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Implementing an Active Learning Environment To Influence Students' Motivation in Biochemistry

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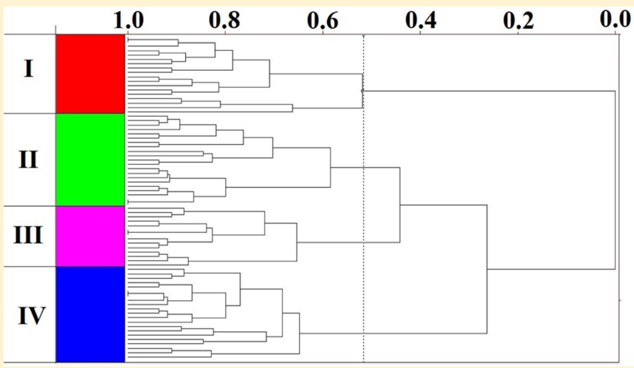
Supporting Information

ABSTRACT: The Biochemistry: Biomolecules Structure and Metabolism course's goal is to promote meaningful learning through an active learning environment. Thus, study periods (SP) and discussion groups (DG) are used as a substitute for lecture classes. The goal of this study was to evaluate how this learning environment influences students' motivation (n = 74). Motivation was evaluated by a questionnaire that was described in the literature and by comparing students' motivation in several courses. The results showed that the students had high achievement and low performance goals in this learning context. This indicates that students worked harder to learn than to get high grades. Students also had high self-efficacy, active learning strategies, and scientific learning values. Moreover, student's motivation in the active learning environment was higher than or equal to other courses in Pharmacy−Biochemistry. These results demonstrate that the active learning environment had a positive impact on students' motivation.



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FEATURE: Chemical Education Research

INTRODUCTION

The current landscape of Biochemistry Education presents many challenges for students and teachers. Several factors that indicate a need to revise how Biochemistry is taught to undergraduate students include an exponential growth of knowledge (especially in genomics and proteomics), the development of new technology, and difficulty articulating knowledge areas that were traditionally taught separately (Biochemistry involves overlaps with Biology, Physics, and Chemistry).[1,2] Moreover, there are important ethical questions that are complex and increasingly important.[2] These arguments justify the need to investigate teaching methods that attend to Biochemistry's formative demands.

Biochemistry is traditionally taught through lecture classes.[3] This passive method is an efficient and economical way to teach in masse. Nonetheless, purely lecture classes contribute little to overcoming the challenges in Biochemistry Education because they do not stimulate creative thinking, attitude or value formation, or collaboration between students for problem solving. Moreover, this method views students as passive receptacles, who tend to memorize rather than use prior knowledge to generate significance.[4−7] Changes in the Biochemistry Education landscape, as well as in the fundamental Sciences for comprehending Biochemistry, are indispensable. Thus, it is necessary to examine alternative teaching methods to lecture classes.

Over the past few decades, active teaching methods have been highlighted as a way to change classroom dynamics.[8−11] These methods have attracted those who search for alternatives to traditional teaching, even though skeptics consider active methods to be mere educational fads.[11]

Active learning can be defined as "the process of having students engage in some activity that forces them to reflect upon ideas and upon how they are using those ideas" (ref 12, p 5). This approach gives students the main responsibility for their own learning.[11,12]

Using active methods allows students to participate in activities that include analysis, synthesis, and evaluation, as well as exploring values and attitudes, rather than being passive receivers of information.[13] In passive methods, these activities are impossible. In active learning, the teacher's role is to provide activities that allow students to be active in constructing knowledge and problem solving. The teacher is also responsible for supervising students during the activities and providing

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feedback. The students' role is to establish/pursue goals to accomplish the activities and select the resources that are needed to meet their educational needs.[14,15] In contrast, in passive learning, the teacher is responsible for organizing and transmitting information. Thus, students (the passive recipients) are stimulated to memorize and reproduce what was transmitted by the teacher.[4,7] Moreover, in active learning, control of the learning process is transmitted from the teacher to the student (the teaching is centered on the student). Students do not constantly depend on the teacher because they appreciate collaborating with other students. As such, students collaboratively solve problems and the teacher provides guidance (instead of ready answers) for developing activities.[14] In contrast, in passive learning, the teaching is dependent on the teacher and students depend on the knowledge that is transmitted.[4,7] Therefore, students have more autonomy and initiative in active learning compared with passive learning, which results from more engagement in the teaching-learning process.[11]

These comparisons serve as the background for selecting the most efficient teaching method given Biochemistry Education's formative demands. From this perspective, we investigated an active learning environment in a Biochemistry course that was offered in the Pharmacy−Biochemistry undergraduate program of the Universidade de São Paulo (USP).

■ ACTIVE LEARNING ENVIRONMENT IN BIOCHEMISTRY EDUCATION

In the Biochemistry: Biomolecules Structure and Metabolism course (offered by the Biochemistry Department of the Chemistry Institute of the Universidade de São Paulo); students (75−90) are randomly divided into three groups (25−30 each) with three teachers (one for each group; they collaborated regularly to sustain the model being used). This course's goal is to promote meaningful learning through an active learning environment. Thus, study periods (SP) and discussion groups (DG) are used as a substitute for lecture classes.

Study Periods

Learning in small groups has vast support in the literature.[16−19] These dynamics allow students to execute tasks without direct supervision from the teacher.[16] In general, students who study in small groups have better academic performance and more positive attitudes than students who study with traditional teaching methods.[17] Moreover, small groups stimulate learning self-regulation strategies because studying in small groups allows for competency and motivational resource development, which are fundamental for students to be able to manage their own learning.[19] However, students must have clarity about the types and goals of the group work and perceive that their peers are competent and prepared to complete the proposed activities.[18]

In the SP, students are divided into groups of five. The teacher and teacher's assistant do not participate in the group composition because they are circling the classroom. They are responsible for orienting the students, without providing ready answers. Teachers and teacher's assistants stimulate the students' ability to think and discuss Biochemistry while providing the support needed to advance learning.

Students collaboratively solve questions in the SP. The questions, which are presented in the study guide, are from the inferior category in the Zoller[20] classification (LOCS, lower-order cognitive skills). Students can consult the book[21] to answer the questions, which is provided by the teacher at the beginning of the term.

In addition to the questions, the guide provides links to software that allow for the concepts to be visualized. The SP only ends after all groups have presented solutions to the questions. After this step, the students are ready for the DG.

Discussion Groups

In the DG, the smaller SP groups are united into a single group, which is composed of 25 to 30 students. The DG includes the teacher and teacher's assistant as part of the group. Students' desks are positioned in a way that allows each student to see everyone else, which helps to keep the discussion focused. The teacher starts the DG by explaining to the students that it is necessary to read the item proposed in the guide aloud. After this step, students are encouraged to propose solutions to the problem. At the beginning of the course, students hope that the teacher (or the teacher's assistant) confirms that the answer is correct. The teacher, in turn, asks students if they agree with the presented conclusions and does not provide the answers. Students are encouraged to discuss the solution with their peers until they reach consensus. Moreover, they are responsible for not allowing the group to advance in the discussion until there is no doubt about the discussed item. Thus, the SP and DG stimulate critical evaluation, group work and the capacity to debate.[22]

The problems discussed in the DG are situated at the superior level in the Zoller[20] classification (HOCS, higher-order cognitive skills). To solve these problems, students cannot consult the book.[21] Exposing ideas in the DG allows for alternative conceptions to be discussed and for doubts/difficulties to be shared. In this approach, the teaching is centered in the student, who actively participates in collaborative activities.

Besides that, students who actively participate in this course achieve the desired performance, it does not occur when they are absent. Having noted the active learning environment's characteristics, we now review students' motivation in this context.

■ ACTIVE LEARNING ENVIRONMENTS AND STUDENTS' MOTIVATION

Motivation, from the Latin *movere*, relates to action/movement.[23,24] In an educational context, motivation is used to explain the effort students invest in various activities. However, these activities may or may not be desired by the teacher.[25] Research on motivation attempts to explain the motives by which students work to reach determined goals, as well as the intensity and the time of the effort and the emotions and feelings that are characterized in the teaching−learning process.[26]

The students' motivation is strongly related to subjective experiences, specifically those related to the will and rationale for getting involved in academic activities and the social relationships that are established in the classroom context.[25,27] Consequently, motivation to learn is not merely the students' responsibility: it is also the result of the teaching provided to the students. Pozo and Crespo (ref 28, p 40) expressed this complexity by stating that "the students do not learn because they are not motivated, rather, they are not motivated because they do not learn [...]".

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Extrinsic and intrinsic factors influence the motivation to learn Biochemistry. Comprehending these terms is fundamental to this research, as quality and performance can differ when students are extrinsically or intrinsically motivated.[24] Moreover, self-efficacy, active learning strategies, and scientific learning values (or task values) are motivational factors that constitute motivation for scientific learning.[29]

Extrinsic motivation occurs when the student has a performance goal. Thus, the student competes with his peers and seeks attention from the teacher.[29] Extrinsic motivation is based on a system of rewards[28,29] that can be short-term (e.g., to get high grades, parents' money and prizes from the teacher) or long-term (e.g., to earn scholarships and get a good job).[25] For students who are extrinsically motivated, engaging in a task is a means to an end because they work hard to get high grades rather than to learn.[30] There is no doubt that extrinsically motivating students if effective, but it has limitations because learning depends on a socially defined desire.[28]

Intrinsic motivation occurs when the student has an achievement goal; in other words, the student experiences pleasure from learning.[29] These students get engaged in academic activities because of the challenge of the task, curiosity in the subject and interest in the required skills. Intrinsically motivated students participate in tasks as an end in itself, rather than being a means to an end.[30] As such, students work hard to learn rather than to get high grades.[28]

These distinctions provide evidence that it is desirable for learning environments to favor intrinsic motivation over extrinsic motivation. However, it is fundamental that when students are not intrinsically oriented, it is better to be extrinsically oriented than to be alienated from the learning environment.[30,31]

Another motivational factor that contributes to students' learning is self-efficacy.[29] This term can be defined as an individual's confidence in his ability to execute certain academic activities.[32] Efficacy perceptions influence compromise because students are more engaged in activities in which they feel competent and secure and less engaged when that does not occur. Self-efficacy also predicts the time and effort that students spend on a task; the higher the sense of efficacy, the higher student's effort and persistence. Moreover, self-efficacy influences students' thinking patterns and reactions: people with low self-efficacy believe that tasks are more complex than people with high self-efficacy.[33]

Students who take an active role in using a variety of learning strategies and who are capable of "managing" their own learning are prone to be more motivated and perform better.[29,34] They are stimulated to take responsibility when they study in active learning environments.[35]

The scientific learning value is also a motivational factor. Students become actively involved in scientific learning when they realize the task's value.[29] Learning environments that allow for social interactions allow students who have high task values to interact with their peers to develop academic activities and positively influence others who have low task values. These students may interact with the teacher to achieve high performance.[36] Thus, active learning environments contribute to students perceiving task values and influencing other students through collaboration. This does not occur in passive learning environments, as there is little (or no) interaction in developing academic activities.

There are several studies that indicate that active learning environments can contribute to students having high achievement goals (intrinsic motivation), high self-efficacy, active learning strategies and scientific learning values (or task values). The basic premise is that active learning strategies may be incorporated into the curriculum to stimulate students' active and autonomous role in the teaching-learning process.[37−40]

Given these considerations, it is evident that it is important to investigate how the active learning environment offered in the Biochemistry: Biomolecules Structure and Metabolism course influences students' motivation. The research on active learning has already examined similar questions. Nonetheless, the active environment analyzed in this study identifies characteristics that have not been explored in the literature. Moreover, few active learning studies have used more than one or two teaching strategies.[41] According to Gardner and Belland,[41] this lack of diversity in teaching studies may be because it is difficult to incorporate several strategies in a cohesive manner. This study examines several active strategies that were combined during classes (i.e., problem solving, software, collaboration, and discussion).

■ OBJECTIVE

The objective of this research was to analyze the effect of the active learning environment in the Biochemistry: Biomolecules Structure and Metabolism course on students' motivation.

■ RESEARCH QUESTION

What is the effect of the active learning environment in the Biochemistry: Biomolecules Structure and Metabolism course on students' motivation?

■ PROCEDURES

Data Collection

This study analyzed students' motivation in the first year of the Pharmacy−Biochemistry course (n = 74, which corresponds to 86% of enrolled students) during the Biochemistry: Biomolecules Structure and Metabolism course. Data were collected at the end of the course (the 15th week) in 2014. The students were asked to sign a consent form and before the data collection. They were informed about the purposes of this research and were aware that the data would be used only for academic purposes and disseminated with anonymity.

Questionnaire

The motivation questionnaire was described by Tuan, Chin, and Shieh.[29] Motivation was evaluated by 29 affirmations that were rated on a Likert scale with seven levels (1 = totally false and 7 = totally true) in five categories: self-efficacy, active learning strategies, scientific learning values, performance goals, and achievement goals. The original instrument was developed by Science Education; thus, small adaptations were made to the affirmations to match the context of Biochemistry Education (the questionnaire was translated from English to Portuguese).

After rating the category items, students compared their motivation in Biochemistry: Biomolecules Structure and Metabolism to other courses using the following scale: +3 = much higher; +2 = higher; +1 = a little higher; 0 = equal; −1 = a little lower; −2 = lower; −3 = much lower. In addition, students indicated the rationale for their ratings (see the Supporting Information).

Data Analysis

Hierarchical Cluster Analysis (HCA) was executed with support from the Pirouette software. The goal for this analysis

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was to group students according to similarities in their motivation responses. In addition, we calculated the means, the standard deviations, and percentages.

■ RESULTS AND DISCUSSION

Cronbach's Alpha was used to determine the questionnaire's internal consistency. Cronbach's Alpha values fluctuate between 0 and 1. Ideally, Cronbach's Alpha should be higher than 0.7. Nevertheless, this value is highly sensitive to the number of items in each category. Low values (e.g., Cronbach's Alpha equal to 0.5) are common in questionnaires that have few items (less than 10). As such, the literature recommends that we also calculate the item-total correlation values.[42] The item-total correlation is a largely used method to examine homogeneity in the responses. The minimum standard item-total correlation value is 0.2. Questionnaire items that have values lower than 0.2 should be discarded.[43] Table 1 shows the Cronbach's Alpha and the item-total correlation values for the motivation questionnaire.

Table 1. Cronbach's Alpha and Item-Total Correlation Values for the Motivation to Learn Biochemistry Questionnaire

Questionnaire Category	Number of Items	Cronbach's Alpha	Item-Total Correlation
Self-efficacy	7	0.78	0.35 to 0.65
Active learning strategies	8	0.78	0.39 to 0.60
Scientific learning values	5	0.72	0.36 to 0.61
Performance goals	4	0.55	0.32 to 0.51
Achievement goals	5	0.71	0.31 to 0.68

Cronbach's Alpha values for self-efficacy, active learning strategies, scientific learning values and achievement goals were acceptable (values ≥ 0.7) However, the Cronbach's Alpha for the performance goal category was less than 0.7. This may be due to the low number of items in this category; thus, it was important to verify the Item-total correlation. The values for this correlation were higher than 0.3, which indicates that the questionnaire has sufficient internal consistency to evaluate students' motivation.

Figure 1 shows the dendrogram obtained by the HCA for the data matrix X (74 × 5), which used students' responses from the motivation to learn Biochemistry questionnaire. The dendrogram branches indicate four groups of students (I to IV) that are 51.6% (0.516) similar. We calculated the ratio between the student's motivation and maximum motivation in each category, so the values been adjusted to 0 to 1.

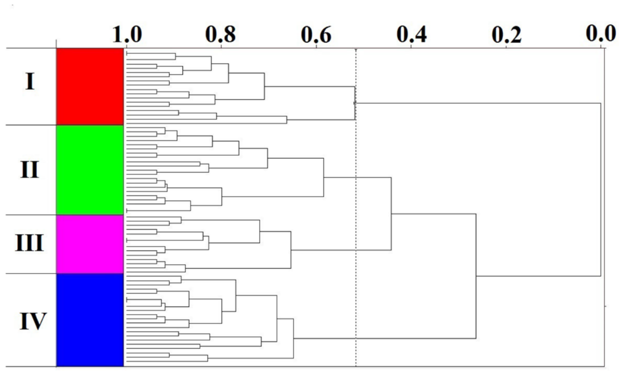

Figure 1. Dendrogram obtained by HCA using the Ward/Incremental method and Euclidean distance. The dashed line indicates that the students are 51.6% similar. Data matrix X (74 × 5).

After the groups were formed by the HCA (Figure 1), we calculated the mean values for each scale from the questionnaire (Table 2). This allowed us to characterize the students' groups according to each motivational factor that was examined in this research.

As suggested earlier, performance goals (extrinsic motivation) and achievement goals (intrinsic motivation) categories were combined in the analysis because it is better when students have high achievement goals and moderate or low performance goals.[30,31] Moreover, for students to be motivated, they must have high self-efficacy, active learning strategies and scientific learning (or task values).

Group I represents 24.3% of the students (n = 18). This group had low performance goals (0.29 ± 0.07) and moderate achievement goals (0.66 ± 0.12). Mean self-efficacy scores were also moderate (0.69 ± 0.10). High values were only indicated in the active learning (0.79 ± 0.08) and scientific learning values (0.78 ± 0.11) categories. Compared with the groups obtained by the HCA, we can infer that Group I was moderately motivated in the active learning environment that was offered by the Biochemistry course.

Groups II and III correspond to 28% (n = 21) and 19% (n = 14) of the students. In these groups, the values for the performance goal category were very low (group II, 0.24 ± 0.08; group III, 0.27 ± 0.06). This should have a positive effect on motivation because the opposite is true for achievement goals (group II, 0.81 ± 0.11; group III, 0.78 ± 0.11). Moreover, in group II, only the self-efficacy category (0.76 ± 0.07) had a value less than 0.8. The same pattern occurs for the achievement goal category (0.78 ± 0.11) in group III. Therefore, the students in these groups had high motivation.

Group IV corresponds to 28% (n = 21) of the students. In this group, the mean for the performance goal category was higher than the others groups scores, however; it was still low (0.47 ± 0.07). In contrast, the achievement goals value was very high (0.87 ± 0.09), which indicates a positive effect on motivation. The other categories had values higher than 0.8. Therefore, these students had very high motivation.

The joint presentation of the data in Table 2 allows us to infer that the students were intrinsically motivated (achievement goals) and had high self-efficacy, active learning strategies and scientific learning values (or task values). The same pattern did not occur for extrinsic motivation (performance goals). It is clear that each motivational aspect varied within each group, however; students were generally motivated in the active learning environment that was provided in the Biochemistry course. According to the results from the combined achievement and performance goal categories, students work harder to learn than to get high grades.[28] This reflects the active learning environment that was offered in the Biochemistry course, which allowed students to be involved in challenging activities that stimulated their curiosity. The results for self-efficacy (moderate and high values) indicate that the students were secure in their capabilities to execute academic activities.[32] This security made students feel competent and contributed to their investment and engagement in the activities.[33] Moreover, the means in the active learning strategies category had very high values (particularly for groups II–IV). This indicates that the learning environment stimulates students' capability to self-

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Table 2. Means and Standard Deviations after the Groups Were Formed by the HCA for Students' Motivation to Learn Biochemistry

	Mean Values (SD) by Group and Motivation Level			
	Group I, n = 18	Group II, n = 21	Group III, n = 14	Group IV, n = 21
Questionnaire Category	Moderate	High	High	Very High
Self-efficacy	0.69 (0.10)	0.76 (0.07)	0.96 (0.05)	0.87 (0.10)
Active learning strategies	0.79 (0.08)	0.91 (0.06)	0.94 (0.06)	0.91 (0.06)
Scientific learning values	0.78 (0.11)	0.95 (0.06)	0.90 (0.08)	0.90 (0.08)
Performance goals	0.29 (0.07)	0.24 (0.08)	0.27 (0.06)	0.47 (0.07)
Achievement goals	0.66 (0.12)	0.81 (0.11)	0.78 (0.11)	0.87 (0.09)

regulate.[35] Finally, the results for the scientific learning value category indicate that the active learning environment provided in the Biochemistry course, contributed to students valuing learning Biochemistry concepts through social interaction.[36]

Students also compared their motivation in the Biochemistry: Biomolecules Structure and Metabolism course to other courses using the following scale: +3 = much higher; +2 = higher; +1 = a little higher; 0 = equal; −1 = a little lower; −2 = lower; −3 = much lower. The teaching method of the other courses don't use SP and DG (traditional teaching/learning strategies), so this comparison is possible. The results are presented in Table 3 (negative scales indicate that students' motivation in the Biochemistry course was higher than in other courses and positive scales indicate the opposite).

Table 3. Response Frequencies for Students' Motivation Comparing Different Courses

	Frequency of Students' Comparative Scores,[a] %						
Course (n)	−3	−2	−1	0	+1	+2	+3
A (71)	54.9	36.7	7.0	0	0	1.4	0
B (72)	45.8	37.5	9.7	4.2	0	2.8	0
C (72)	16.7	33.3	27.8	13.9	4.1	2.8	1.4
D (72)	66.6	12.5	15.3	2.8	2.8	0	0
E (71)	39.5	19.7	21.1	16.9	2.8	0	0
F (70)	70.0	12.8	12.9	4.3	0	0	0
G (71)	14.1	19.7	31.0	29.6	2.8	1.4	1.4
H (72)	4.2	13.9	23.6	29.2	11.1	11.1	6.9
I (70)	8.6	17.2	20.0	37.1	5.7	7.1	4.3
J (72)	15.3	20.8	30.5	26.4	2.8	4.2	0
L (70)	15.7	27.1	28.6	21.4	2.9	0	4.3
M (70)	25.7	28.5	22.9	15.7	2.9	2.9	1.4
N (70)	32.9	21.4	24.3	18.6	1.4	1.4	0
O (70)	50.0	18.6	15.7	12.9	1.4	1.4	0

[a]Students made comparisons using the following scale: +3 = much higher; +2 = higher; +1 = a little higher; 0 = equal; −1 = a little lower; −2 = lower; −3 = much lower.

As shown in Table 3, students' motivation in the Biochemistry: Biomolecules Structure and Metabolism course was higher than or equal to other courses that were taken in the junior year of the Pharmacy−Biochemistry. For courses A to F and M to O, there were many low values on the motivation scale; for courses G to L, there was a high frequency of 0 (equal motivation). Moreover, to better understand the observed similarities and differences, students indicated which factors influenced their evaluations. The results are indicated in Table 4.

In Table 4, we observe that three factors greatly contributed to similarities and differences in the students' motivation. The results for content were expected because the concepts studied in Biochemistry are related to practicing as a Pharmacist. Therefore, students were motivated because this course was very relevant to the Pharmacy−Biochemistry profession. In contrast, the teaching method and affective factors arise from the active learning environment. The study periods (SP) and the discussion groups (DG) increase student−student and teacher−student interactions, which motivate the students. In addition, these students believed that the method was innovative. In sum, the results reinforce the positive effect of the active learning environment that is provided by the Biochemistry course on students' motivation.

Table 4. Distribution of Student Attribution of Factors Contributing to Their Motivation

	Factors Rated as Affecting Student Motivation,[b] %		
Scale[a]	Content	Teaching Method	Affective
0	1.4	5.4	5.4
1	0	5.4	4.1
2	0	5.4	4.1
3	2.7	1.4	6.8
4	4.1	6.8	2.7
5	13.5	8.1	18.9
6	28.3	24.3	12.1
7	50.0	43.2	45.9

[a]Students rated factors on a scale of 1−7, with 1 indicating contributed "little" and 7 indicating contributed "much"; 0 indicates "did not contribute". [b]n = 74.

■ CONCLUSIONS

We presented a study about the effects of the active learning environment offered in the Biochemistry: Biomolecules Structure and Metabolism course on students' motivation. The SP and DG strategies allowed students to actively participate in the teaching-learning process and are promising ways to overcome the challenges presented by the current Biochemistry Education landscape. The potential for SP and DG will continue to be explored for additional characteristics. In addition, we believe that the ideas presented here can easily be applied to other content areas and across teaching levels. However, as a lot of variables can interfere in the analysis of this learning environments, the extrapolations must be made with caution. Ultimately, this perspective contributes to developing teaching methods that promote engaging students in the teaching-learning process.

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■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00965.

Questionnaire to compare students' motivation in Biochemistry: Biomolecules Structure and Metabolism to other courses. (PDF)

Questionnaire to compare students' motivation in Biochemistry: Biomolecules Structure and Metabolism to other courses. (DOC)

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Notes

The authors declare no competing financial interest.

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