Adv Physiol Educ 49: 862–870, 2025.
First published August 5, 2025; doi:10.1152/advan.00093.2025

ADVANCES IN PHYSIOLOGY EDUCATION

EDUCATION RESEARCH

Effects of blended active methodology on learning about blood pressure control, students' perception, and test-induced stress and anxiety

Fernanda Klein Marcondes,[1,2] Lais Tono Cardozo,[1] Patricia Oliveira Lima,[1] Karina Reche Casale,[1] and Maria Antonia Ramos de Azevedo[2]

[1]*Department of Biosciences, Piracicaba Dental School, University of Campinas (UNICAMP), Piracicaba, São Paulo, Brazil and* [2]*Study and Research Group in University Pedagogy, Department of Education, Institute of Biosciences, State University of São Paulo (UNESP), Rio Claro, São Paulo, Brazil*

Abstract

This study aimed to analyze the effect of blended active method (BAM) on blood pressure (BP) control learning, pretest stress and anxiety, and students' perceptions. With approval from the institutional ethics committee, two freshman Dentistry classes were assigned to either a traditional method (TM; $n = 50$) or BAM ($n = 49$) group. All students completed the State-Trait Anxiety Inventory (STAI) and provided saliva samples for cortisol and alpha-amylase measurements at baseline and before the exam. The TM group attended two lectures on BP control. In BAM, *class 1* involved team discussions of clinical scenarios involving BP alterations. Before *class 2*, students watched pre-class videos with embedded questions (Edpuzzle) and completed an interactive online lesson (Lt-Kuracloud) with exercises and immediate feedback. In *class 2*, students took an individual test and, in teams, analyzed which BP control systems were activated in the previous scenarios, explaining the physiological responses involved. In *class 3*, both groups completed the STAI, performed saliva collection, and a summative exam on BP control. Test scores were compared using *t* tests; anxiety and biomarker stress levels were analyzed with two-way ANOVA. BAM students achieved significantly higher exam scores (8.75 ± 1.17) compared to TM (7.27 ± 1.82). Before the exam, the TM group showed higher alpha-amylase, cortisol, and anxiety levels than BAM. According to student perceptions, BAM strategies effectively supported BP control learning. Overall, BAM improved learning outcomes and helped reduce pretest stress and anxiety compared to traditional teaching.

NEW & NOTEWORTHY This study demonstrates that a blended active method (BAM), combining team discussions, interactive online lessons, and formative assessments, improves learning outcomes and reduces pretest stress and anxiety in university students studying blood pressure control. Unlike traditional lectures, BAM provided immediate feedback and opportunities for collaborative problem-solving. The study also measured physiological stress markers (cortisol and alpha-amylase), confirming BAM's effectiveness in promoting both cognitive performance and emotional well-being in a higher education health sciences setting.

blended learning; cardiovascular physiology; innovative teaching; technology

INTRODUCTION

The control of blood pressure (BP) is a fundamental topic in health-related courses. In addition to understanding the morphology and physiology of the heart, blood vessels, and lymphatics, students are expected to integrate this knowledge with principles of hemodynamics. Initially, they need to understand how cardiac function (chronotropy and inotropy), blood volume, and peripheral resistance (vasoconstriction and vasodilation) influence systolic and diastolic pressure. From this knowledge, they should be able to identify and understand which responses are activated by control systems to maintain BP and ensure adequate tissue perfusion in physiological situations in a healthy organism, such as during physical exercise (1). Furthermore, learning about BP control equips future healthcare professionals to recognize the pathophysiological mechanisms of cardiovascular diseases.

In the Dentistry course, it is necessary for students to understand that, although they are not responsible for diagnosing or treating patients with cardiovascular diseases, they will play a fundamental role in the clinical practice of identifying potential patients with heart problems and referring them for the necessary treatment. Dental patients often experience anxiety and fear regarding treatment, which can increase BP. In addition, during the anamnesis, the dentist may identify signs indicative of cardiovascular alterations, making it necessary to advise the patient to consult a cardiologist and be able to clarify any questions they may have about these alterations.

In this context, active methodologies can be useful as they facilitate the understanding of content and the integration of knowledge, increase students' interest, and promote a learning environment in which they learn without fear of making mistakes, collaborating with their peers (2). Additionally, it

Correspondence: F. K. Marcondes (ferklein@unicamp.br).
Submitted 21 April 2025 / Revised 16 June 2025 / Accepted 25 July 2025

1043-4046/25 Copyright © 2025 The Authors. Licensed under Creative Commons Attribution CC-BY-NC 4.0.
Published by the American Physiological Society.

Downloaded from journals.physiology.org/journal/advances at CAPES-UNESP (200.145.035.211) on May 26, 2026.

has been observed that active learning contributed to students' confidence in the knowledge they have acquired, reducing the stress and anxiety associated with exams (3).

Moreover, considering the difficulty young people have in maintaining attention during long theoretical lectures, as they are constantly connected to mobile devices and exposed to multiple simultaneous and appealing stimuli (4–6), incorporating technology into the teaching and learning process can also enhance student engagement (7). During remote teaching in 2020, we observed that combining active learning strategies on digital platforms with formative assessments helped first-year students in a health-related program better organize their out-of-class study routines. According to the students' own perceptions, this approach provided them with a greater sense of confidence regarding their learning (8, 9). After returning to in-person classes in 2022 and 2023, we combined face-to-face strategies with online activities. This integration has contributed to making classroom sessions more dynamic, as part of the theoretical content is delivered through pre-class videos, while individual study is supported by the Lt-Kuracloud online platform. In-person sessions include brief, dialogued theoretical lessons and team activities featuring educational games and clinical case discussions.

Building on this previous teaching experience, the aim of this study was to evaluate whether the use of a blended active methodology could enhance dental students' understanding of BP control systems and help reduce exam-related anxiety and stress.

MATERIALS AND METHODS

Ethical Considerations and Experimental Design

The study involved freshmen from the Piracicaba Dental School at the University of Campinas, enrolled in the mandatory Biosciences II course, over a 2-year period (2019 and 2023). This study was approved by the Research Ethics Committee of Piracicaba Dental School, University of Campinas. In 2020 and 2021, due to the COVID-19 pandemic, the Biosciences II course was delivered through remote learning. In 2022, in-person classes resumed, but we chose not to conduct the study that year, as it was difficult to predict the students' condition, considering their levels of stress and anxiety, which could influence the results. Therefore, the blended active learning group was implemented in 2023.

For the first group ($n = 73$), the traditional teaching methodology for BP control systems consisted of two theoretical lectures in 2019. The second group ($n = 66$) participated in the course with blended active methodologies in 2023. Of these, 50 and 49 students, respectively, agreed to participate in the study and signed an informed consent form. These students participated in all the teaching and assessment activities and did not report any pathology that could influence stress and anxiety levels or learning, such as a diagnosis of learning, neurological, or psychiatric disorders.

It was necessary to evaluate whether there were differences in prior knowledge required for learning cardiovascular physiology between the groups, as this could introduce a bias in interpreting the results. Therefore, a diagnostic test was administered in the first class, consisting of four tests on topics covered in the previous semester related to neuromuscular physiology. To ensure that the students did not have any prior knowledge of physiology that could facilitate their understanding of the topics studied, which could have positively influenced their performance in the assessments, results from students who were retaking the Biosciences II course, had prior experience with a human physiology course at another educational institution, and had completed any other higher education course in the health field were excluded of the study.

The sequence of activities, analysis, and teaching strategies on BP control systems used is presented in Fig. 1.

Assessment of Stress and Anxiety Levels

Baseline stress and anxiety levels were determined in the first physiology class of the Biosciences II course, which took place during the first week of the semester. This timing was chosen because there would be no exams, assignments, or other evaluative activities in any of the courses the students were taking, thereby controlling for the effect of stress due to assessment. Additional saliva samples and State-Trait Anxiety Inventory (STAI) (10) were administered 15 min before the BP control exam (Fig. 1), between 8 and 10 AM to control the influence of circadian rhythm on cortisol secretion, according to Cardozo et al. (3).

Stress levels were assessed by measuring the concentration of salivary cortisol and alpha-amylase, an enzyme whose secretion increases in response to sympathetic stimulation of the salivary glands and is considered a biomarker of stress (11). For saliva sample collection, after hand antisepsis with 70% alcohol, students received a Salivette container, which contains a sterile cotton swab. They were instructed to place the cotton swab in their mouth and move it around for 5 min to stimulate salivation. The saliva-soaked cotton swab was then placed back in the Salivette tube and kept in an ice container (11). Immediately afterward, the tubes were centrifuged for 2 min at 1,000 *g*, and the saliva was stored in 1-mL aliquots in Eppendorf tubes at $-70°C$ for later measurement of cortisol and alpha-amylase using enzyme immunoassay kits from Salimetrics (11). Samples were assayed in duplicates according to the manufacturer's instructions.

Anxiety levels were determined using the validated Portuguese version of STAI (10). This questionnaire consists of 20 questions and is divided into 2 parts: the first pertains to the participant's state, and the second to the trait of anxiety at the moment (10). STAI was applied immediately after the collection of the saliva samples (3).

Learning Assessments

The impact of the teaching methodologies on learning was determined by the grades obtained in a summative assessment (exam) administered in *class 3*. The same assessment was given to both groups participating in the study (Fig. 1). This exam consisted of two scenarios describing cases of BP changes:

1) João is an engineer who enjoys trying different kinds of food. One day, at a street party around lunchtime, he decided to try a colorful mayonnaise. A few hours later, he began experiencing severe abdominal pain, which led to intense watery diarrhea that lasted until the early

Downloaded from journals.physiology.org/journal/advances at CAPES-UNESP (200.145.035.211) on May 26, 2026.

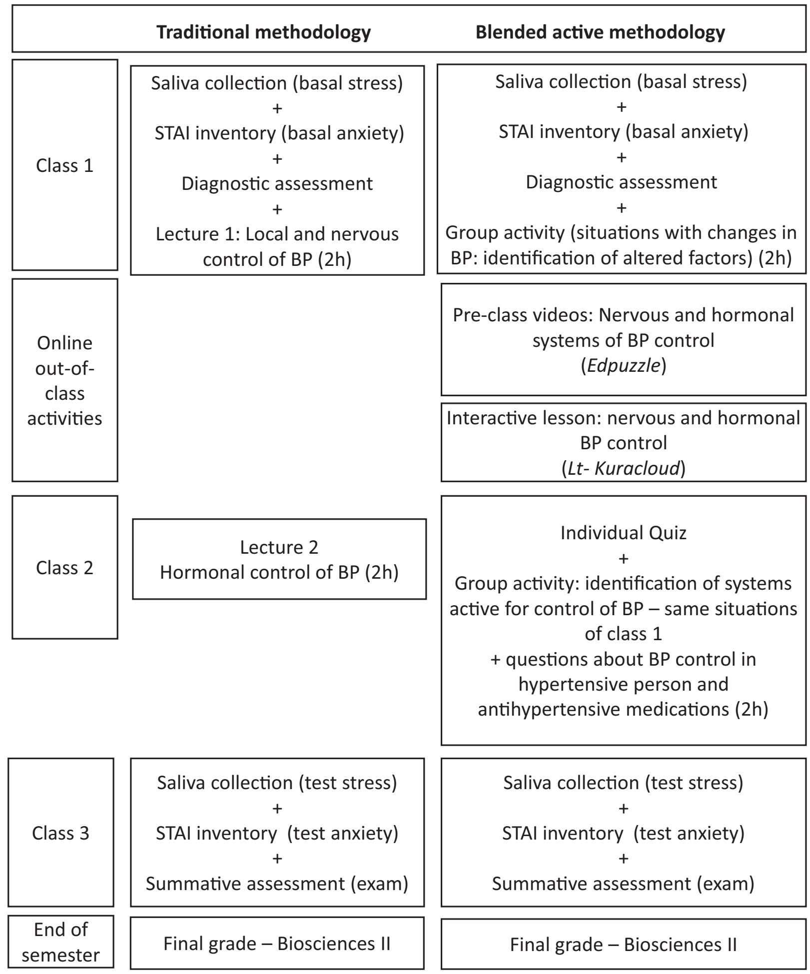

Figure 1. Sequence of activities and teaching strategies on blood pressure (BP) control systems. STAI, State-Trait Anxiety Inventory.

hours of the morning, when he sought help at an urgent care facility, approximately eight hours after ingestion.

2) Maria has a habit of always adding extra salt to her food during meals. She has noticed that some of her clothes are fitting more tightly and that her urine output has increased — in other words, she has been urinating more frequently.

Students were required to identify whether BP had increased or decreased and indicate which BP control systems were activated and what cardiac, vascular, and renal responses these systems mediated in each situation. They were also asked to specify if there was an indication of any reflex response already activated and what that response would be. This assessment aimed to verify whether students had understood the topic studied and could apply it in practical situations.

To control for potential differences between the groups related to the teaching-learning process (e.g., one group "studying more" or "having more interest in the topics" than the other), the final averages of the students in the course that included the research project were compared. If differences existed in this regard, differences in the summative assessment scores could not be attributed solely to the teaching strategies used. Each learning assessment was graded on a 10-point scale, as well as a diagnostic test applied in the first class of Biosciences II.

Teaching-Learning Methodologies

The traditional methodology consisted of two expository theoretical lessons on the nervous and hormonal control of BP, respectively, in which the instructor used PowerPoint slides. During the theoretical explanation, the professor presented situations involving changes in BP, described the altered factors (blood volume, heart rate, and contractile force, vasoconstriction, or vasodilation), and explained how the body senses BP changes. She detailed the activation of the baroreceptor system, the renin-angiotensin-aldosterone system, antidiuretic hormone, and/or natriuretic hormone, as well as the mechanisms of action of neurotransmitters, hormones, and medicines involved in BP regulation. The scenarios addressed included the following:

1) Dental stress: During a dental appointment, the dentist checked the patient's pulse and measured their BP using a sphygmomanometer after taking the medical history and before starting treatment. The patient reported not having hypertension or any heart condition. Their heart rate and BP were 70 beats/min and 110/70 mmHg, respectively. The dentist then explained the procedures to be performed, including the reason for and method of administering local anesthesia. About 10 minutes after the treatment began, the patient said they were afraid of feeling pain and reported experiencing palpitations

Downloaded from journals.physiology.org/journal/advances at CAPES-UNESP (200.145.035.211) on May 26, 2026.

(their heart was beating faster and more forcefully). The dentist then stopped the procedure and measured the patient's pulse and BP again. Based on the information above, what change would likely be observed in the patient's BP during the second measurement?

2) Hemorrhage: Almost daily, we hear in the media about serious traffic accidents caused by drivers who were under the influence of alcohol. The deaths and injuries resulting from these accidents are related to the severity of the trauma and hemorrhaging. During a hemorrhage caused by such accidents, a large volume of blood may be lost. What change occurs in BP in the case of severe hemorrhage?

3) Physical exercise: During physical exercise, active skeletal muscles must receive increased blood flow, and cardiac activity is elevated. What change occurs in BP?

These lectures were followed by guidance for home study on the content covered in class: textbooks and scientific articles were recommended for reading, and students were encouraged to either email their questions to the professor or bring them to the following classes.

For the blended active methodology group, at the beginning of the semester, the instructor organized 16 teams following the principles of team-based learning (12). To form the groups, the professor created a list with the names and final grades of the students in the Physiology course from the previous semester. First, the students were ranked from highest to lowest average. The top 16 students were numbered from 1 to 16. Then, the remaining students were organized from the lowest to the highest average and also numbered from 1 to 16, repeating this sequence four times. Students with the same number were assigned to the same team; 16 teams were formed, each consisting of 5 students. In this approach, teams were intentionally diverse, taking into account students' performance in a basic course offered in the previous semester. This ensured that each team included students with varying levels of difficulty, avoiding the formation of teams based on personal friendships. This rationale was explained to the students, emphasizing the aim of fostering the development of teamwork skills, essential in the professional environment, which should be independent of personal affinities.

Blended active methodology involved the following sequence of in-class activities and asynchronous activities conducted on digital platforms.

Class 1: Team Activity

In *class 1*, the students were divided into teams and analyzed the same BP-related scenarios that had been presented to the traditional methodology group. In each situation, the teams identified whether BP increased or decreased and which factors were altered (blood volume, heart rate, and contractile force, vasoconstriction, or vasodilation). During this activity, students were guided to reach consensus answers, engaging in discussions and helping each other to ensure that everyone in the team understood the answers. A collective discussion and correction session was conducted, led by the professor, who explained that in the next class, the teams would revisit the same situations to learn which BP control systems would be activated in each case to return BP to normal levels.

For the next class, activities were made available on digital platforms for students to study the BP control systems. No theoretical explanation about these systems was given during the class. Students were advised that they were expected to study in preparation to contribute to their team in the subsequent class, and that an individual assessment would be administered at the beginning of the session. The same textbooks and scientific articles recommended for the traditional methodology group were also recommended for the blended active methodology group, and the students in this group were likewise invited to send their questions to the professor by email or bring them to the following classes.

Online Out-of-Class Activities

Pre-class videos.

Three videos (5–10 min each) about BP control systems were made available on the free platform Edpuzzle to be accessed up to one day before *class 2*. These videos consisted of recorded theoretical explanations by the professor, including questions about the BP control systems. The videos would not progress until the questions were answered. Before selecting their answers, students had the option to review parts of the video. Participation was graded based on whether students watched the videos in their entirety and answered all questions, as recorded by the digital platform. It was explained that grades would be assigned based on completion rather than correct answers, as the goal was for students to learn about the topic and prepare to contribute to their team in the in-person class, taking responsibility for their learning.

The use of questions that students had to answer to continue watching the videos allowed them to check their understanding. This process of verifying learning is called formative or processual assessment, enabling both students and the professor to adjust their actions (13). This approach allows for the identification and review of unlearned content before the final exam or the end of the course (5).

Interactive lesson on Lt-Kuracloud platform.

For individual study, an interactive lesson was made available on the Lt-Kuracloud platform (ADInstruments) (8, 14). This lesson had to be completed over the following weeks and finished before the summative assessment. Students could access the platform on different days and times to complete it. The lesson included explanations with diagrams and exercises with immediate feedback, allowing students to check their learning and submit questions to the professor and teaching assistants. This interactive lesson complemented textbook study. As the exercises provided feedback on answers, the interactive lesson also served as a form of formative assessment, whose importance in the teaching-learning process has been previously explained.

Class 2: Individual Quiz

In the first part of this class (30 min), the pre-class video questions were projected on slides by the professor and were answered individually by students using the free Socrative app. This individual quiz allowed the professor to assess the number of students who got each question right or wrong in real time. After the allotted time for each question, the teams discussed the question orally, fostering collaborative learning.

Downloaded from journals.physiology.org/journal/advances at CAPES-UNESP (200.145.035.211) on May 26, 2026.

Subsequently, the question was corrected through a general class discussion. During these discussions, doubts were addressed using the same slides from the pre-class videos or new slides prepared by the professor based on the errors and difficulties identified in the video platform reports.

The pre-class videos, the interactive class on the Lt-Kuracloud platform, and the individual quiz did not show real-life examples of when BP might change. They explained how the body senses these changes, which systems react to higher or lower BP, and how chemicals like neurotransmitters, hormones, and medicines help control BP.

Class 2: Team Activity

In the second part of this class (1 h and 20 min, with a 10-min break), teams received a worksheet with the situations described in *class 1* and discussed which BP control systems would be activated in each scenario, identifying the reflex responses triggered to correct the BP.

In addition, the teams also analyzed the following questions to integrate their knowledge of the physiology of BP control systems: *1*) In a hypertensive person, is the baroreceptor reflex also activated in the situation of dental stress? If so, is there a difference in how these reflex functions compared to a normotensive person? *2*) Considering the BP control systems, explain how the following antihypertensive medications work: diuretics, beta-blockers, angiotensin-converting enzyme inhibitors, angiotensin II receptor antagonists, and describe how they affect cardiac output and/or peripheral resistance.

This class was conducted with eight teams at a time, involving the participation of three professors and three teaching assistants who were available to clarify doubts. At the end of this class, the students were advised that an individual assessment would be administered at the beginning of the next class.

In the group blended active methodology, deadlines were set for the completion of the videos and the online interactive lesson before *class 2*, with participation grades assigned, rather than grades based on correct or incorrect answers, for these activities as well as for participation in team discussions during class. The aim of assigning this participation grade was to encourage students' individual preparation before the class.

Student Perception

At the end of the semester, the students in the blended active methodology group were invited to complete an online questionnaire on Google Forms about their opinion regarding the methodology used. They were asked to indicate whether the strategies employed had been useful for their learning, using a Likert-like scale: 0 = not useful for my learning and 5 = very useful for my learning. They were also asked to justify their responses in an open-ended question, explaining why each strategy had been considered not useful or useful for their learning. Similar justifications were grouped by frequency of occurrence, in absolute numbers and the percentage of students who selected each option.

The objective of this analysis was to evaluate how different strategies for promoting active learning impacted the teaching-learning process, investigating the reasons behind the positive effects observed with the use of the blended active methodology.

Statistical Analysis

The grades obtained in the learning assessments and the final averages in the Biosciences II course were compared using the Student's t test for unpaired samples. STAI scores and salivary concentrations of cortisol and alpha-amylase, at baseline and before the summative assessment, were compared using two-way ANOVA, analyzing the main effects of methodology (traditional and active) and assessment time (baseline and exam), as well as their interaction. When significant interaction was found, differences were identified using Tukey's test. The significance level was set at 5% (P value of 0.05).

RESULTS

There was no significant difference between the groups in the scores obtained on the diagnostic assessment (Table 1; $P = 0.6743$). The score on the summative assessment (exam) was significantly higher for the group that participated in classes using blended active methodology compared to the group that attended traditional lectures ($P < 0.0001$), with no significant difference in the final course grade between the groups (Table 1; $P = 0.0788$).

No significant differences were observed in baseline salivary cortisol ($P = 0.8420$) and alpha-amylase ($P = 0.8410$) levels as well as in anxiety scores ($P = 0.9386$) between the groups (Fig. 2). Before the exam on BP control, the group that attended theoretical lectures showed an increase in salivary cortisol ($P < 0.0001$; Fig. 2*A*) and alpha-amylase ($P = 0.0047$; Fig. 2*B*) concentration compared to their respective baseline values. In addition, before the exam, the traditional method group also presented higher salivary cortisol ($P = 0.0021$; Fig. 2*A*) and alpha-amylase ($P = 0.0039$; Fig. 2*B*) compared to the active blended group before the exam (Fig. 2). No significant difference was observed between baseline and pre-exam salivary cortisol ($P = 0.1260$; Fig. 2*A*) and alpha-amylase ($P = 0.8752$; Fig. 2*B*) values in the group that studied the topic through active methodology.

Anxiety levels increased compared to baseline values in both groups ($P < 0.0001$; Fig. 2*C*). Pre-exam anxiety scores were significantly higher among students who had attended theoretical lectures compared to those who had studied the topic using active blended methodology ($P = 0.0026$; Fig. 2*C*).

The results presented in Table 2 reflect the students' perceptions of the usefulness of various teaching strategies adopted for teaching BP control systems. Of the 49 students in the blended active methodology group, 45 responded to the questionnaire.

The results obtained indicate that, in the students' opinion, the strategies used favored learning about BP control systems. Regarding the justifications provided, students indicated that the team discussion of situations involving BP changes allowed them to identify the practical application of the concepts studied. Additionally, students reported feeling more comfortable asking questions and making mistakes and helping and being helped by their peers in a more

Downloaded from journals.physiology.org/journal/advances at CAPES-UNESP (200.145.035.211) on May 26, 2026.

Table 1. *Scores obtained by students in assessments following instructional activities on blood pressure control systems, using either a traditional methodology or blended active methodology*

Learning assessment	Traditional Methodology (n = 50)	Blended Active Methodology (n = 49)
Diagnostic assessment	6.56 ± 1.72	6.74 ± 2.41 (P = 0.6743)
Exam	7.27 ± 1.82	8.75 ± 1.17* (P < 0.0001)
Final course grade	8.12 ± 0.49	8.24 ± 0.64 (P = 0.0788)

Results are presented as mean ± SD. *Significant difference compared to the traditional method (Student's t test). Learning assessments and course grade were graded on a 10-point scale.

pleasant and dynamic learning environment. Concerning the pre-class videos and the online interactive class, they stated that these strategies allowed them to study the subject interactively, as they had questions to answer, helping them verify what they were or were not understanding during the study. Additionally, grading based on participation and individual tests changed the way students studied, organized their time, and engaged with the topics covered. It encouraged them to study not only for the exam but also helped them identify what they were or were not truly learning.

DISCUSSION

Our results demonstrated positive effects of the blended active methodology, as evidenced by improved performance and lower increase in stress and anxiety levels before the exam. However, this effect could potentially be attributed to differences in prior knowledge of physiology, study habits, or interest in the subject matter among the participating groups. Considering that no significant differences were observed between the groups in the diagnostic assessment or the final course grades, the difference found in the exam performance appears to be associated with the teaching methodologies employed.

These findings are consistent with a previous study that reported enhanced learning and reduced stress and anxiety before a cardiac physiology exam taught through an educational game combined with formative assessments, compared to a BP control systems exam taught through traditional lectures (3). Therefore, the findings of the present study reinforce the evidence that the use of active methodologies in academic settings improves learning outcomes while reducing test-related stress and anxiety, in comparison with theoretical lectures.

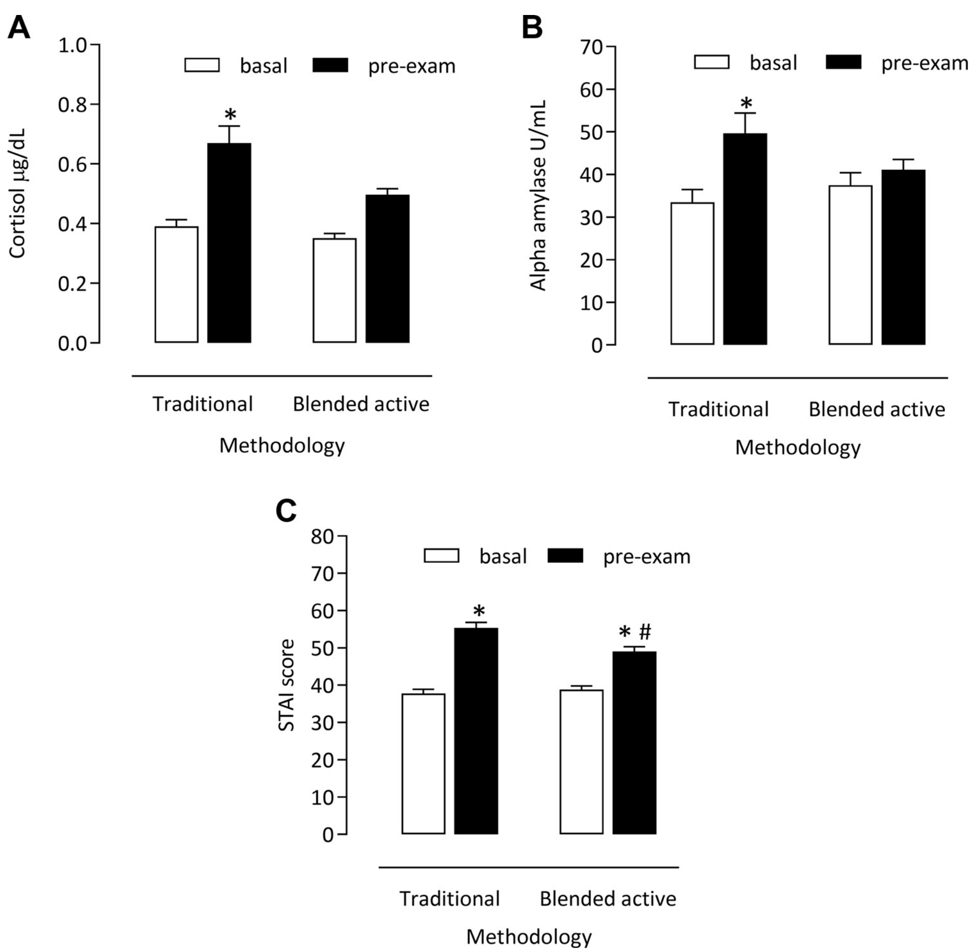

Figure 2. Salivary cortisol (*A*) and alpha-amylase (*B*) concentration and anxiety levels assessed by the State-Trait Anxiety Inventory (STAI; *C*) of students, before the exam administered after classes using traditional (n = 50) or blended active (n = 49) methodology, on blood pressure control. *Statistically different from baseline values within the same group. #Statistically different from pre-exam values in the traditional group (two-Way ANOVA + Tukey's test, P < 0,05).

Downloaded from journals.physiology.org/journal/advances at CAPES-UNESP (200.145.035.211) on May 26, 2026.

Table 2. *Students' perception of the usefulness of the strategies used in the hybrid active methodology group for learning blood pressure control*

Teaching-Learning Strategy	Answer (*n* = 45)
Team discussion on situations involving blood pressure changes during *class 1* and *class 2*	4.53 ± 0.59
Pre-class videos with questions (Edpuzzle)	4.24 ± 0.91
Interactive class with exercises and immediate feedback on the online platform Lt-Kuracloud	4.76 ± 0.53
Grading based on participation for pre-class videos, online interactive lessons, and in-class activities	4.60 ± 0.91

Results are presented as mean ± SD.

The variations observed in salivary concentrations of cortisol and alpha-amylase were within physiological ranges and confirm that emotional factors influence learning (21). Stress hormones can affect brain regions such as the hippocampus, amygdala, and bed nucleus of the stria terminalis, which play a role in learning associations and the formation of strong memories (23). The reduction in stress and anxiety before the exam may have supported reasoning by integrating and selecting memorized information to solve the proposed problems. This reduction in stress markers, along with the student perception results, suggests that in the blended active methodology, the variety of learning situations combined with formative assessments appears to have promoted a positive attitude toward organizing study routines and preparing individually to solve in-class and exam problems with greater confidence (3, 5, 23).

These results are also consistent with our previous study, which evaluated a methodology implemented during remote teaching (8). In that study, pre-class videos, educational games, team activities, and exercises on a digital platform were used to promote active learning in cardiac physiology and to encourage students' engagement in their learning process. Positive feedback from participating students indicated that these strategies contributed to better organization of their study routines and fostered a greater sense of confidence regarding the content learned.

According to students' perception, the positive effects observed in the present study may be related to the way the content was introduced. Rather than beginning with a theoretical explanation, sessions started with questions illustrating the practical application of the topic in everyday situations or dental clinical practice. This approach encouraged students to think critically about the material presented and to perceive its relevance to their future professional activities, helping to sustain interest in the class, the study material, and the proposed activities. When students fail to recognize the connection between course content and their future practice, they are more likely to lose interest (15).

Additionally, formative assessments played a role in the findings of the present study. In the traditional methodology, the instructor delivered the content, students studied at home, and learning was assessed through the exam. In contrast, in the blended active methodology used in this study, various formative assessments were applied: quizzes embedded in the pre-class videos, exercises in the online interactive lesson, team discussions, and an individual test. The students realized that the formative assessments allowed them to recognize what they had understood and identify their doubts. Therefore, they could adjust their study plans accordingly (13). Formative assessments are a fundamental premise of active learning methodologies, precisely because they enable process-oriented evaluation, that is, assessment of the teaching-learning process while it is still taking place (15, 16). On the other hand, when only summative assessment is applied at the end of the process, the class schedule typically does not include opportunities to recover unlearned content. In such cases, part of the knowledge that should have been acquired remains unlearned, which may undermine students' confidence in their knowledge and affect future learning of content, skills, and attitudes.

Also, the positive effects of the blended active methodology may be associated with the individual preparation before class and collaborative interactions in class. The use of digital platforms for flipped learning, in the present study, may have generated a more "pleasant and stimulating" learning process because students are digital natives and enjoy and are used to using electronic devices and digital tools (17). Medical students reported increased attention and engagement (18) and nursing students developed self-directed learning skills (19) during interactive online learning. Flipped learning offers flexibility, enabling students to learn at their own pace and monitor their progress through informal formative assessments.

Another factor to highlight is that, in the present study, assigning participation grades motivated students to prepare thoroughly for in-class activities, promoting a sense of responsibility not only for their own learning but also for their peers' learning (20). Students reported that during team discussions, they had the opportunity to receive help from peers at one moment and offer help at another, feeling more comfortable expressing their doubts. Such processes are unlikely to occur in a traditional lecture-based setting, where students primarily listen, watch, and receive information without sufficient time to process content and identify uncertainties (5). Another important point is that group activities in class were carefully planned and supervised by professors and teaching assistants to ensure that all team members actively participated and remained focused on solving the proposed problems. Interventions and guiding questions were directed at students when signs of disengagement were observed, such as inattentiveness or using mobile phones for unrelated activities. This strategy also addressed a common challenge in today's classrooms: students' difficulty maintaining focus and interest during lessons and academic activities.

Participation within teams was actively encouraged, fostering a sense of belonging: a key factor in academic success during higher education. In this environment, students were able to develop communication and argumentation skills (21) within a safe space for learning, where they felt comfortable expressing doubts, making mistakes, and learning from them (22, 23). These processes may contribute to greater confidence

Downloaded from journals.physiology.org/journal/advances at CAPES-UNESP (200.145.035.211) on May 26, 2026.

in their learning during summative assessments, which helps explain the reduction in anxiety and stress observed.

Despite evidence of the positive effects of blended learning, it is necessary to consider that its implementation requires investment in infrastructure and personnel. Students must have access to a good internet connection and mobile devices, which should not be limited to mobile phones, since the quality of images and procedures may be restricted compared to tablets and computers. The investment in personnel refers to the need for teachers to have available time to prepare activities and provide feedback on formative assessments. Additionally, for group activities in large classes, it is often necessary to have monitors available to supervise the groups and guide students with their questions and problem-solving.

In contrast to the findings of the present study, some authors have reported no significant differences in the academic performance of students exposed to active learning methodologies compared to those taught through traditional approaches (24–26). Although most of these studies noted increased student engagement and more favorable attitudes toward active learning strategies, they failed to demonstrate measurable improvements in learning outcomes. Moreover, these studies often lack details regarding how the active or innovative methods were implemented, the extent of peer collaboration involved, or whether activities were guided and supervised by instructors: critical factors highlighted in our study. Additionally, formative assessments, which played a central role in the teaching-learning process in this research, were not employed in those studies. It is important to note that simply shifting students from a passive role of receiving information to one of active participation does not automatically translate into improved learning or better preparation for applying acquired knowledge in future professional contexts (8, 15).

In the present study, the professor explained the proposed activities, asking students to reflect, both during in-class and extracurricular tasks, whether they were investing in their own learning, paying attention to the activities they were engaged in, and adequately preparing for group discussions. In this way, the goal was to encourage students' metacognitive skills, prompting them to consider whether they were taking responsibility for their own learning and adopting attitudes that would support meaningful, lasting learning. In this way, the students could think about their own learning process and the attitudes they adopt to support it (22).

This study followed a quasi-experimental design, as it involved two distinct cohorts of students from different academic years. Although efforts were made to maintain similar conditions between the groups, such as using the same instructors, content, and assessments, this design inherently limits internal validity, as it was not possible to control for factors unrelated to the intervention itself, such as differences in prior academic preparation, motivation, or external circumstances affecting each class. Therefore, we discuss the results while acknowledging that interpretations are limited to the specific conditions of the study, restricting broader generalizations.

To conclude, this study highlighted the positive impact of adopting a blended active methodology for teaching BP control physiology in higher education, which also helped reduce students' anxiety and stress levels before assessments when compared to conventional teaching approaches.

DATA AVAILABILITY

The raw data supporting the conclusions of this article will be made available by the authors without restriction upon reasonable request.

GRANTS

This study was supported by Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) Grant 2019/05987-4 (to F.K.M.); Fundo de Apoio ao Ensino, Pesquisa e Extensão, UNICAMP Grant 2288/20 (to F.K.M.); and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) Fellowship 140918/2019-1 (to L.T.C.).

DISCLOSURES

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

AUTHOR CONTRIBUTIONS

F.K.M. conceived and designed research; F.K.M., L.T.C., P.O.L., and K.R.C. performed experiments; F.K.M., L.T.C., P.O.L., K.R.C., and M.A.R.d.A. analyzed data; F.K.M., L.T.C., P.O.L., K.R.C., and M.A.R.d.A. interpreted results of experiments; F.K.M. prepared figures; F.K.M. drafted manuscript; F.K.M., L.T.C., P.O.L., K.R.C., and M.A.R.d.A. edited and revised manuscript; F.K.M., L.T.C., P.O.L., K.R.C., and M.A.R.d.A. approved final version of manuscript.

REFERENCES

1. **Silverthorn DU.** *Fisiologia Humana: uma Abordagem Integrada* (7th ed.). Editora Artmed, 2017.
2. **Xavier AR**, **Carrasco LB**, **Azevedo MA.** Pensar inovação curricular e pedagógica no contexto universitário: relações entre PPP e desenvolvimento profissional docente. *Braz J Dev* 6: 61312–61322, 2020. doi:10.34117/bjdv6n8-521.
3. **Cardozo LT**, **Lima PO**, **Carvalho MS**, **Casale KR**, **Bettioli AL**, **Azevedo MA**, **Marcondes FK.** Active learning methodology, associated to formative assessment, improved cardiac physiology knowledge and decreased pre-test stress and anxiety. *Front Physiol* 14: 1261199, 2023. doi:10.3389/fphys.2023.1261199.
4. **Abdulmajed H**, **Park YS**, **Tekian A.** Assessment of educational games for health professions: a systematic review of trends and outcomes. *Med Teach* 37, *Suppl* 1: S27–S32, 2015. doi:10.3109/0142159X.2015.1006609.
5. **Kulasegaram K**, **Rangachari PK.** Beyond "formative": assessments to enrich student learning. *Adv Physiol Educ* 42: 5–14, 2018. doi:10.1152/advan.00122.2017.
6. **Raes A**, **Vanneste P**, **Pieters M**, **Windey I**, **Van Den Noortgate W**, **Depaepe F.** Learning and instruction in the hybrid virtual classroom: an investigation of students' engagement and the effect of quizzes. *Comp Educ* 143: 103682, 2020. doi:10.1016/j.compedu.2019.103682.
7. **Al-Hariri MT**, **Al-Hattami AA.** Impact of students' use of technology on their learning achievements in physiology courses at the University of Dammam. *J Taibah Univ Med Sci* 12: 82–85, 2017. doi:10.1016/j.jtumed.2016.07.004.
8. **Cardozo LT**, **Azevedo MA**, **Costa R**, **Pessoa PT**, **Casale KR**, **Marcondes FK.** University pedagogy for emergency remote teaching of cardiac physiology during the covid-19 pandemic. *Physiol Mini Rev* 8: 4–11, 2021.
9. **Casale KR**, **Bettioli AL**, **Santos DA**, **Graciola MA**, **Pelissoni AS**, **Consoni JB**, **Marcondes FK.** Estratégias para promover a adaptação de alunos ingressantes à universidade no ensino remoto emergencial: oficinas de autorregulação da aprendizagem e plataforma online Lt-Kuracloud. *Rev Grad USP* 7: 33–42, 2023. doi:10.11606/issn.2525-376X.v7i1p33-42.
10. **Biaggio AM**, **Natalício L.** *Manual para o Inventário de Ansiedade Traço-Estado (IDATE)*. Centro Editor de Psicologia Aplicada-CEPA, 1979.

Downloaded from journals.physiology.org/journal/advances at CAPES-UNESP (200.145.035.211) on May 26, 2026.

11. **Lima PO**, **Calil CM**, **Marcondes FK.** Influence of gender and stress on the volatile sulfur compounds and stress biomarkers production. *Oral Dis* 19: 366–373, 2013. doi:10.1111/odi.12011.
12. **Bollela VR**, **Senger MH**, **Tourinho FS**, **Amaral E.** Aprendizagem baseada em equipes: da teoria à prática. *Medicina (Ribeirão Preto)* 47: 293–300, 2014. doi:10.11606/issn.2176-7262.v47i3p293-300.
13. **Hoffmann J.** *Avaliação Mediadora*. Mediação, 2019.
14. **Lima KR**, **das Neves BH**, **Ramires CC**, **Dos Santos Soares M**, **Martini VÁ**, **Lopes LF**, **Mello-Carpes PB.** Student assessment of online tools to foster engagement during the COVID-19 quarantine. *Adv Physiol Educ* 44: 679–683, 2020. doi:10.1152/advan.00131.2020.
15. **Marcondes FK**, **Cardozo LT**, **Azevedo MA.** *Metodologias ativas no ensino superior: o que o professor deve saber para que não seja um modismo?* In: *Metodologias Ativas – Modismo ou Inovação*. Editora IGM, 2021, p. 175–189.
16. **Kibble J.** Use of unsupervised online quizzes as formative assessment in a medical physiology course: effects of incentives on student participation and performance. *Adv Physiol Educ* 6: 253–260, 2019.
17. **Cortelazzo AL**, **Fiala DA**, **Piva D Jr.** *Metodologias Ativas e Personalizadas de Aprendizagem para Refinar seu Cardápio Metodológico*. Editora Alta Books, 2018.
18. **Gellisch M**, **Morosan-Puopolo G**, **Wolf OT**, **Moser DA**, **Zaehres H**, **Brand-Saberi B.** Interactive teaching enhances students' physiological arousal during online learning. *Ann Anat* 247: 152050, 2023. doi:10.1016/j.aanat.2023.152050.
19. **Bayram SB**, **Gülnar E**, **Ozveren H**, **Kan NC.** The effect of flipped learning on blood pressure knowledge and self-directed learning skills of first-year nursing students: a randomized controlled trial. *Nurse Educ Pract* 67: 103557, 2023. doi:10.1016/j.nepr.2023.103557.
20. **Fragelli R.** *Método Trezentos: Aprendizagem Ativa e Colaborativa, para Além do Conteúdo*. Penso, 2019.
21. **Downing VR**, **Cooper KM**, **Cala JM**, **Gin LE**, **Brownell SE.** Fear of negative evaluation and student anxiety in community college active-learning science courses. *CBE Life Sci Educ* 19: ar20, 2020. doi:10.1187/cbe.19-09-01862.
22. **Carvalho CG**, **Campos Junior DJ**, **Souza GA.** Neurociência: uma abordagem sobre as emoções e o processo de aprendizagem. *Rev Univ Vale Rio Verde* 17: 1–10, 2019. doi:10.5892/ruvrd.v17i1.5619.
23. **Dehaene S.** *É Assim que Aprendemos*. Editora Contexto, 2022.
24. **Smallhorn M.** The flipped classroom: a learning model to increase student engagement not academic achievement. *Success* 8: 43–53, 2017. doi:10.5204/ssj.v8i2.381.
25. **Knutstad U**, **Småstuen MC**, **Jensen KT.** Teaching bioscience to nursing students-what works? *Nurs Open* 8: 990–996, 2021. doi:10.1002/nop2.709.
26. **Sourg HA**, **Satti S**, **Ahmed N**, **Ahmed AB.** Impact of flipped classroom model in increasing the achievement for medical students. *BMC Med Educ* 23: 287, 2023. doi:10.1186/s12909-023-04276-3.

Downloaded from journals.physiology.org/journal/advances at CAPES-UNESP (200.145.035.211) on May 26, 2026.