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Student response to a cooperative learning element within a large physiology class setting: lessons learned

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Student response to a cooperative learning element within a large physiology class setting: lessons learned. Adv Physiol Educ 44: 269–275, 2020; doi:10.1152/advan.00165.2019.—Physiology students grapple with large amounts of subject content and hence memorize facts to pass examinations. In parallel, students display limited critical-thinking and creative skills, integration abilities, and/or a deeper engagement with subject content. This study aimed to assess the feasibility of introducing active learning methods (cooperative learning) in a relatively large class to final-year undergraduate physiology students (Bachelor of Science stream) at Stellenbosch University in South Africa. An assignment designed to enhance active and engaged learning was made available to the students (n = 225) during the second week of a 5-wk cardiovascular physiology series of lectures. Students were instructed to freely form working groups (n = 3/group) and the assignment was due by the end of the module. Student groups were expected and encouraged to continuously work on the assignment (outside class time). Three cooperative learning slots were also created during class time, with the lecturer and postgraduate students acting as guides. After the module, students anonymously completed an electronic questionnaire. This study revealed three major findings in terms of implementing cooperative learning in large classes within a South African context, i.e., 1) relatively good reception by students with some indication of group work; 2) it is logistically feasible in relatively large classes, although adequate support is crucial; and 3) additional measures need to be adopted to ensure its success.

active learning methods; cooperative learning; undergraduate physiology classes

INTRODUCTION

Physiology students grapple with large amounts of subject content and typically memorize facts to pass tests and examinations. Some students can, therefore, display “surface” versus “deep” learning that results in relatively limited acquisition of critical-thinking and creative skills, integration abilities, and/or a deeper engagement with subject content. This occurs due to a multitude of underlying factors, with a key one being that students are sometimes expected to act as spectators during the learning process that occurs within classrooms (10, 17). Such problems stem from the passive mode of information transfer (from lecturer to student), referred to as “passive learning,” that still dominates in many tertiary institutions (9). By contrast, active learning approaches encourage students to engage far more with the subject content by not only “doing” but also thinking about what they are doing within the classroom setting (10). Active learning includes numerous activities, e.g., quizzes, pair-share exercises, and cooperative learning, and is increasingly encouraged as a meaningful way to improve student performances and to also promote a more inclusive classroom environment (8). There is strong evidence that active learning methods work, e.g., a survey of pre/posttest data for 62 introductory physics courses revealed that active teaching methods resulted in improved conceptual and problem-solving test results, although the author was unable to distinguish the underlying factors responsible for this (12). Moreover, others have shown that there is good evidence that active learning, student-centered approaches work better than more passive approaches (8, 13).

This study aimed to bridge this knowledge gap by employing Chickering and Gamson’s (5) principle of cooperative learning, where students work together in small groups (inside and outside the classroom) with the aim to enhance active learning and to increase student engagement. Here the lecturer is expected to play a more meaningful role to help students construct knowledge and also by creating a suitable classroom environment to achieve this goal. Such an approach should also expand critical/creative thinking abilities to solve real-world problems (7). However, despite the evidence available for active learning interventions, its adoption within classrooms has been relatively slow and only to a limited extent (20). Tharayil et al. (20) identified several underlying reasons that may explain this phenomenon, including concerns regarding 1) effectiveness of these new methods; 2) preparation time; 3) class time available to implement such activities in terms of the ability to cover the syllabus; and 4) student resistance. For example, some studies revealed that students responded positively to active learning strategies, while others reported mixed responses and resistance (2, 11). An important factor underlying student resistance is the issue of self-perception of their own learning. For example, a study evaluating physics students’ self-reported perception of learning with their actual learning showed that the perception of their own learning “can be anticorrelated with their actual learning under well-controlled implementations of active learning versus passive lectures” (6). Thus, even though students were learning more by active methods, lowered perceptions of learning may result in them rather preferring passive pedagogical methods (6).

In light of this, the present study set out to investigate student perceptions regarding the introduction of cooperative learning into the classroom of a relatively large undergraduate
physiology class at Stellenbosch University (Stellenbosch, South Africa). As students were not previously exposed to cooperative learning within a relatively large classroom setting, we expected that these data would be most useful to ensure its successful implementation.

METHODS

Subjects

The cooperative learning assignment was implemented during the cardiovascular physiology component of the Physiology 314 semester module (n = 225 students). This is a final year semester module for the Human Life Sciences stream of the BSc degree offered by the Faculty of Science at Stellenbosch University (Stellenbosch, South Africa). The cardiovascular component consisted of 16 lecture periods (each 45 min), with three lecture periods per week. The student cohort largely consisted of South Africans from diverse backgrounds. The entire 5-wk section was taught by a single lecturer who also facilitated the in-class group work.

Design

Early during the second week of the 5-wk cardiovascular physiology module component, a special assignment, designed to enhance active and engaged learning, was made available to the students. The students were given an initial briefing regarding cooperative learning and how exactly they should tackle the assignment within this context. This message was repeated on several occasions during the 5-wk module component. The range of assignment questions was in line with Bloom’s revised taxonomy for assessment (1). The assignment included several multiple-choice-type questions, the design of mind maps, writing an abstract after reading a journal article, reading a journal article and then answering questions regarding the content, designing a table to compare and contrast cardiac methodological approaches, and a medical case study with related questions to stimulate critical-thinking and problem solving.

The first section of the assignment consisted of 25 multiple-choice questions with five possible answers, whereas the rest of the assignment questions were as follow:

Question 1. Construct a mind map to show what happens to ejected blood just after the left ventricle contracted and as it now enters the aortic vessel. Include information regarding:

- The heart valve
- What happens to arterial walls and the pressures acting on it
- The nature of blood flow (pulsatile or nonpulsatile)
- Degree of pressure at this point.

How would aging impact on this step? What would happen as blood moves away and eventually into venous system (focusing on pressure)? (15 marks).

Question 2. Construct a mind map to show how the sympathetic nervous system affects heart rate, contraction, and blood pressure. In addition, indicate on this map how sympathetic activation can affect circulating free fatty acid levels with acute myocardial infarction. (15 marks).

Question 3. Construct a mind map that demonstrates compensatory mechanisms that are triggered in response to blood volume loss with hemorrhagic shock. Consider the impact of the loss of blood volume and how organs such as the brain and the kidney would play a role to restore arterial blood pressure and also blood volume. Thus a reflection of cross-talk between organs is also important in this instance. (15 marks).

Question 4. Your father just suffered a heart attack, and, upon your arrival at the hospital, you learned that they found elevated free fatty acids in his bloodstream. Additional tests reported increased carnitine palmitoyltransferase 1 (CPT1) activity. Explain to your relatives the sequence of metabolic events that may have contributed to your father’s condition. (15 marks).

Question 5. Carefully read the article entitled: “The CANTOS trial: one important step for clinical cardiology but a giant leap for vascular biology” by Baylis et al. (3). After reading, each member of your group should now complete a 70-word summary of the article to best sum up the key message(s). Thus there would be three different versions in terms of the summary of the article. After this is done, you can combine these three answers into a single one. Submit both the joint one as well as the three individually completed ones. Before submission of this answer, you need to complete a Turnitin analysis for this text. Only answers with a percentage <15% similarity will be accepted for evaluation. (20 marks).

Question 6. Reperfusion injury can lead to cardiac dysfunction. Devise an annotated diagram to explain this statement. Then proceed and construct a table that focuses on three emerging strategies to prevent lethal reperfusion injury. The table’s columns should include the following headings:

1. Principle of method
2. Practical feasibility
3. Strengths of method
4. Weaknesses of method

Question 7. Please read the article entitled: “Air pollution and cardiovascular disease” by Rajagopalan et al. (16) and answer the following questions. Note: it is key to substantiate all of your answers with proofs and mechanistic insights.

1. Do you think air pollution a concern in South Africa? Please substantiate your answer. (3 marks)
2. Do you think the issue of air pollution as a risk factor for cardiovascular diseases deserves attention in South Africa versus other pressing health concerns, e.g., tobacco smoking or alcohol abuse? (3 marks)
3. Drug abuse is also listed as a risk factor in Fig. 1 in Rajagopalan et al. (16).
   a. How would the drug cocaine act to exert effects on the nervous system? (2 marks)
   b. Can it trigger effects on myocyte electrical conduction? (3 marks)
   c. What impact would prolonged, heavy usage have on blood pressure? (2 marks)
   d. What impact would cocaine usage elicit in someone already suffering from coronary artery disease? (3 marks)

4. Refer to Fig. 2 in Rajagopalan et al. (16) and answer the following questions:
   a. What is the difference between atrial and ventricular fibrillation? What are the major clinical symptoms of each respective condition? (8 marks)
   b. Produce (your own, not copied and pasted) two ECG diagrams to compare atrial fibrillation versus the normal heart rhythm. (2 marks)

5. Why do you think persons with coronary artery disease will be especially vulnerable to the damaging effects of air pollution? (4 marks)

6. Imagine you are a senior physiology researcher who is keen to find a way to limit the damaging effects of pollution on the cardiovascular system. Now refer to the “Central Illustration” on page 2060 of the Rajagopalan et al. (16) article and select one of these pathways or regulators as a therapeutic target. Explain the rationale for your choice and how its inhibition/activation will affect the entire system in a beneficial way. Also think of any potential side-effects that this action may (or may not) trigger. In this case, you must choose a physiological target and not focus on lowering the pollution itself. (10). (40 marks).

Students were instructed to freely form working groups (n = 3 per group) and were informed that the group assignment was due by the end of the 5-wk period. Here, the rationale was that a smaller group...
size would be appropriate for the level of questions (pitched at a midlevel difficulty) set for this assignment. In support, previous work showed that smaller groups tend to perform slightly better academically than larger groups, and that it also leads to greater student satisfaction (18). We also allowed students to self-select their group members due to logistical considerations, as several students reside off-campus (in different neighboring towns), making it difficult to meet outside the fixed university time slots during the day. This is especially relevant in South Africa, which is saddled with one of the highest crime rates in the world and where personal safety is a major concern, especially at night times. The student groups were expected and encouraged to continuously work on the assignment (outside class time) as the module proceeded, while three of the module class periods (one each for weeks 3, 4, and 5 of the course) were specifically set aside for group work. These classes were part of the allocated lecture slots and not specially arranged ones. During such classes, the lecturer and three trained postgraduate students circulated between groups while engaging in Socratic type of discussions to promote critical thinking and reflection and to also act as sounding boards. Each student group was expected to submit its completed assignments for evaluation, with final marks awarded per group. This meant that each student in a particular group was awarded the same final mark. The assignment made up 30% of the final test mark of the students, for each student in a particular group was awarded the same final mark. The remaining 70% derived from a written test (covering cardiovascular physiology) that was completed a few weeks later.

Questionnaires

After completion of the written test, the students were requested to complete an in-house developed electronic questionnaire, consisting of “yes” and “no” type of responses, and also some questions using a Likert scale. Here 79 students completed the questionnaire, equating to a −35% response rate. Although repeated requests were sent to students (by e-mail) to complete the questionnaire, we still only managed to obtain a relatively low response rate. This was done to assess the students’ experience(s) of the learning process and also to gain insights (from their perspective) into whether they have indeed developed a greater and deeper understanding of the subject content. The data were anonymously collected, as the format of electronic questionnaire did not allow for the identification of respondents, and are presented as a percentage (out of total number of respondents).

Ethics

This study was approved (no. 9377) by the Research Ethics Committee (Human Research) of Stellenbosch University (Stellenbosch, South Africa) and also received institutional clearance. The online questionnaires were anonymously completed (after consent given), while written consent was obtained from each participant who took part in the focus group interviews. The participants were informed that they were completely free to express their honest opinions (positive, negative, neutral), and that nothing would be held against them as a result of this process. The participants were also reassured that they had the right to withdraw at any time, and that they were under no obligation to answer a question(s) they did not wish to. Data generated were securely managed and stored (password protected). The main findings generated by this study were also shared with the Physiology 314 class of 2019.

Data Analysis

The online survey data were collated and expressed as percentages for each of the respective question(s).

RESULTS

Our findings show that the students performed best in the multiple-choice-type questions, with relatively lower percentages obtained for the case study and abstract generation exercise (Fig. 1). Overall, the quality of the submitted work was of a relatively high standard and showed that a significant amount of effort was put into its completion. It also suggests that there was a relatively good and deeper understanding of the subject content covered. For example, for the mind maps, the students often expanded the concepts over several A4 pages to best ensure they produced comprehensive and complete answers to such questions. The marks obtained were relatively high compared with other assignments and tests completed at the third-year level, although they scored on the lower end of the scale for the case study and abstract tasks. We initially set out to determine whether the cooperative learning assignment was successful in terms of actual group work undertaken, and also from a logistical point of view when considering the large and densely packed lecture hall. In terms of group dynamics, students indicated that 23% completed the assignment by a division of labor with minimal group work. By contrast, 77% attempted to work as groups, with 42% in this case employing a mixed type of approach (Table 1). Similarly, 68% of respondents concurred with the statement that group work was useful, as it provided a better opportunity for discussions (Table 1). This suggests a reasonable degree of success, although addi-

Table 1. Student assessment regarding the nature of their group work for the assignment

| In terms of the group dynamics, how did the following apply in your case: | % |
| --- | --- |
| The group worked together for almost all questions. | 35 |
| The group did some questions together; the rest we assigned to specific members. | 42 |
| All questions were divided between us, so the group only existed on paper. | 23 |
| Would you prefer doing this assignment within a group setting, with opportunity for discussion, or by yourself, as part of a solo assignment? | 100 |
| Group setting: It provides better opportunity for discussions. | 68 |
| Solo assignment: I discuss the questions with my peers anyway. | 24 |
| Solo assignment: I don’t like group discussions. | 8 |

Values are percentage of students who chose each response.
tional measures should be considered to further increase effective group work. In terms of the logistics for the classroom group work, the students indicated that there was a reasonable degree of support (52% scoring >4) (Table 2). However, the data suggest that there is still room to improve the quality of help provided to students during the “active” classroom sessions.

Our findings also indicate that students were more likely to discuss and explain concepts with their fellow students during the classroom sessions (Table 2). They also showed a preference for peer discussions and group work outside of the classroom environment. However, the students felt that there was insufficient support available during the active classroom sessions (Table 3). With a total of four persons (lecturer plus three postgraduate students) assisting, this amounts to one individual being available for $18$ groups during such classroom sessions. Here, 64% of respondents indicated that additional support is required, with around one-half suggesting one or two more assistants be coopted. In terms of drawbacks, the students indicated that the venue itself was not ideal, together with the lack of adequate support during the active classroom sessions (Table 3).

We next evaluated the perceptions of students regarding the cooperative learning sessions that were held during class time. The majority of the respondents (69%) were happy with such learning sessions during class time, with only 18% expressing negative sentiments (Table 3). At the start of the assignment, only 19% were favorable toward the assignment, while this stance markedly shifted to 72% by the end of the lecture series (Table 4). We also assessed the perceptions of students regarding whether the completed exercise helped with their understanding of subject content, identifying weak points, and in terms of their test preparations. Overall, the students strongly indicated that the assignment assisted them in this regard (Table 4). Some students also felt (41–47% of the respondents) that cooperative learning enhanced a deeper understanding and integration of concepts and application skills (Table 5). In addition, they felt strongly regarding the promotion of creative and critical-thinking skills (Table 5).

### Table 2. Student perceptions regarding the quality of assisted classroom sessions

| Question                                                                 | Scale |
|--------------------------------------------------------------------------|-------|
| Rate the quality of help you received: (1 = poor, 5 = excellent)         | 0 3 45 42 10 |
| During the sessions, how often did you do the following: (1 = never, 5 = frequently) |
| Asked help from either lecturer or assistants                           | 14 42 31 10 2 |
| Asked help from the surrounding students                                | 10 24 37 21 8 |
| Explained an answer to surrounding students                             | 18 15 44 20 3 |
| Discussed a question with the surrounding students                      | 12 9 40 30 10 |
| Had peer discussions relating to the assignment, outside of class       | 6 10 35 32 17 |

Values are percentage of students who chose each response.

### Table 3. Student perceptions regarding the practicality/usefulness of assisted classroom sessions

| Question                                                                 | %    |
|--------------------------------------------------------------------------|------|
| Did you feel that there were enough people to assist you during the class sessions? |
| Yes, there were enough assistants.                                       | 36   |
| No, needed one or two more assistants.                                   | 49   |
| No, needed many more assistants.                                         | 15   |
| 100                                                                      |      |
| What were some of the drawbacks that accompanied this assignment?       |      |
| The venue did not accommodate proper help.                              | 26   |
| There was not enough time to get answers for my questions.              | 25   |
| I can’t focus in a class setting.                                       | 24   |
| There was not adequate time to prepare for the class sessions.          | 25   |
| 100                                                                      |      |
| Did you feel that the class sessions were a good use of your time?      |      |
| Yes, I find it a great use of lecture time.                             | 69   |
| Yes, but the session was too long.                                      | 13   |
| There were some benefits, but it should not have been in class time.    | 17   |
| No, it was a total waste of my time.                                    | 1    |
| 100                                                                      |      |

Values are percentage of students who chose each response.

### Table 4. Student perceptions regarding the usefulness of the cooperative learning assignment

| Question                                                                 | %    |
|--------------------------------------------------------------------------|------|
| At the beginning of the module, when first hearing about the assignment, were you favorable toward it? |
| Yes                                                                      | 19   |
| No                                                                       | 51   |
| Neutral                                                                  | 30   |
| 100                                                                      |      |
| If not, do you feel favorable toward this method of assessment now?      |      |
| Yes                                                                      | 72   |
| No                                                                       | 7    |
| Neutral                                                                  | 21   |
| 100                                                                      |      |
| Do you feel that the nature of the questions aided in your understanding of the topic? |
| Yes                                                                      | 83   |
| No                                                                       | 4    |
| Partial                                                                  | 13   |
| 100                                                                      |      |
| Did this assignment help you identify weak points in your interpretation of the work? |
| Yes                                                                      | 83   |
| No                                                                       | 17   |
| 100                                                                      |      |
| Did this assignment ultimately help you to prepare for tests/exams?     |      |
| Yes                                                                      | 73   |
| No                                                                       | 27   |
| 100                                                                      |      |

Values are percentage of students who chose each response.
support, case studies are known to promote critical thinking, for future interventions to ensure an even better outcome. In process regarding subject content, are particular areas to target concepts and problem solving, together with a deeper thinking (72% average) and the abstract writing (69% average) exercise, respectively high, with the lowest scores obtained for the case study answer would be shared with the rest of the group (19).

example, if one of the group members solves a problem, then the learning exercise, as it is known to offer significant benefits. For significant proportion of students benefitted from this cooperative meeting as a group to discuss and refine the respective answers. A mixed type of approach, i.e., dividing the questions but then still the questions among themselves. Others stated that they adopted outside classes, it is clear that, in some cases, there was only cooperative learning occurred both within the classroom and also trepidation and skepticism. Although the students indicated that ing, and hence it is likely they viewed the exercise with some utility in large classes. This question, therefore, requires further investigation, and our larger physiology classes offer a good opportunity for future studies in this regard.

Students with Some Indication of Group Work

Our data shows that the majority of respondents (close to 70%) indicated that they worked together as groups, with increased enthusiasm displayed at the end (72% positive) compared with the start (19% positive) of the assignment. The latter is not surprising, as the students were not previously exposed to cooperative learning, and hence it is likely they viewed the exercise with some trepidation and skepticism. Although the students indicated that cooperative learning occurred both within the classroom and also outside classes, it is clear that, in some cases, there was only “nominal” group work, with students choosing to simply divide the questions among themselves. Others stated that they adopted a mixed type of approach, i.e., dividing the questions but then still meeting as a group to discuss and refine the respective answers. Thus, in a broad sense, our findings indicate that it is likely that a significant proportion of students benefitted from this cooperative learning exercise, as it is known to offer significant benefits. For example, if one of the group members solves a problem, then the answer would be shared with the rest of the group (19).

The overall marks obtained for the assignment were relatively high, with the lowest scores obtained for the case study (72% average) and the abstract writing (69% average) exercise, respectively. This indicates that the application of knowledge/concepts and problem solving, together with a deeper thinking process regarding subject content, are particular areas to target for future interventions to ensure an even better outcome. In support, case studies are known to promote critical thinking, stimulate group discussions, and allow students to apply their knowledge to solve a particular problem(s) (14), while abstract writing involves a thinking process, i.e., “Thinking and writing are recursive processes: one often has to go back to go forward” (15).

Our findings also suggest that, from a student perspective, their understanding and integration of subject content increased, together with the development of critical- and creative-thinking skills acquired. As we did not include an end point in this study, e.g., a comparison of test marks obtained with previous years, it weakens such findings to some extent. Of note, a meta-analysis of 225 studies comparing traditional lecturing versus active learning—focusing on examination scores and failure rates in undergraduate science, technology, engineering and mathematics courses—provides some insights in this regard. The authors reported that active learning increased examination performances, together with a decrease in failure rates (34–22%) (8, 21). However, a limitation is that the authors found the greatest effects in small (n ≤ 50) classes, which leaves lingering questions regarding its applicability and utility in large classes. This question, therefore, requires further investigation, and our larger physiology classes offer a good opportunity for future studies in this regard.

Relatively Good Reception by Students with Some Indication of Group Work

Our findings also suggest that, from a student perspective, their understanding and integration of subject content increased, together with the development of critical- and creative-thinking skills acquired. As we did not include an end point in this study, e.g., a comparison of test marks obtained with previous years, it weakens such findings to some extent. Of note, a meta-analysis of 225 studies comparing traditional lecturing versus active learning—focusing on examination scores and failure rates in undergraduate science, technology, engineering and mathematics courses—provides some insights in this regard. The authors reported that active learning increased examination performances, together with a decrease in failure rates (34–22%) (8, 21). However, a limitation is that the authors found the greatest effects in small (n ≤ 50) classes, which leaves lingering questions regarding its applicability and utility in large classes. This question, therefore, requires further investigation, and our larger physiology classes offer a good opportunity for future studies in this regard.

Cooperative Learning Is Logistically Feasible in Relatively Large Classes, Although Adequate Support Is Crucial

The students derived benefits from the classroom sessions when they were able to be assisted. Although the lecture hall layout was far from ideal—narrow elongated design with a sharp, upward slope—only about one-fourth of the respondents indicated that this was a problem. A significant problem though was the lack of sufficient postgraduate student assistants to ensure all groups received adequate help. The data show that, when students were actually reached, then they were happy with the quality of help offered by the lecturer and the postgraduate student assistants. The undergraduate students also indicated that they interacted more with their class mates during this time, and this is likely a beneficial outcome of the limited capacity to assist, as it “forced” the students to consult with their peers.

Additional Measures Need to Be Adopted to Ensure Future Success

Based on the student feedback obtained, we suggest several measures that can be introduced to ensure improved implementation of cooperative learning within relatively large undergraduate classes. 1) Students should be prepared well in ad-

Table 5. Student perceptions regarding academic development during cooperative learning assignment

| Question                                                                 | 1 | 2 | 3 | 4 | 5 |
|------------------------------------------------------------------------|---|---|---|---|---|
| How did the group work impact your physiology knowledge? (1 = no help, 5 = enormous help) | 8 | 22 | 30 | 22 | 19 |
| Have a deeper understanding of the work                                | 8 | 18 | 31 | 27 | 17 |
| Can better integrate information                                       | 9 | 17 | 27 | 28 | 19 |
| Can better apply information to real world situations                  | 12 | 15 | 36 | 22 | 15 |
| Long-term retention of knowledge                                       | 9 | 12 | 28 | 39 | 13 |
| Your creative-thinking skills                                          | 6 | 14 | 28 | 37 | 14 |
| Your critical-thinking skills                                          | 1 | 2 | 3 | 4 | 5 |

Values are percentage of students who chose each response.
vance regarding the notion of active learning and that they will benefit from activities such as cooperative learning. This is crucial, as the lack of such a briefing(s) may create negative perceptions regarding the adoption of active learning approaches and in terms of the sustained cognitive efforts that are typically required (6). 2) The introduction of online cooperative learning strategies should be considered as additional tools to help facilitate group work for students (4). This should help in cases where group work is harder for traveling students than for those residing on or around the university campus. However, this may not always be possible, as online access may not necessarily be available for students from resource-strapped homes. 3) The cooperative incentive structure is an important consideration to try and modify student behavior. This is crucial, as an excellent mark obtained by the group may only be due to one or two students who were responsible for major inputs, thus defeating the objective of the cooperative learning exercise (19). This may include awarding a group mark for the assignment (as done here), but also combining this with an individual assessment to test each student’s understanding of the subject content covered (19). In support, a review on the achievement effects of cooperative learning concluded that, “Cooperative learning methods that use group rewards and individual accountability consistently increase student achievement more than control methods” (19). Here the introduction of worksheets to be signed off by all group members, as an indication of their respective participation, may also be considered. Of note, the inclusion of such additional measures (individual assessments, worksheets) will increase the administrative and time burden placed on the instructor(s), which, in turn, may lead to increased resistance by faculty to adopt such active teaching methods. 4) An additional number of postgraduate student assistants should be co-opted to increase the degree of help available per group during the active classroom sessions. In this instance, we suggest a more rapid interaction between tutors and students to ensure all students have access to inputs/feedback. 5) Further studies are required to investigate a firm end point(s), i.e., more regular written tests being completed during the 5-wk module, and to then compare the marks with the respective student responses (before and after each test). 6) The assignment should be subdivided into several parts, with each part released on a weekly basis. This would mean more regular submissions by the students over the 5-wk period, and, if coupled with rapid (weekly) assessments, this should help them to identify weaknesses earlier in terms of their understanding of the course content and hence take remedial actions(s) as needed.

Limitations

The student response rate (35%) was relatively low, and this weakens our overall findings. Future studies should incentivize student responses to ensure a higher response rate. Moreover, the questionnaire was completed after the students received their assignment marks (but before their written test), and this may have influenced the final data generated.

In summary, cooperative learning is a feasible approach to implement in relatively large undergraduate classes, although it requires additional measures to ensure its successful implementation. It is also in tune with the needs of contemporary university students and has the potential to develop their understanding of subject content, together with critical-thinking and problem-solving abilities. In agreement, Goodman et al. (10) stated that, “As students learn more by doing physiology than by listening to and memorizing physiology, the solid foundation that they construct will benefit their lives and future careers as it strengthens their lifelong learning goals.” Such generic skills (critical thinking, problem solving, and teamwork) can, therefore, be relatively easily cultivated in undergraduate classes and is crucial to ensure suitable employment for graduates, especially within the Fourth Industrial Revolution context.

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DISCLOSURES

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

AUTHOR CONTRIBUTIONS

M.F.E. conceived and designed research; M.F.E. and L.B. performed experiments; M.F.E. and L.B. analyzed data; M.F.E. and L.B. interpreted results of experiments; L.B. prepared figures; M.F.E. drafted manuscript; M.F.E. and L.B. edited and revised manuscript; M.F.E. and L.B. approved final version of manuscript.

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