RESEARCH ARTICLE

Effects of self-experimentation during practical classes on student learning [version 1; peer review: awaiting peer review]

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Abstract

Background: This article reports an experiment based on the measurement of the academic achievement of students submitted to self-experiments during practical classes compared with students who attended regular practical classes (control group) to assess whether this intervention could help assess the influence of self-experiments on student learning. Methods: This study involved 71 students in the second terms of the degree of Bachelor of Pharmaceutical Sciences, studying the Cell Biology unit. Experiments were conducted using the students themselves as subjects under conditions that mimic situations observed in daily life, fasting and ingestion of carbohydrates. The performance of students in health college student assessments and the degree of motivation in performing these experiments was assessed at the Anhanguera college, Brasilia, Brazil. In total, 33 students (46.5%) participated actively in the experiment and the rest only observed the experiment carried out by the first group. In Cell Biology, the students study cell types, cell components and their respective functions, during one term, with a total workload of 60 h.

Results: In the test that preceded the experiment carried out in the present study, the grades of the students that participated actively and of those that only observed were not statistically different (p > 0.05). In the test applied after the experiment, both groups reached higher grades (p < 0.01), but the individuals that participated actively in the experiment obtained higher grades than those that only observed it (p < 0.05).

Conclusions: The findings of this study indicate that active learning, in which the students use their own organism and blood in practical classes, can increase their grades in knowledge tests. The teaching tool showed in the present study is a positive alternative for university students in health sciences.

Keywords

Self-experiment, active-learning method, motivation to study, practical class
Introduction
Several studies have shown that active learning is more attractive and generates more interaction than passive methods. Among active-learning strategies, some studies point out that practices that mimic routine activities increase learning compared to practices without this characteristic. For example, the use of virtual patients by medical students can increase their degree of learning, and the use of case-based learning increases deep learning, the involvement of students, and their interest in content. Problem-based learning (PBL), which frequently involves simulations of real situations (e.g., diagnosis of a hypothetical patient with some symptoms), has been an important tool to improve knowledge retention.

Another active-learning strategy that may increase academic achievement is the use of self-monitoring and self-assessment methods. For example, after answering questions of a knowledge test, when students are allowed to see their colleagues’ answers and revise their own answers, the number of correct answers increases. Evidence indicates that practices that involve both routine activities and self-monitoring promote even greater interaction of students for classes, as well as greater interaction during classes. A previous study submitted university students to the ingestion of pizza and pasta and the measurement of biochemical parameters. This method made it possible to cover important topics of metabolism in the final exam and to show how the metabolic machinery of the human organism reacts to different diets. In the period when this method was applied, the grades were higher than in previous periods. However, there was no control group, which hindered assessing the real efficiency of this method. Other studies in which the students used their own body (self-experiments) did not investigate the influence of this practice on learning.

The few reports on self-experiments frequently involve activities that are not part of the students’ routine.

As far as we know, there are no studies on the impact on learning of practical classes using the students’ own bodies in routine situations. A experiment based on the measurement of the academic achievement of students submitted to self-experiments during practical classes compared with students who attended regular practical classes (control) could help assess the influence of self-experiments on student learning. The present study shows a new active-learning method, which is more efficient than the methods commonly used in classrooms.

The present study aimed at analyzing the impact of self-experiments under conditions that mimic everyday situations – fasting and ingestion of carbohydrate-rich oral solution with glucose and fructose – on the achievement in exams of university students of health sciences and their degree of motivation and satisfaction in carrying out these experiments.

Methods
Experimental design
To analyze the impact of self-experimentation on learning in health sciences, randomly selected students from one class of university students studying Pharmacy participated actively in one experiment, whereas the other part only followed the study as observers. The students actively participating in the research were randomly divided into three subgroups; groups 1 and 2 (those who ingested glucose and fructose oral solutions, respectively) and group 3 (the fasting group). The experiment allowed the students to study some of the content comprised in Cell Biology. It involved the collection of blood samples of the students at times that mimic everyday situations – fasting and ingestion of different carbohydrates. In addition, the effect of the experiment on the degree of motivation and satisfaction of students was assessed. According to a sample calculation performed using G*Power 3.1 software, the group should contain a total of 71 students of the second term the Bachelor of Pharmaceutical Sciences (33 active and 38 observers) to achieve a statistical power of 60% to achieve the objectives. A total of 33 students (46.5%) were randomly assigned to participate actively in the experiment and the rest observed the experiment carried out by the first group. In Cell Biology, the students study cell types, cell components and their respective functions, during one term, with a total workload of 60 h. The assessment of the students’ knowledge levels occurred through two written, closed-notes, and closed-book tests and the application of questionnaires on the topics studied in the classroom. The tests were the same for all groups. The study took place in March-April 2015.

Procedures of the control and treatment groups
After eight weeks of classes, the teacher applied the first individual test that assessed the knowledge level of the students about cell biology, which included lipids, carbohydrates, and cell organelles. The test results were revealed in the next class, one week later. After the first written test, the teacher (A.M.L.N.E.) told the students about the experiment that she intended to carry out and all agreed to participate. An anthropometric questionnaire was applied to the students, after they agreed to participate in the project and provided written informed consent. Then, a biochemical experiment was performed by the students. All students that participated actively in the experiment were asked to fast overnight for 12 h. The first capillary blood sample was collected in the morning after 12 h of fasting, at the beginning of class, by some trained students of the same class together with the researcher responsible for the project. The students that took part in the experiments had two other capillary blood samples collected at 30 and 120 min and were randomly assigned to one of the following conditions: fasting (fasting group), ingestion of 1 g/kg of glucose solution (glucose group, 17 students), and ingestion of 1 g/kg fructose solution (fructose group, 16 students). The fructose and glucose solutions were prepared with 5 ml/kg of water. The control group only observed sample collection and the experiment, i.e., observed all procedures, but did not donate blood or ingest any solution. The experiment was carried out in two class days separated by a week. In addition to taking part in or only observing the experiments, all students studied the content of the subject cell biology under the same teaching methodology: audiovisual aided lectures, in which the teacher allowed and stimulated student participation with questions and observations. The subtopics taught were: lipids, carbohydrates, proteins, enzymes, and cell metabolism, all correlated with the central topic of the subject. After the practical/experimental
part of the course, all students answered a questionnaire, available as Extended data21, in the classroom, with questions about motivation and the importance of the practical class to learning. After carrying out the experiment and answering the questionnaire in the classroom, all students did a second individual test with the contents of the subject Cell Biology.

Ethics and consent
This research project was approved by the Research Ethics Committee registered through the Research Ethics Committees (CEPs, acronym in Portuguese) and the National Research Ethics Commission (CONEP, acronym in Portuguese) also known as the CEP/CONEP system (approval number 19059513.3.0000.5372 and expert review nº 434.935). Written informed consent from all subjects involved was obtained for participation in the study.

Statistical analysis
To test for the homogeneity of qualitative variables between the “control/observer” and “active” groups, we used the Fisher exact test. To compare grades between groups before and after the intervention, we used the Mann-Whitney test. To test whether the grades before and after the intervention differed between groups, we used the Wilcoxon test. The software used for the analysis was R 3.0.1.

Results
Learning indicators
The objective of applying two tests about the topics of Cell Biology was to analyze the impact of self-experiments under conditions that mimic everyday situations – fasting, ingestion of water and carbohydrate oral solution ingestion (glucose or fructose) – on the achievement of university students of health sciences. In the test that preceded the experiment carried out in the present study, the grades of the students that participated actively and of those that only observed were similar (p > 0.05). In the test applied after the experiment, both groups reached higher grades (p < 0.01), but the individuals that participated actively in the experiment obtained higher grades than those that only observed it (p < 0.05; Figure 1 and Table 1). Test results for each student are available as Underlying data21.

Considering the differences between the subgroups of the students who participated in the experiment, there was no significant difference in grades among the subgroups fasting, glucose, and fructose (p > 0.05). Considering the differences within subgroups, only the students of the glucose and fructose groups showed an increase in their grades after the experiment (p < 0.05; Figure 2, Table 2)

Perception of practical classes
Over 90% of the students answered that learning is deeper when they have practical classes, that they are more important than theoretical classes, and that they are essential for learning. Over 70% of the students stated having high motivation. There was no difference in the distribution of answers in the questionnaire between the individuals that participated actively in the experiment and those that only observed it (Table 3). Raw survey results are available are available as Underlying data21.

![Figure 1](image)

**Figure 1. Effect of self-experiments on learning.** Comparison of achievement in tests between students who participated actively in the experiments and students who only observed them. *p < 0.05.
Discussion

This study showed that students that provide blood samples for biochemical experiments in practical classes obtained higher grades than students that only observed the experiment. After the application of this teaching method, the group of students that participated actively in the practical classes (by providing blood samples) obtained higher grades than the group of students that only observed the experiment. However, both groups increased their grades, as shown by the learning assessment tests. This increase in learning corroborates the results generated by several authors, which indicate the efficacy of active-learning methods and several studies that showed an increase in learning through the use of active learning\[22-25]. Nevertheless, most studies whose authors affirm that active-learning methods are better than others are based on theory, as they do not show experimental results or do not use proper control groups\[26]. Several studies with a proper control group did not observe differences in learning between active-learning methods and passive, traditional methods\[27,28]. Finally, some studies show that the use of active learning methods can even result in lower grades\[29,30].

These differences in results obtained with different learning methods suggest that other factors affect the efficacy of these methods and can occur regardless of the teaching method being more or less active. One of those factors seems to be the teacher’s behavior. For example, a teaching improvement tends to occur when teachers propose problems and questions, and stimulate a working atmosphere that give students freedom to take risks, make mistakes, and learn from their own mistakes\[31]. Indeed, the attractiveness of educational activities developed is higher in the physical presence of the teacher\[32,33]. Hence, we expect the learning strategies that provide the best learning atmosphere to be also the most efficient. The most

| Test                          | Active experiment participant? | N  | Average | SE  | 1ºQ | 2ºQ | 3ºQ | p-value  |
|-------------------------------|---------------------------------|----|---------|-----|-----|-----|-----|----------|
| Before self-experimentation   | No                              | 38 | 6.49    | 0.18| 5.50| 6.50| 7.00| 0.074    |
|                               | Yes                             | 33 | 6.92    | 0.20| 6.50| 7.00| 8.00|          |
| After self-experimentation    | No                              | 38 | 7.33    | 0.24| 7.00| 7.00| 8.00| 0.017    |
|                               | Yes                             | 33 | 8.11    | 0.23| 7.00| 8.50| 9.00|          |

1 Mann-Whitney test. SE, standard error.

**Table 1.** Descriptive statistics of the tests before and after self-experimentation by observer and active groups.

**Figure 2.** Effect of self-experiments on learning. Comparison of achievement in tests by students who participated actively in the experiment among the groups fasting, glucose, and fructose \*: p < 0.05.
### Table 2. Frequency and descriptive statistics for the active group.

| Variables                                      | Participants, n† | %† |
|------------------------------------------------|------------------|----|
| Total                                          | 33               | 100|
| Sex                                            |                  |    |
| Female                                         | 27               | 81.8%|
| Male                                           | 6                | 18.2%|
| Motivation                                     |                  |    |
| Low                                            | 1                | 3.0%|
| Medium                                         | 8                | 24.2%|
| High                                           | 24               | 72.7%|
| Learning is deeper in practical classes        |                  |    |
| No                                             | 2                | 6.1%|
| Yes                                            | 31               | 93.9%|
| Practical classes are more interesting than theoretical classes | | |
| No                                             | 3                | 9.1%|
| Yes                                            | 30               | 90.9%|
| Practical classes are essential for learning   |                  |    |
| No                                             | 1                | 3.0%|
| Yes                                            | 32               | 97.0%|
| Blood glucose levels                           |                  |    |
| Glucose group, mg/dL*                          |                  |    |
| Fasting                                       | 86.0             | [84.5; 93.0]|
| 30 min                                         | 141.0            | [120.0; 146.0]|
| 120 min                                        | 103.0            | [99.5; 119.5]|
| Fructose group, mg/dL*                         |                  |    |
| Fasting                                       | 87.0             | [69.0; 90.0]|
| 30 min                                         | 96.0             | [91.0; 100.0]|
| 120 min                                        | 88.0             | [84.5; 95.0]|
| Fasting group, mg/dL*                          |                  |    |
| Fasting                                       | 89.0             | [82.0; 92.5]|
| 30 min                                         | 98.0             | [90.5; 100.0]|
| 120 min                                        | 88.0             | [85.0; 95.0]|
| Age, years                                     | 26.0             | [20.0; 33.0]|
| Height, m†                                     | 1.6              | [1.6; 1.7]|
| Motivation to participate in practical classes†| 10.0             | [7.0; 10.0]|

†Unless indicated.

*Quantitative variables (median, interquartile range).

### Table 3. Descriptive statistics for the questions (Q1-Q5) answered by the students in active and observer groups.

| Variables                                      | Participated in the experiment | p-value* |
|------------------------------------------------|-------------------------------|----------|
| Motivation                                     |                               |          |
| Low                                            | No (N=38) Yes (N=33)           | 0.427    |
| Medium                                         | 4                             | 10.5%    | 1 3.0%    |
| High                                           | 11                            | 28.9%    | 8 24.2%   |
| Learning is deeper in practical classes        |                               | 0.594    |
| No                                             | 1                             | 2.6%     | 2 6.1%    |
| Yes                                            | 37                            | 97.4%    | 31 93.9%  |
| Practical classes are more interesting than theoretical classes | | |
| No                                             | 5                             | 13.2%    | 3 9.1%    |
| Yes                                            | 33                            | 86.8%    | 30 90.9%  |
| Classes in which the student participates actively are more motivating than regular classes | | |
| No                                             | 2                             | 5.3%     | 0 0.0%    |
| Yes                                            | 36                            | 94.7%    | 33 100.0% |
| Practical classes are essential for learning   |                               | 0.618    |
| No                                             | 3                             | 7.9%     | 1 3.0%    |
| Yes                                            | 35                            | 92.1%    | 32 97.0%  |

*By Fisher's exact test.
striking result of the present study was the higher increase in grades of the group of students that participated actively in practical classes compared to the group of students that only observed them. This finding corroborates positive results of methods that involve self-assessment of learning by the students14. To our knowledge, this is the first study that shows that a teaching method in which the students assess their own body promotes deeper learning. Other studies have already showed that classes involving education of students using their own body as a subject can bring benefits15,16, but no study has used control groups. One explanation for this phenomenon would be that this method ensures deep compulsory involvement of the student, which could increase their degree of attention and focus in the experiment and avoid distractions.

The results obtained by the students during the practical class could show them how the human organism responds to common everyday situations. In the groups that ingested carbohydrates, there was an increase in blood sugar and this increase was higher in the group that ingested glucose than in the group that ingested fructose. Similar to our experiment, several studies intended to measure blood sugar at the ingestion of glucose and fructose solutions17,18,19, and the everyday diet of people18,19. The lack of difference in grades in the test after the experiment among the subgroups that participated actively in the experiment (fasting, glucose, and fructose) indicates that the collection of one’s blood increases information comprehension and retention about the entire practical class and not only the result of one’s own organism or one’s own group. Hence, those that ingested glucose understood what occurs when one ingests fructose or remains fasting. This method may be more attractive to the students and may drive their attention. The data of the analysis of the three groups that participated in the experiment also corroborate that. The significant increase in the grades only in the subgroups that participated actively in the experiment (fasting, glucose, and fructose) indicates that the ingestion of solutions helped the students reach deeper learning compared to the students who only donated blood. The method used in the present study involves different forms of active participation and at the same time a study about the students’ own bodies at everyday situations and provides an active visceral learning.

Surprisingly, the motivation and satisfaction in doing experiments, which was measured through a questionnaire, did not differ among subgroups. This result was unexpected, as more active learning methods tend to generate more interest20,21. However, the lack of difference may be due to the participation, as observers, of the students that did not use their own bodies in the practical classes. This explanation is corroborated by the fact that over 90% of the students answered that practical classes are more interesting and provide deeper learning. Other studies showed different values. For example, although medical students and residents subjected to active learning are more engaged and interact more with each other (43%) and with the teacher (57%), they reported lower perception of the objectives of learning2. In another study, most medical students studying clinical biochemistry (73%) opined that an active-learning method was more motivating, aroused the interest in the subject, and increased learning2. Another explanation for the results of our study is a possible insensitivity of the questions used in the questionnaire to subtle perceptions of students. Maybe the application of qualitative questions could better define the relationship between motivation and teaching method.

We conclude that active learning, in which the students use their own organism and blood in practical classes, can increase their grades in knowledge tests. This method led to an increase in learning compared to the control group, which only observed the experiments. In addition, the analysis of the three subgroups that participated actively in the experiment showed that the students who ingested glucose and fructose solutions had a significant increase in their grades, whereas those students who remained fasting did not. Such a difference suggests that a method that combines two different strategies, active learning and self-assessment, increases attention. The teaching tool showed in the present study is a positive alternative for university students in health sciences.

Data availability
Underlying data
Figshare: Eduardo et al datasheet. https://doi.org/10.6084/m9.figshare.9725522.v21.

This project contains the following underlying data:

- Eduardo et al.2019 dataset2 observers.xls.xlsx (survey and test results for each student).
- Eduardo et al.2019 dataset1.xls (blood glucose levels before and after the experiment for each student actively participating in self-experimentation)

Extended data
Figshare: Eduardo et al datasheet. https://doi.org/10.6084/m9.figshare.9725522.v21.

This project contains the following extended data:

- QUESTIONNAIRE.docx (English translation of the questionnaire given to each student).

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

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