the cardiac cycle phases, atrial and ventricular relaxation.

The research material sources were learning assessment exercises and questions taken from the academic exam on cardiac physiology. The assessment exercises were used to follow the students’ teaching-learning process and were not counted as a grade to pass the subject. These questions were used for formative evaluation throughout the subject, allowing the teacher to identify concepts that were learned and those that had to be revised to achieve effective learning. The sequence of procedures is shown in Fig. 1.

The control group had a 2-h theoretical class (class 1) about the characteristics of cardiac cells, physiology of the pacemaker and its control by the autonomous nervous system, comparisons between the action potential of the skeletal muscle and plateau action potential of the cardiac muscle, cardiac conduction fibers, and transmission of the electrical stimulus in the heart. In this lecture, there was also a detailed description of the phases of the cardiac cycle and a discussion on the relations between the heart characteristics and events of the cardiac cycle. The teacher showed how the special characteristics of cardiac cells contribute to the cardiac cycle. At the end of this class, students were instructed to study the topic in the textbook indicated and were informed that there would be an assessment during the next class. After 4 days, at the beginning of the next class (class 2), the teacher

Fig. 1. Sequence of the procedures used in the experimental design.
or contraction, valves opening and closing, and heart sounds. These are used for filling in the table (25). Students were instructed to fill in the table with chips that indicated the state of the atria and ventricles (contracted or relaxed) and the cardiac valves (open or closed), the name of each stage of the cardiac cycle, and the time when cardiac sounds occurred (26).

This educational game has been considered a puzzle because each chip has only one correct place where it must be included in the table. However, differently from jigsaw puzzles, the chips do not give clues about where they fit. This is deliberate, to prevent students solving the puzzle without actually having understood the events of the cardiac cycle and the relationship between cardiac morphology and physiology. This puzzle represented a challenge because it was necessary to recall previous knowledge to place the chips in their correct places and answer questions about the relations between heart morphology and physiology, as previously described (25, 26).

Another characteristic of puzzles is the immediate feedback to the player about whether or not the piece has been correctly placed. In the activity with the cardiac cycle puzzle, this feedback is provided by postgraduation students and two physiology teachers, who act as monitors. The monitors evaluate how the table has been filled out and inform the students whenever there was an inaccuracy. The monitors do not explain the subject to the students. They ask questions to enable the students to find the mistake and correct it. Students have to “discover” the answers and the relations between the characteristics heard and cardiac cycle events by themselves.

During the activity, students had to use the game to describe the sequence of cardiac cycle events to a monitor and explain how the morphological (gap junctions between muscle cells, valves, the atrium, and ventricular muscles) and physiological characteristics (pacemaker action potential, plateau action potential, delay of the action potential in the atrioventricular node, and conduction speed of the electrical stimulus) of the cardiac muscle participated in the cardiac cycle.

At the end of this activity, students did the same assessment exercise as applied to the control group. So that there would be no difference in the treatment of the students from the control and game groups, after the test, students from the control group also carried out the activity with the puzzle.

The maximum score for the assessment exercise, containing 6 questions, was a grade of 10. Of these, the first three questions were concerned about the special characteristics of heart cells. In the first question, students were requested to analyze two graphs and identify which one illustrates the excitation-contraction coupling of the heart muscle and of a skeletal muscle. In the second question, students had to use the above-mentioned graphs to explain why there is no tetany in the heart muscle, considering the different ion channels of skeletal and cardiac muscles. In the third question, students had to discuss the importance of having summation of contractions in skeletal muscle and not in the heart muscle. In the fourth question, students had to describe which special characteristics of the cardiac cells allow that the ventricles to contract rapidly and simultaneously after the delay of action potential in the atrial-ventricular node. In the fifth question, students had to explain, in their own words, what are and what causes the sounds we hear as heartbeats. The last question presents nine sentences to be classified as true or false. These sentences were about the cardiac cycle and the relationship between the special characteristics of the heart and the continuous and efficient cardiac blood pumping.

To evaluate short-term learning, the numbers of right and wrong answers marked by both the control and game groups in the exercise assessment of class 2 were compared. The hypothesis to be tested was that the game would have improved the students’ learning and that the game group would show better performance in this exercise compared with the control group. The control group had a lecture about the characteristics of cardiac cells followed by textbook reading and “discovered” the relations between these characteristics and the cardiac cycle during the activity with the puzzle. In a later class (class 3), 7 days after class 1, all students participated in a theoretical class in which a general discussion was held about the cardiac cycle and the groups were invited to show their answers.

To evaluate medium-term learning, the grades obtained by students from both the control and game groups in the questions about cardiac physiology that formed part of the academic exam of the subject were compared. This test was applied 25 days after class 1. Considering that before this test both the control and game groups had carried out the activity with the puzzle, the hypothesis was that there should be no difference in performance between the groups.

The academic exam consisted of 29 questions, with 10 questions being on histology, 4 questions on biochemistry, and 15 questions on physiology. The physiology questions were divided as follows: 4 questions on endocrine physiology, 4 questions on respiratory physiology, 2 questions about cardiac physiology, 3 questions about the regulation of blood arterial pressure, and 2 questions about hypertension. To evaluate the effect of the game, the two questions about cardiac physiology were considered to this study. These questions covered similar topics to those of questions in the assessment exercise. One of these was a multiple-choice question, and the second question consisted of eight sentences that had to be checked as true or false. These issues dealt with the relation between the characteristics of heart cells and the sequence of events of the cardiac cycle. In the academic exam, each question was worth 0.34 points. Therefore, the issues about cardiac physiology totaled 0.68 points. This sum was normalized to 10, and normalized grades of the control and game groups were compared.

Student perceptions about the puzzle were analyzed by means of a survey applied in the last class, after the last exam, at the end of the semester. All students were invited to answer the following questions: “In the classes on cardiovascular physiology, the cardiac cycle puzzle was used. How did you evaluate the activity with this puzzle? Did it help you with your learning process? Why?” Forty-nine students answered the question. This survey was anonymous and therefore the answers were not separated by groups.

The researcher responsible for this study was the teacher who taught the classes to the students. Because of this, to assure the volunteers’ autonomy and reduce the vulnerability of the students in the decision to participate in the study, the request to use the data in research was presented to students at the end of the term, after the release of the final grades in the subject of Biosciences II. The invitation was made outside class time, at a time scheduled for this purpose. On that day, students were also invited to answer the question about what they thought of the puzzle as a way of learning.

For statistical data analysis, the number of wrong answers obtained in the assessment exercise as well as the grades obtained in this exercise and in the academic exam by both the control and game groups were compared using the unpaired Student’s t-test at the 5% level of significance.

RESULTS

Of the 67 students who were invited to participate in this study, 62 students gave their consent: 28 and 34 students in the control and game groups, respectively.

In the exercise applied in class 2, the game group presented a lower number of errors and higher score compared with the control group (P < 0.05). In the academic exam, applied after the use of the puzzle by both groups, there was no difference in the scores obtained by the control and game groups in the questions about cardiac physiology (P > 0.05; Table 1).
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Table 1. Students’ performance in the assessment exercise and test questions about the cardiac cycle

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Students</th>
<th>Number of Mistakes (Assessment Exercise)</th>
<th>Grade (Assessment Exercise)</th>
<th>Grade (Test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>28</td>
<td>5.62 ± 0.68</td>
<td>5.51 ± 0.35</td>
<td>8.93 ± 0.40</td>
</tr>
<tr>
<td>Game</td>
<td>34</td>
<td>2.74 ± 0.42*</td>
<td>7.20 ± 0.22*</td>
<td>9.12 ± 0.33</td>
</tr>
</tbody>
</table>

Values are means ± SE. The assessment exercise was applied in class 2 to evaluate short-term learning immediately after (game group) or before (control group) the activity with the cardiac cycle puzzle. The test was applied 25 days after both groups had carried out the activity with the cardiac cycle puzzle.

During the activity with the game, the teacher and monitors observed the discussion in the group of students. They noted that students were engaged and interested in the content and showed satisfaction with being able to solve the puzzle.

Considering the perception about the puzzle, 49 students answered the survey. Of these, 47 students (96%) considered that the activity with the puzzle helped in their learning process because it helped them to understand the subject, made the subject easier, helped them to think about the topics, made it easier to visualize the processes, and made it a fun and interactive way to study. Two students answered that the activity did not help them because they were able to learn about the subject in the lecture only.

DISCUSSION

The results of this study showed that the use of an educational game improved the learning process of undergraduate dental course students on the subject of cardiac physiology and confirmed student perceptions that the use of this game helped them to understand the topic better.

These results are in agreement with the studies of Stetzik et al. (41) and Su et al. (42). Stetzik et al. (41) compared the performance of medical students through games and a test after theoretical classes and classes with puzzles about anatomy and physiology throughout a school semester. They reported an improvement in the students’ performance after use of the games compared with the performance obtained after the theoretical classes. Su et al. (42) assessed the effectiveness of a game of cards about human immunology by a pre- and posttest comparison.

Our results are also in line with the study of Rubinstein et al. (38), with medical school students, in which traditional classes were compared with classes using a puzzle on the ECG. Students were divided into two groups: one group had a traditional lecture on ECG interpretation followed by a test and a lesson with the puzzle and another group had a class with the puzzle followed by the same test and the traditional lecture on ECG. Student perspectives of the teaching method were also analyzed. The puzzle contained parts that fitted together to form a basic diagnostic ECG and other pieces that combined to form other diagnoses. As a result, an improved understanding of the subject was obtained when the lecture was combined with the puzzle compared with using the puzzles or lecture only. Most students evaluated the method as being useful and less stressful than when they only attended the traditional lecture.

The authors of the present study considered the educational game used in their study to be a puzzle because it has the following characteristics of puzzles: generality, the Eureka factor, and entertainment value. Considering generality, its solution requires students to relate their previous knowledge and morphology to the function of the heart. This is a strategy that will, for example, allow them to understand cardiovascular responses to exercise or stress. The Eureka factor is provided by continuous and immediate feedback by monitors, allowing the students to know whether the solution is correct or not and making them find their mistakes and correct them. Moreover, according to the students’ evaluation, the cardiac cycle puzzle also fulfilled the criterion of the entertainment factor, because it helped them to understand the subject in an interactive way that was fun.

The difference between the ECG puzzle of Rubinstein et al. (38) and the cardiac cycle puzzle used in the present study is that in this puzzle the chips do not give clues to where they fit. This characteristic was deliberate to ensure that the students understood the subject when they placed a chip in the table. Apart from this difference, the present study added evidence showing how a puzzle made with simple and cheap materials could help university students to understand key topics in cardiovascular physiology.

Our study was carried out in a real class situation, during the development of a mandatory curricular subject schedule. The teacher, F. K. Marcondes, has been using the cardiac cycle puzzle since 2003 and noted that its use seemed to improve students’ comprehension of the subject. According to the students, the game helped them to understand the concepts and events of the cardiac cycle (26). Nevertheless, its effect on learning has not yet been evaluated in accordance with scientific research guidelines. One of the difficulties of this type of study is that, at first, it could lead to impairment in learning if the puzzle were in fact efficient and were not used with the control group.

Therefore, for the design of this study, we proposed a comparison of students’ performance between the control and game groups, respectively, before and immediately after the use of the educational game. Furthermore, after the assessment exercise was done, the activity with the cardiac cycle puzzle was also used with the control group. This comparison allowed evaluation of the short-term performance of the students with (game group) and without (control group) use of the puzzle. The smallest number of mistakes and the highest grade obtained by the group that had used the game compared with the group that had only attended the theoretical class indicated that the game group showed better comprehension of the topic at the time.

Students in the game group had attended a short class in which the teacher had not given all the information and had instructed the students to study the topic in the textbook that the teacher had indicated. In the theoretical class, the special characteristics of the heart were presented; however, how they were related to the cardiac cycle events was not described, nor was the sequence of the cardiac cycle. For this group, the activity with the puzzle was a strategy to promote the students’ learning process, leading them to “discovering” some of the concepts and relating the morphology to the physiology of the heart.

Students in the control group had a “full” theoretical class in which the teacher passed on all the information about the...
cardiac cycle, indicating the importance of the morphological and physiological characteristics of the cardiac muscle in each phase. This group was also instructed to do the same reading indicated to the game group. For the control group, the use of the puzzle was a complementary activity to the class, to strengthen the content previously taught. The difference observed in the students’ performance indicated that the information taught orally to the control group was less efficient in promoting the students learning process compared with the process of discovery and group discussions developed during the activity with the puzzle.

On the day of the academic exam, applied 25 days after the activity with the puzzle, both the control and game groups had done the activity with the game. The fact that there was no statistical difference between the groups in the scores obtained in the academic exam confirms the efficiency of the puzzle. This interpretation was supported by the fact that the difference between the groups, observed on the day of the activity with the puzzle, when one group responded to the assessment exercise before and the other after having used the game, was no longer evident after students from both groups participated in the activity with the game.

Due to these conflicting data, it is not possible to rule out the possibility that the difference in performance observed in the present study might be related to the Hawthorne effect, through which people react positively to a new situation (33). The activity with the game allowed greater proximity between students and teachers and might have made the teacher’s concern about their learning more perceptible by the students. In the theoretical classes, the teacher’s role was to pass on the information, and, to learn, it would be up to the student to study the information received. In the activity performed with the game, the teacher and monitors helped the students to build their knowledge, developing effective teacher-student interactions. In this situation, students feel appreciated by the teacher, that is, they realize that the teacher is indeed interested in their learning.

Another factor that might have influenced the results obtained in the present study was the affectivity between the individual who learns and the topic “to be learned.” Cognition is influenced by emotions and vice versa (3, 45). In this context, the classroom environment as well as teacher-student and student-student relationships influence the relationship between the student and the object of study. When the classroom environment and the interpersonal relationships are pleasant, a positive affectivity is developed, favoring the teaching-learning process (23).

Although we did not take any objective measurements during the theoretical classes taught to the control and game groups, there was little teacher-student interaction. This interaction was limited to questions asked by a few students. On the other hand, during the activity with the game, the teacher observed the discussion in the group of students, giving positive feedback by indicating right answers or asking questions to lead the students to noticing and correcting the wrong answers. These interventions were made cordially, not showing surprise or frustration when a student had a doubt or was wrong even in a basic concept. The teacher also guided the interactions with other members of the group, so that everyone’s doubts were heard and respected. It was emphasized that everyone was there to help each other and learn together.

One of the factors responsible for the positive effect of educational games may be related to the formative evaluation during their use. Formative evaluation provides the students with feedback and also allows the teacher to identify what the students know, and this is a critical component of student-focused teaching (20). This type of evaluation allows the student to learn the previous concept before being introduced to new concepts (13). Bailey et al. (5) developed games to teach gastrointestinal physiology in a medicine course. The content was divided into five topics, and, at the end of each topic, one of the games was introduced to the students. The authors discussed the importance of games so that teacher and students could receive feedback about the topics that needed to be reviewed. In the present study, the formative evaluation occurred during the group discussions held during the activity with the puzzle. Each student could identify what he or she had in fact understood and if he or she had any doubts. Thus, students were continuously evaluated throughout the teaching-learning process.

In the present study, students also found that the activity with the puzzle helped in their learning process because the game made it easier to understand the topics studied and was a fun and interactive way to learn. These data confirm the perception of the students, described in a previous study (26), in which the game was useful in obtaining a better comprehension of the content studied.

Since the students’ engagement and their satisfaction in solving the puzzle were noted by the teacher and monitors, it seems that the interactions during the activity with the game may have promoted their approach toward topic studied. According to Rodenbaugh et al. (37), solving a puzzle game involves investigation, discovery, visualization, prediction, and solution of problems. Therefore, students experience a feeling of fulfillment as they conclude the puzzle challenge, which is important because the reward for concluding a challenge builds the confidence to take on new challenges (37).

For a long time, the teacher was the students’ source of information and knowledge. Nowadays, students acquire information in different ways because they have knowledge of information technologies and, from the time they are very young, they have access to the Internet and have mastered its use. It is necessary for teachers to acknowledge that students no longer depend exclusively on them to acquire information and that the lack of this perception may justify students’ low attendance and inattention during classes. Teachers must rethink their role and assess what students cannot do efficiently on their own (40).

In the perception of teachers and students, educational games can increase students’ motivation and participation in class and facilitate their learning (26, 44), representing a change in the teaching pattern, in which students go from “learning by listening” to “learning by doing” (16).

Although online games are different types of educational games, they also show positive effects on learning (8). Using an online game, 100 first-year medical school students correctly performed a blood transfusion in a virtual patient. After the activity, student perceptions of the game were assessed. Most students reported that the game helped them to understand blood typing and strengthened what they had learned. They evaluated the activity as fun, which is important to break monotony of the classes and increase students’ active partici-
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pation. Moreover, the students would like to have this type of activity for other topics (8).

Rodengaugh et al. (36), in a study conducted in a nursing course, built a skeletal muscle model during the class and, as a result, the teacher noted a high level of students’ engagement during construction of the model, differently from what happened during the classes without construction of this model. The students’ engagement was assessed by their level of attention and the quality of their discussions and teamwork.

The limitations of the present study were that the effect of the game was evaluated in the short term; however, we attempted to complement this analysis, by assessing the performance of the students in a test after both groups had accomplished the activity with the cardiac cycle puzzle. This setting was necessary to respect class times of the subject involved. This study could have been conducted experimentally only, outside class time; however, the goal of this study was to evaluate the effectiveness of the game inside the real routine in the classroom. In a future study, we intend to analyze the effect of the game on long-term learning, by assessing what the students can still remember about the topic by the time they reach the second to fifth year of the undergraduate course.

In conclusion, in this study, a positive effect of the cardiac cycle puzzle on the students’ learning process was evident. This effect was identified by analyzing the students’ performance in an assessment exercise and in an academic exam as well as student perceptions of the methodology that was used. The present study shows an important collaboration of the active teaching methodologies, by showing a possible setting for use in a real situation during the development of an undergraduate course subject. In addition, this study makes a contribution to learning/teaching by showing how simple didactic material may be developed to help students understand basic concepts and relate the morphology to the physiology of organs and organic systems. This approach may be adapted to other topics and subjects.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS


REFERENCES


