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Students’ perception of animal or virtual laboratory in physiology practical classes in PBL medical hybrid curriculum

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Submitted 10 January 2019; accepted in final form 1 August 2019

Over the years, much criticism against animal use for physiology teaching has been made. Hence, replacement by suitable alternatives has increased in several pedagogical approaches. This study examined students’ perceptions of animal versus virtual (video/computer) laboratory classes in physiological sciences associated with the effectiveness of the problem-based learning (PBL) hybrid curriculum. Three cohorts of medical students from the University of Ribeirão Preto, who participated in animal or virtual physiology classes or both, were asked to fill out a 5-point Likert questionnaire about knowledge acquisition/motivation, importance to PBL learning goals, skills acquired, need for animal use, academic formation, learning impairment, and alternative methods. We also assessed their grades in the final exam. A total of 350 students were included, in which 108 participated only in virtual classes, 120 only in practical animal laboratory classes, and 122 in both approaches. The majority agreed that the two methods improved their knowledge acquisition/motivation and helped to reinforce tutorial goals and to acquire skills. However, the cohort who experienced both approaches favored animal laboratory. Students believe animal use is needed and did not impair their learning. Conversely, their opinion about academic formation without animal laboratory classes was divided, as was whether this approach inspired them to seek alternative methods. Despite the different perceptions, there was no difference among the groups’ final grades (7.3 ± 1 vs. 7.2 ± 1 vs. 7.2 ± 2 for virtual or practical animal laboratory classes or both, respectively). Therefore, virtual activities are not as effective as animal use in the opinions of the students, but they are successful strategies in physiology learning that can be used in practical classes in a hybrid PBL curriculum.

animal use alternatives; instructional films and videos; physiology; problem-based learning; virtual laboratories

INTRODUCTION

In physiology teaching, the use of animals in laboratory-based practical classes is a common practice used to illustrate and consolidate concepts (23). Working in a laboratory environment with animals allows students to acquire important cognitive skills and create opportunities for analytic thought process (28), which is consistent with the pedagogy of problem-based learning (PBL) (16). Laboratory experiences, as dynamic components to develop hands-on skills, are complementary to active learning approaches in medical education (7, 23). Besides, data collected through laboratory observations help tutors to raise targeted questions, motivating students to search for answers, which support their hypothesis and problem solving (1, 2).

Nevertheless, over the last 20 yr, discussions about the use of live species have been raised regarding ethics, moral, and quality of education. Moreover, criticism has been made due to the fact that living preparations can be replaced by suitable alternatives (13, 27). For these reasons, from 1980 to 2000, there was a steady decline in animal use in physiology and pharmacology courses (9, 23). In the U.S., most medical schools are not using live species in any of their physiology, pharmacology, or surgery courses (15). At the same time, there is an increased use of alternatives, particularly those based on virtual technologies such as slides, video, computer-assisted instruction, and computer simulations (18, 27).

One aspect that should be considered related to this issue is the perception of students and their learning preferences. Educational activities involving animals may be unpleasant for some of them (6), whereas for others they may be exciting and helpful (7, 27). In this sense, the students’ cognitive preferences may occasionally affect their performance in different subject areas (13, 27). With this background, there is a need to analyze this teaching approach and implement a reduction, replacement, and refinement of animal experiments, as described by W. Russell and R. Burch (see Ref. 21).

In regards to knowledge acquisition, several studies have shown no measurable advantages of the practical activities using live species in comparison with recently developed alternative educational modalities (9, 22). Nevertheless, results from these studies were generated from traditional classroom-based learning scenarios. The hypothesis of our study is that the replacement of animal experiments through videos and computer activities is equally effective in physiology learning, and both methodologies contribute to the learning goals in a medical school structured in a PBL hybrid curriculum. Therefore, the aim of this study was to compare the students’ perceptions of animal laboratory classes versus video/computer-based learning in physiological sciences associated with the effectiveness of the PBL method.
METHODS

Background and General Setting

This was an observational, cross-sectional study that was conducted in the Medical School of the University of Ribeirão Preto Medical School (UNAERP). Since 2003, our curriculum has been based on the PBL method, and, during this period, our group has contributed to the improvement of this learning approach (4, 5, 8). Details of our PBL curriculum have been described elsewhere (5).

Physiology Teaching

In our hybrid PBL curriculum, from the first to the fourth semester, physiology content is divided into modules, e.g., Cardiovascular, Endocrine, and Neural, among others, each lasting ~6 wk. In addition to the tutoring sessions of the module, students also have theoretical and practical physiology classes.

From 2013 until 2014, most of the practical classes in these modules were conducted using live species (rats), broaching the essential physiology concepts required in the medical school syllabus. Five practical classes were conducted as follows:

Class 1 (second semester). This class aimed to teach students how to immobilize and anesthetize rats and to demonstrate the effect of the neurotransmitters from the autonomic nervous system in organs. Students were divided into three groups, and one rat was provided for each group. Students anesthetized the animals and opened their abdomen and thorax to instill norepinephrine and acetylcholine in the intestine and heart to observe the effects. After the drug administration and before the heart stopped beating, the students removed the rat’s heart and immersed it in a potassium chloride solution to observe the cardiac automatism and the effect of potassium excess in the heart.

Class 2 (third semester). This class aimed to demonstrate the effect of thyroid hormone administration and the blockade of thyroid hormone synthesis in rats. Previous to the class, hyper- or hypothyroidism was induced in animals by means of a thyroid hormone injection (intraperitoneal, 1 wk,) or methimazole administration (diluted in drink water, 1 mo). On the day of practical class, students were divided into three groups, and a rat was provided for each group. After anesthetizing the rats, students obtained the body weight and length (from the nose tip to the tail tip), the body temperature, and the weight of heart, thyroid, fat, and pituitary from control and hyper- and hypothyroid rats.

Class 3 (third semester). This class aimed to demonstrate the effect of dexamethasone treatment in rats. After a week of dexamethasone administration, on the day of the practical class, students were divided into four groups, and one rat was provided for each group (2 control and 2 treated with dexamethasone). After anesthetizing the animals, students obtained the body weight, glycemia, and weight of fat, adrenal, and pituitary glands from control and dexamethasone rats.

Class 4 (fourth semester). This class aimed to demonstrate the physiological effects of sex hormones in female and male rats. Rats were previously submitted to oophorectomy, orchidectomy, or sham surgeries by technicians. After 1 wk of recovery, the rats were divided into groups: 1) sham + vehicle; 2) oophorectomy/orchidectomy + vehicle; and 3) oophorectomy/orchidectomy + hormone replacement. At the end of treatment, on the day of the class, students were divided into six groups, and one animal was provided for each group. After anesthetizing the animals, the body weight and the weight of fat, prostate, seminal glands, and uterine horns were obtained from the rats.

Class 5 (fourth semester). This class aimed to demonstrate the effect of alcohol in the motor coordination of rats. Students submitted animals to a rotarod performance test and collected the time taken for them to perform the test before and after alcohol or saline administration.

These practical classes were designed to drive students to collect and interpret data, aiming to integrate practical aspects of the physiological principles with the learning goals previously achieved during the PBL tutorial sessions. All protocols developed during practical classes were previously submitted and approved by the Institutional Review Board and the Ethic Committee at UNAERP.

In 2015, due to ethics and moral concerns, all physiology practical classes with animals were replaced by video/computer activities with the same purposes. In this virtual approach, all of the procedures on animals were recorded and displayed through high-quality videos with interactive activities, e.g., tables and graphics building using Excel software. By watching these videos, as well as participating in practical animal laboratory classes, students were able to use the same methods to collect and comprehend the data, and then to interpret and discuss the obtained results with their peers and the tutor. Also, the time each group spent on animal laboratory or virtual classes was exactly the same. Even though the videos took less time than in vivo protocols, the remaining time was filled with interactive activities, e.g., tables and graphics building using Excel software for data analysis and discussion of target questions.

Owing to this transition from 2014 to 2016, three different groups of medical students experienced practical classes with live animals (animal laboratory classes), video/computer classes (virtual classes), or both approaches, through their respective second, third, and fourth semesters. As a result, their perceptions could be analyzed concerning the relevance of these learning methods in a PBL curriculum, the use of animal and its replacement, and the importance of alternative methods. The students who had taken part in both methodologies (virtual and animal laboratory) were an important control group, since they participated in classes 1 and 2 with in vivo protocols and classes 3, 4, and 5 with video/computer activities. Hence, the time to complete the modules was also the same for all groups, having a fair treatment of the three cohorts.

Students/Subjects

Medical students (n = 350) were requested to fill out a Likert-type scale questionnaire to query their perception regarding the learning acquisition in physiology through the use of live species or virtual activities as practical classes instead of the animal laboratory. Additionally, at the end of the questionnaire, the students answered the qualitative question, “Which skill did you acquire during practical classes with live animals or video/computer activities?”, to report the skills they had acquired through animal laboratory and virtual classes. Students could answer this question or not, and most of them did.

Students were categorized into three cohorts, as follows: group A (animal laboratory), students who had animal laboratory classes only (n = 120); group B, students who had both methodologies (n = 122), comprising students who experienced the transition from practical to virtual practical classes; and group V, students who had had virtual classes only (n = 108).

Questionnaire and Students’ Grade Assessment

The questionnaires consisted of a 5-point Likert scale ranging from “strongly disagree” to “strongly agree,” which comprised sentences grouped in the following topics (Tables 1–4): 1) knowledge acquisition and motivation; 2) importance of reinforcing PBL learning goals; 3) skills acquired; 4) need for animal use; 5) academic formation without animals use; 6) learning impairment; and 7) think about alternative methods.

In addition to students’ evaluation of the methodological approaches, the acquired knowledge from the practical activities and its integration to the PBL learning goals was systematically assessed in the final exams. The final scores from the third semester, when the transition of the classes happened, were compared among the groups.

Ethical Considerations

Participants were provided with written, informed consent. Before getting the answers, this written, informed consent was properly
collected. Taking part in the study was the deliberate choice of the students. No student was identified by name. All of the answers were kept anonymous and confidential. Permission to conduct the study was granted by the UNAERP Ethics Committee (protocol no. 54657316.9.0000.5498).

Statistical Analysis

Because there were few answers of “strongly disagree” or “strongly agree” in the data analysis, which could make our statistical analysis weak, we have pooled “strongly disagree” plus “disagree,” and “strongly agree” plus “agree.” This way, the statistical analysis was performed using the three answers, “disagree,” “neutral,” and “agree.” The χ² was applied as a proportion test for the general analysis among the answers collected from all groups of students. To identify the statistical significance, the contingency test was applied to test two variables at a time. The students’ grades in the final exams were compared by means of a one-way analysis of variance. The Excell from Microsoft software and GraphPad Prism (version 5.0) were used to analyze the data. A P value < 0.05 was considered statistically significant.

RESULTS

Independent of the group, the majority of the students agreed or strongly agreed that using animal or virtual methods as physiology practical classes had improved their knowledge acquisition and motivation [χ² (4 × 3) = 29.1, P < 0.01] and had helped to reinforce PBL learning goals [χ² (4 × 3) = 20.3, P < 0.01] (Tables 1–4). Considering the agreement distribution on the knowledge acquisition and motivation and the importance of reinforcing PBL learning goals, there were no statistical differences between students who had only animal laboratory (Table 1) and those who had only virtual classes (Table 4). Interestingly, in group B, which had experienced both methods (Tables 2 and 3), there was a statistical difference in favor of the agreement that animal laboratory classes are important for knowledge acquisition and motivation [χ² (2 × 3) = 27.1, P < 0.001] and also for reinforcing PBL learning goals [χ² (2 × 3) = 15.2, P < 0.001] in comparison with the other groups’ agreements.

In regard to skill acquisition during practical physiology classes, the vast majority of students from all groups agreed or strongly agreed that both animal laboratory (Table 1) and virtual activities (Table 4) were fundamental [χ² (4 × 3) = 84.4, P < 0.01]. However, the agreement of the group that had the opportunity to take both classes favored animal laboratory classes [group B-A, 85% (Table 2) vs. group B-V, 29% (Table 3), χ² (2 × 3) = 78.6; P < 0.001]. We also asked which skills students could have acquired with these different class approaches. Several different skills were mentioned, and the words most used for students who had animal laboratory classes were “surgical instruments manipulation,” “manual skills,” and “animal manipulation,” whereas students who participated in virtual classes mentioned “graph software manipulation,” “data analysis,” and “information technology skills.” In both groups, many students also cited “physiology, anatomy, and pharmacology understanding.”

Table 1. Topics of 5-point Likert questionnaire applied to medical students who participated in animal laboratory classes from group A and the number (percentage) of “strongly disagree,” “disagree,” “neutral,” “agree,” and “strongly agree” responses for each topic

| Likert Questionnaire                                      | Animal Laboratory, Students’ Views |
|----------------------------------------------------------|-----------------------------------|
| Knowledge acquisition and motivation                     | SD      | D     | N     | A     | SA    |
| The practical classes with laboratory animals helped me to understand and remember the structures visualized and the physiological phenomena discussed in the theoretical classes. | 4 (3)   | 9 (8) | 10 (8) | 47 (39) | 50 (42) |
| The scene visualization and animal images in the practical classes with laboratory animals had a positive impact on my learning. | 7 (6)   | 11 (9) | 24 (20) | 33 (37) | 34 (28) |
| My motivation for studying the discipline related to the practical classes with laboratory animals was stimulated. | 9 (8)   | 19 (16) | 22 (18) | 36 (30) | 34 (28) |
| The importance of reinforcing PBL learning goals         | 6 (5)   | 13 (11) | 10 (8) | 54 (45) | 37 (31) |
| The practical classes with laboratory animals assisted in the tutorial objectives sedimentation in the related module. | 14 (12) | 22 (18) | 17 (14) | 41 (35) | 25 (21) |
| Skills acquired                                          |                                   |
| During practical classes with laboratory animals, new skills useful for my academic development were acquired. | 12 (10) | 15 (12.5) | 16 (13) | 50 (42) | 27 (22.5) |
| Need for animal use                                      |                                   |
| Based on my experience in practical classes, it is fundamental to use and manipulate animals in practical classes. | 16 (13) | 15 (13) | 22 (18) | 43 (36) | 24 (20) |
| Academic formation without animals                       |                                   |
| Medical students can be professionally well prepared without using animals in practical classes in Human Physiology. | 20 (17) | 22 (19) | 30 (25) | 29 (24) | 18 (15) |
| Learning impairment                                      |                                   |
| The difficulty in handling animals impaired my learning of the objective of the respective practical class. | 54 (45) | 44 (37) | 7 (6) | 11 (9) | 4 (3) |
| Think about alternative methods                          |                                   |
| The practical classes with laboratory animals inspired me to question the methodology and to seek alternative methods equally effective in teaching. | 13 (11) | 32 (27) | 37 (31) | 25 (21) | 12 (10) |

Values are n, no. of responses (with percentage in parentheses) to a 5-point Likert questionnaire. PBL, problem-based learning; SD, strongly disagree; D, disagree; N, neutral; A, agree; SA, strongly agree.
A greater proportion (>50%) of the students in all groups agreed or strongly agreed (Tables 1, 2, and 4) that animal use during practical classes is needed \( (\chi^2(3 \times 3) = 9.5, P = 0.05) \). However, there was a significant difference between group B (Table 2) and group V (Table 4), demonstrating students who had only virtual classes agreed less than those who had experienced both methods \( (\chi^2(2 \times 3) = 7.9, P = 0.01) \). At the same time, when students were asked if it is possible to have an

### Table 2. Topics of 5-point Likert questionnaire applied to medical students who participated in animal laboratory classes from group B and the number (percentage) of “strongly disagree,” “disagree,” “neutral,” “agree,” and “strongly agree” responses for each topic

| Likert Questionnaire                                                                 | SD      | D       | N       | A       | SA      |
|-------------------------------------------------------------------------------------|---------|---------|---------|---------|---------|
| Knowledge acquisition and motivation                                                |         |         |         |         |         |
| The practical classes with laboratory animals helped me to understand and remember   | 2 (2)   | 2 (2)   | 3 (2)   | 32 (26) | 82 (68) |
| the structures visualized and the physiological phenomena discussed in the theoretical|         |         |         |         |         |
| classes.                                                                            |         |         |         |         |         |
| The scene visualization and animal images in the practical classes with laboratory    | 2 (2)   | 3 (2)   | 6 (5)   | 39 (32) | 72 (59) |
| animals had a positive impact on my learning.                                       |         |         |         |         |         |
| My motivation for studying the discipline related to the practical classes with       | 3 (2)   | 5 (4)   | 17 (14) | 32 (26) | 65 (54) |
| laboratory animals was stimulated.                                                   |         |         |         |         |         |
| The importance of reinforcing PBL learning goals                                     |         |         |         |         |         |
| The practical classes with laboratory animals assisted in the tutorial objectives     | 2 (2)   | 4 (3)   | 2 (2)   | 44 (36) | 70 (57) |
| sedimentation in the related module.                                                |         |         |         |         |         |
| The practical classes with laboratory animals have the same importance for learning   | 6 (5)   | 10 (8)  | 13 (11) | 39 (32) | 53 (44) |
| the theme discussed in the theoretical class.                                        |         |         |         |         |         |
| Skills acquired                                                                      |         |         |         |         |         |
| During practical classes with laboratory animals, new skills useful for my academic   | 1 (1)   | 5 (4)   | 12 (10) | 46 (38) | 58 (47) |
| development were acquired.                                                           |         |         |         |         |         |
| Need for animal use                                                                  |         |         |         |         |         |
| Based on my experience in practical classes, it is fundamental to use and manipulate  | 10 (8)  | 11 (9)  | 16 (13) | 27 (22) | 57 (48) |
| animals in practical classes.                                                        |         |         |         |         |         |
| Academic formation without animals use                                               | 15 (12) | 32 (26) | 34 (28) | 29 (24) | 12 (10) |
| Medical students can be professionally well prepared without using animals in practical|         |         |         |         |         |
| classes in Human Physiology.                                                         |         |         |         |         |         |
| Learning impairment                                                                   |         |         |         |         |         |
| The difficulty in handling animals impaired my learning of the objective of the       | 65 (53) | 44 (36) | 7 (6)   | 4 (3)   | 2 (2)   |
| respective practical class.                                                          |         |         |         |         |         |
| Think about alternative methods                                                       | 12 (10) | 33 (27) | 38 (31) | 31 (25) | 8 (7)   |
| The practical classes with laboratory animals inspired me to question the methodology|         |         |         |         |         |
| and to seek alternative methods equally effective in teaching.                       |         |         |         |         |         |

Values are \( n \), no. of responses (with percentage in parentheses) to a 5-point Likert questionnaire. PBL, problem-based learning; SD, strongly disagree; D, disagree; N, neutral; A, agree; SA, strongly agree.

### Table 3. Topics of 5-point Likert questionnaire applied to medical students who participated in virtual classes from group B and the number (percentage) of “strongly disagree,” “disagree,” “neutral,” “agree,” and “strongly agree” responses for each topic

| Likert Questionnaire                                                                 | SD      | D       | N       | A       | SA      |
|-------------------------------------------------------------------------------------|---------|---------|---------|---------|---------|
| Knowledge acquisition and motivation                                                |         |         |         |         |         |
| The practical classes with video/computer activities helped me to understand and     | 4 (3)   | 16 (13) | 21 (17) | 58 (48) | 23 (19) |
| remember the structures visualized and the physiological phenomena discussed in the  |         |         |         |         |         |
| theoretical classes.                                                                |         |         |         |         |         |
| The scene visualization and animal images in the practical classes with video/computer| 1 (1)   | 10 (8)  | 22 (18) | 68 (56) | 21 (17) |
| activities had a positive impact on my learning.                                    |         |         |         |         |         |
| My motivation for studying the discipline related to the practical classes with      | 6 (5)   | 37 (30) | 35 (29) | 39 (32) | 5 (4)   |
| video/computer activities was stimulated.                                           |         |         |         |         |         |
| The importance of reinforcing PBL learning goals                                     |         |         |         |         |         |
| The practical classes with video/computer activities assisted in the tutorial        | 3(2)    | 15 (13) | 23 (19) | 61 (50) | 20 (16) |
| objectives sedentation in the related module.                                       |         |         |         |         |         |
| The practical classes with video/computer activities have the same importance for     | 4 (3)   | 24 (20) | 22 (18) | 55 (45) | 17 (14) |
| learning the theme discussed in the theoretical class.                               |         |         |         |         |         |
| Skills acquired                                                                      |         |         |         |         |         |
| During practical classes with video/computer activities, new skills useful for my    | 13 (11) | 28 (23) | 44 (37) | 29 (24) | 6 (5)   |
| academic development were acquired.                                                 |         |         |         |         |         |

Values are \( n \), no. of responses (with percentage in parentheses) to a 5-point Likert questionnaire. PBL, problem-based learning; SD, strongly disagree; D, disagree; N, neutral; A, agree; SA, strongly agree.

Advances in Physiology Education • doi:10.1152/advan.00005.2019 • http://advan.physiology.org
academic formation without animal use (Tables 1, 2, and 4), the answers were relatively proportional among agree, neutral, and disagree in the three cohorts $[\chi^2 (3 \times 3) = 0.96]$.

A small proportion of students (3%) refused to participate in classes due to animal use, whereas in virtual classes nobody refused to take part. For this reason, we speculated if the difficulty in handling animals for students from groups A and B could impair their learning for the purpose of the practical class. The majority of the students who experienced animal laboratory classes (Tables 1 and 2) disagreed or strongly disagreed with this statement [group A: 82%; group B-A: 89%, $\chi^2 (2 \times 3) = 4.4$, $P < 0.05$]. In addition, we also questioned, for groups A and B, if live animal classes inspired them to think about and to seek alternative methods (Tables 1 and 2), and the students’ opinions were equally spread among agree, neutral, and disagree $[\chi^2 (2 \times 3) = 0.03]$.

The complete analysis that put together the accomplishment for integrative aspects of both PBL learning goals and the skills developed during the practical activities was evaluated in the final exams. This analysis allowed us to assess students’ learning using different approaches in the practical classes. It revealed that there were no statistical differences among the groups’ grades in the third semester (group A = 7.3 ± 1; group B = 7.2 ± 1; group V = 7.2 ± 2; $P > 0.05$), showing that students’ learning was similar between the methods.

**DISCUSSION**

To date, this is the first study showing the association of PBL achievement with the students’ perception of their acquired knowledge through different approaches in physiology laboratory classes. Practical classes in the physiology syllabus for medical students may be a foundation for understanding concepts, enforcing learning, and complimenting other teaching approaches. This facilitates learning to employ meaningful and hands-on experiences that enable students’ practicing skill, required for future physicians (2, 13).

While practical classes are most common in traditional learning (29), in the PBL curriculum the number of theoretical and practical classes is reduced, and students are encouraged to take self-guided study most of the time (8, 12). Due to some difficulties for Brazilian students adapting to the PBL method, our medical college implemented a hybrid curriculum in which some lectures and practical classes were introduced to supplement students’ learning needs (5). In the present study, we demonstrated that both approaches of the practical classes had a positive impact on students’ learning and motivated them toward self-studying. In addition, most students also agreed that these classes assisted them in the sedimentation of tutorial objectives, having a similar importance for learning the subject discussed in the tutoring unit. Other studies have also already introduced laboratory classes in the PBL curriculum and obtained good results (2, 3, 12). Azer et al. (2) showed that students’ feedback after the introduction of integrated laboratory classes in their PBL curriculum was positive and most encouraging. Furthermore, the authors demonstrated that these classes encouraged students to develop meaningful learning and to enhance their short- and long-term retention.

Studies have shown that the learning process is enhanced by laboratory work engagement (20). Although videos also demonstrate the animal experiments conducted in a laboratory class, live observations involve a significant emotional experience, which changes students’ neural circuitry and facilitates storage of new knowledge (2, 13, 20). In addition, the intrinsic heterogeneity and unpredictability of the experiments allow scholars to make observations, interpret data, raise hypotheses, integrate basic physiology principles, and develop meaningful

Table 4. Topics of 5-point Likert questionnaire applied to medical students who participated in virtual classes from group V and the number (percentage) of “strongly disagree,” “disagree,” “neutral,” “agree,” and “strongly agree” responses for each topic

| Likert Questionnaire                                                                 | Virtual, Students’ Views |
|-------------------------------------------------------------------------------------|--------------------------|
|                                                                                     | SD  | D  | N  | A  | SA |
| Knowledge acquisition and motivation                                               |     |    |    |    |    |
| The practical classes with video/computer activities helped me to understand and remember the structures visualized and the physiological phenomena discussed in the theoretical classes. | 3 (3) | 14 (13) | 12 (11) | 47 (43) | 32 (30) |
| The scene visualization and animal images in the practical classes with video/computer activities had a positive impact on my learning. | 2 (2) | 12 (11) | 18 (17) | 47 (43) | 29 (27) |
| My motivation for studying the discipline related to the practical classes with video/computer activities was stimulated. | 9 (8) | 23 (21) | 27 (25) | 33 (31) | 16 (15) |
| The importance of reinforcing PBL learning goals                                    |     |    |    |    |    |
| The practical classes with video/computer activities assisted in the tutorial objectives sedimentation in the related module. | 1 (1) | 9 (8) | 10 (9) | 57 (54) | 30 (28) |
| The practical classes with video/computer activities have the same importance for learning the theme discussed in the theoretical class. | 2 (2) | 30 (28) | 21 (19) | 37 (34) | 18 (17) |
| Skills acquired                                                                      |     |    |    |    |    |
| During practical classes with video/computer activities, new skills useful for my academic development were acquired. | 5 (5) | 21 (20) | 24 (22) | 45 (42) | 12 (11) |
| Need for animal use                                                                   |     |    |    |    |    |
| Based on my experience in practical classes, it is fundamental to use and manipulate animals in practical classes. | 13 (12) | 22 (21) | 15 (14) | 44 (41) | 13 (12) |
| Academic formation without animals use                                               |     |    |    |    |    |
| Medical students can be professionally well prepared without using animals in practical classes in Human Physiology. | 8 (7) | 31 (29) | 28 (26) | 30 (28) | 11 (10) |

Values are n, no. of responses (with percentage in parentheses) to a 5-point Likert questionnaire. PBL, problem-based learning; SD, strongly disagree; D, disagree; N, neutral; A, agree; SA, strongly agree.
learning. On that account, the changing of animal laboratory classes to video demonstrations has received some criticism, since it limited the value of practical classes and encouraged passive learning (2, 14).

Indeed, our data indicated that, when the same students compared both approaches, virtual activities were not as effective as animal use in many aspects of their perceptions (knowledge acquisition/motivation, the importance in reinforcing PBL learning goals, skill acquired). However, when we compared students submitted only to virtual or only to animal laboratory physiology classes, the impact on their learning perceptions was similar. Besides, no differences in the final exam scores among the three cohorts were found, indicating that students can learn physiology concepts with virtual or animal laboratory class formats.

As far as skill acquisition was concerned, we have shown that, even though students who learn from virtual activities might lack hands-on skills practice, they still develop crucial abilities, such as “information technology skills” and “data analysis.” Most importantly, students from both groups similarly reported “physiology, anatomy, and pharmacology understanding” as a skill acquired after practical classes. These data showed that students who had experienced virtual classes are not necessarily less skilled regarding physiology concept learning. Indeed, competency in computing skills is essential these days, owing to the widespread use of computers and the abundance of computer-based resources available for supporting teaching and learning in the medical sciences (17, 18).

At this point, we raise an important ethic discussion about the need for animal use in practical classes and alternative methods. Despite the fact that most students from the three groups agreed that live animals are important in physiology-applied classes, they do not have a clear perception whether their academic formation could be impaired without it. Besides, up to 12% of students from the animal laboratory class group believed their learning was impaired, and at least 3% refused to participate in these classes. These data showed that some students took part in these classes, but, at the same time, felt uncomfortable with animal manipulation and live experiment observation. In addition, it is likely that some of them were concerned about the number of rats used and their welfare. These concerns are potential social and emotional barriers for the development of cognitive abilities and attention, resulting in learning impairment, even with outstanding teaching approaches (6). However, our data demonstrated that animal laboratory classes did not urge most students to question the methodology and to seek alternative methods equally effective in teaching.

Similar results have helped to raise this discussion. Rochelle et al. (24) demonstrated that dentistry and pharmacy students agreed that animal use is important for physiology and pharmacology learning disciplines. However, as depicted in our study, many scholars expressed mild to average discomfort when live species were used, and some of them refused to participate in practical classes, mainly from the pharmacy course. These authors also observed that students had a divided opinion about animal replacement by alternative methods. Most pharmacy students agreed that animal use should be replaced by alternative methods, whereas the majority of dentistry students disagreed.

Several studies have shown that students using virtual laboratories designed to offer alternative approaches to the traditional physiology practical class can learn similarly or even better than those using live animals (10, 11, 25). Moreover, the use of substitute methods can demonstrate a number of advantages, such as 1) reduction in teaching time and costs; 2) clear visualization of drug effects with less chance of experimental errors; 3) demonstration of difficult preparations using the computer; 4) students’ individual observation and observation at their own pace; 5) application to visual, audio, and kinesthetic learners; and 6) repeated observation of the experiments (18, 19, 22, 26, 27). In our institution, we experienced most of these advantages, which contributed to encouraging other professors to replace animal use by alternative approaches.

This study had some limitations. Having used a cross-sectional design, we applied the questionnaire for all students after the end of the transition from animal laboratory to virtual physiology practical classes in the same week, i.e., just after the last group of students participated in the virtual practical classes (group V), but ~1.5 yr after the first group participated (group A). This time frame could have had an impact on students’ answers. Nevertheless, the perceptions from groups A and V about the different methods were very similar, showing it was not an important aspect that interfered in our results. Also, due to study design, it was impossible to apply a test before and after intervention to assess students’ knowledge acquisition about only one issue and to evaluate short- and long-term retention. For this reason, we only analyzed the average of the final exam score obtained from the module in the third semester related to physiology concepts, when the transition in practical classes happened for group B.

In conclusion, our data indicated that animal use in physiology classes greatly enhanced students’ experience and learning, especially in the cohort that compared both animal and virtual laboratory activities. However, when these approaches are isolated and applied, students’ perceptions and the impact on their final scores are equivalent, indicating that undergraduates can also learn using virtual approaches. Thus, although video/computer activities are not as effective as in vivo protocols in student opinions, they are ethical strategies that can be used in practical physiology classes and are associated with the hybrid PBL educational method.

ACKNOWLEDGMENTS

We thank all of the medical students who volunteered to participate in this study. We also thank Carla Kitanishi Antonietto for technical assistance in preparing practical classes with animals and Paul Christopher Tobitt for revising the English text.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

M.d.T.D., C.B.A.R., and R.B.B. conceived and designed research; M.d.T.D. and C.B.A.R. performed experiments; M.d.T.D. and M.F.Jr. analyzed data; M.d.T.D. and C.B.A.R. interpreted results of experiments; M.d.T.D. and A.C.D.W. prepared tables; M.d.T.D., C.B.A.R., and A.C.D.W. drafted manuscript; M.d.T.D., C.B.A.R., L.B.C., and R.B.B. edited and revised manuscript; M.d.T.D., C.B.A.R., A.C.D.W., M.F.Jr., L.B.C., and R.B.B. approved final version of manuscript.

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