Perception of undergraduate students of a Brazilian University about the Biochemistry course

Percepção de estudantes de graduação de uma Universidade brasileira sobre a disciplina de Bioquímica

Pablo A. Nogara¹, Gabriela L. Schmitz², Luiza M. Eisenhardt³, Bruna L. T. Moura⁴, João B. T. Rocha^{1,2}, Cláudia S. Oliveira^{1,2,*}

¹Programa de Pós-Graduação em Ciências Biológicas: Bioquímica Toxicológica, Centro de Ciências Naturais e Exatas, Universidade Federal de Santa Maria, RS, Brazil; ²Programa de Pós-Graduação em Educação em Ciências: Química da Vida e Saúde, Centro de Ciências Naturais e Exatas, Universidade Federal de Santa Maria, RS, Brazil; ³Curso de Medicina Veterinária, Centro das Ciências Rurais, Universidade Federal de Santa Maria, RS, Brazil; ⁴Curso de Ciências Biológicas, Centro de Ciências Naturais e Exatas, Universidade Federal de Santa Maria, RS, Brazil.

*e-mail: claudia.bioquimica@yahoo.com.br

Support: CAPES/PROEX, CNPq, FAPERGS

Abstract

Biochemistry is an essential science that deals with the chemical bases of life, being an important discipline for several areas. Thus, the objective of this work was to evaluate the opinion of students about the Biochemistry course. An instrument, involving questions about the discipline, the professors, the monitors, and a self-evaluation was applied to 231 students from 12 undergraduate courses, divided into 3 areas of knowledge: Natural, Health and Rural Sciences. The majority of the students answered that they consider Biochemistry an important discipline, but they presented a reasonable comprehension of the contents, probably by a lack of chemical skills. The students consider the credit hour of the discipline sufficient but badly used. They said that the Professor performance is reasonable to good, and miss a correlation between the class and the professional acting, especially in the Rural Science. This study showed that the Biochemistry classes need to be rethought for the areas of action of each course. In addition, the students' basic pre-knowledge should be improved.

Keywords: Biochemistry; teaching; students' perception

Resumo

A Bioquímica é uma ciência essencial, que trata das bases químicas da vida estudada em várias áreas. Assim, o objetivo desse trabalho foi avaliar a opinião de estudantes quanto à disciplina de Bioquímica. Um instrumento, envolvendo questões sobre a disciplina, os professores, a monitoria e uma auto avaliação, foi aplicado para 231 estudantes, os quais já haviam cursado a disciplina, de 12 cursos de graduação, divididos em 3 áreas de conhecimento: Ciências Naturais, da Saúde e Rurais. A maioria dos alunos respondeu que consideram a Bioquímica uma disciplina importante, mas apresentam uma compreensão razoável dos conteúdos, provavelmente por falta de conhecimentos em química. Os alunos consideram a carga horária da disciplina suficiente, mas mal utilizada. O desempenho dos professores foi razoável a bom, mas falta correlação entre as aulas e a atuação profissional do curso, especialmente na Ciência Rural. Este estudo mostrou que as aulas de Bioquímica precisam ser repensadas para as áreas de ação de cada curso, além disso, os pré-conhecimentos básicos dos estudantes deve ser aprimorado.

Palavras-chave: Bioquímica; ensino; percepção dos estudantes

1 Introduction

Biochemistry studies the chemical basis of life. It concerned with the chemical constituents of living cells and with the reactions and processes involved. Several areas are encompassed by Biochemistry, such as Chemistry, Cell Biology, Molecular Biology, Genetics, Pharmacology, Physiology, among others (Figure 1). In addition, the study of Biochemistry can explain the origin of life, for instance, how simple molecules interacted and harnessed energy from the environment via chemical reactions to create and maintain living organisms [1-4].

Figure 1. Examples of courses encompassed by Biochemistry.

Biochemistry course is required for several undergraduate and graduate courses once this discipline combines concepts of Chemistry and Biology explaining various biological phenomena. The study of Biochemistry contents is imperative to understand the chemical and physical process that occurs in living organisms being important to undergraduate and graduate courses such as Chemistry, Nutrition, Medicine, Agriculture, Biology, Dentistry, among others. The knowledge of the nature of the chemical reactions is essential to understand the process involved in the genetic information transmission, cellular architecture, and metabolism. Understanding the Biochemistry concepts the student will be able to understand other subjects, for example, the metabolic process that is important to investigate the origin, causes, and cures of diseases, as well as the development and reproduction of the living organisms [4,5].

Different countries have different methods to teach Biochemistry subjects, varying from theoretical-expository classes to problem-solving classes. For example, the Australian researcher Shaw [6] reported that in the United States (Ohio State University and Wright State University), the Biochemistry students were challenged with problem-solving questions. On the other hand, Australians Biochemistry students attend basically to theoretical classes. In addition, countries such as Pakistan, Indonesia, Egypt, Sudan, India, Hong Kong, China, Taiwan, Portugal, Japan, and the Philippines had the

encouragement of the Education Committee of the International Union in Biochemistry, through congresses and lectures, to improve the teaching of Biochemistry at the academic level and also to discuss the problems faced by Professors and the possible solutions [7].

In Brazil, one of the first reports and/or evaluation on how the Biochemistry was being taught was carried out in the 80's by Zancan [8]. Briefly, a questionnaire was sent to all the Brazilian institutions that offered the Biochemistry discipline; the form of teaching and the positive and negative points in the Professor's view was evaluated. Ninety percent (90%) of the surveyed opted for an expositive theoretical class and the majority uses audiovisual resources. The most frequent method of evaluation was discursive tests. The main weakness cited by the Professors were the library, the laboratories, and the students' quitting. A report by Vella [9] indicated that the major problem of Biochemists in Brazil was the low level of undergraduate education in Biochemistry.

Nowadays, there are many studies with the aim to improve the student's motivation and learning in Biochemistry classes. For example, Dorea et al. [10] proposed new tools (computers resources), which permit that the students experience and integrate the Biochemistry contents. Cicuto et al. [11] carried out a study about the effects of the active learning on students' motivation in the Biochemistry classes. The study periods and discussion group's strategies allowed students to participate actively in the teaching-learning process and are promising ways to overcome the challenges presented by the current Biochemistry traditionally taught lecture classes. Recently, Silva and Galembec [12] propose laboratory classes to develop the students' autonomy to plan, perform, and interpret experiments. As results, the students' autonomy enhanced, not only by engaging them to make decisions concerning their experiments but also by developing their capability to think for themselves.

Although there is an increase in the number of literature data suggesting new ways to teach and to motivate the students, few studies have been carried out trying to understand the student view about the Biochemistry discipline once Biochemistry is a complex discipline and request time and dedication to the complete assimilation of its subjects. Recently, Pinheiro et al. [13] evaluated the academic perception of the Physiotherapy undergraduate students about the Biochemistry classes. In this study, the majority of the students declare to understand the subjects taught in the discipline, however, the assimilation of these contents is not satisfactory.

The perception of the students about the Biochemistry discipline is of extreme importance. With this type of research, we can identify the main problems faced by the

students regarding their understanding of Biochemistry subjects, i.e., whether the teaching methodology adopted by the Professor and/or the subject's syllabus is in accordance with the needs of each undergraduate course. Based on the answers of the students, the Biochemistry Professors could direct their classes to supply the punctuated problems cited by the students, and the collegiate course can improve its respective curriculum. Thus in this work, the perception of the undergraduate students of a Brazilian University about the Biochemistry discipline was evaluated.

2 Materials and Methods

2.1 Data collection

Data were collected during the school year of 2017 with the approval of the students and Professors.

The data was collected using an instrument (see Table 1) composed by nineteen questions, concerning of the students' opinion about the Biochemistry classes, professors, content, tests and the application of the Biochemistry content in other disciplines and in the students' professional areas. This instrument was adapted from the questionnaire proposed by Pinheiro et al. [13].

Table 1. Questionnaire applied to undergraduate students of a Brazilian University.

First Part:	
Perception of the undergraduate students about the Biochemistry discipline	
1. During the Biochemistry discipline, do you think your Professor failed to relate theory to the practice in your course?	☐ Yes ☐ No
2. How do you consider the semester in which the Biochemistry discipline is offered?	☐ Adequate ☐ Inadequate
3. How do you consider the credit hour of the Biochemistry discipline?	☐ Sufficient ☐ Insufficient ☐ Badly used ☐ Well used
4. Nowadays, what is your vision of the Biochemistry discipline?	☐ It is an important and essential discipline. ☐ It could be redesigned to better meet the needs of the professional in my area. ☐ It could have addressed topics more related to human health. ☐ No reformulation required. ☐ It could be an optative discipline.
5. Which disciplines do you think are correlated with the Biochemistry discipline?	
Second Part:	
Perception of the undergraduate students about the Biochemistry Professor	
6. When you are taking classes in another discipline and the contents are about	☐ Highlight that the topic is about Biochemistry ☐ Just explain the topic without mentioning the

Biochemistry, what does the Professor does?	discipline of Biochemistry () Do not explain the Biochemical details
7. During the Biochemistry classes, did the Professor correlate the topics covered with other subjects/disciplines of your course?	() Yes () No
8. How do you evaluate the performance of your Biochemistry Professor during the explanations of the Biochemistry subjects?	() Insufficient () Bad () Reasonable () Good () Excellent
9. How you classify the way of how the content taught in Biochemistry classes was evaluated in the test?	() Insufficient () Bad () Reasonable () Good () Excellent
Third Part:	
Perception of the undergraduate students about the monitoring	
10. Was it mentioned during the Biochemistry classes the existence of monitoring?	() Yes () No
11. In your opinion, monitoring in Biochemistry is...	() Necessary () Dispensable () Mandatory () No answer
12. How were the monitors?	() Necessary () Dispensable () Mandatory () No answer
Fourth Part:	
Students' self-evaluation	
13. In your opinion, to study biochemistry is	() Important () Necessary () Dispensable
14. Do you study periodically?	() Yes () No
15. Do you enjoy studying Biochemistry? Justify the question 16.	() Yes () No
16. Why?	() I have affinity for the subject () I have no affinity for the subject () I can see the application of the subjects discussed in the classroom () I can not see the application of the subjects discussed in the classroom
17. Do you revise Biochemistry topics?	() Yes () No
18. Could you satisfactorily understand the Biochemistry contents taught in the classroom?	() Yes () No
19. How you evaluate your chemistry skills based on your high school knowledge?	() Complete () Incomplete () Bad

2.2 Sample

Students enrolled in the Biochemistry class in the second semester of 2016 composed the sample of this study. We evaluated the perception of undergraduate students about the Biochemistry course, two semesters after they completed it (i.e., in the second semester of 2017) because we want to know if other courses correlated the Biochemistry topics.

The undergraduate course supervisor and the students permitted the data collection. The 12 undergraduate courses evaluated in this study were Agronomy, Animal Science, Biology, Chemistry, Dentistry, Food Technology, Forestry Engineering, Nursing, Occupational Therapy, Pharmacy, Physical Education, and Veterinary Medicine. The Federal University of Santa Maria presents 17 courses that have the Biochemistry as an obligatory discipline. We obtained the permission of the majority of the courses, which indicates a sufficient sampling.

The characteristics of the sample are described in Table 2. The undergraduate courses were grouped into three areas: Natural Sciences, Health Sciences, and Rural Sciences (Table 2), according to the University unit's classification. The total number of students who answered the questionnaire was 231 students.

Table 2. Characteristics of the participants.

Area	Course	Number of Participants	Male %	Female %
<i>Natural Sciences</i>	Biology	33	33	67
	Chemistry	3	0	100
<i>Health Sciences</i>	Dentistry	21	38	68
	Nursing	11	9	91
	Occupational Therapy	15	0	100
	Pharmacy	29	31	69
	Physical Education	11	64	36
<i>Rural Sciences</i>	Agronomy	35	66	34
	Animal Sciences	15	20	80
	Food Technology	17	6	94
	Forest Engineering	7	43	57
	Medicine Veterinary	34	68	32

2.3 Data Analysis

The data analysis was performed with the percentage of answers, considering the difference between the numbers of respondents in each undergraduate course.

3 Results and Discussion

Based on the high indices of reprobation and abandonment of undergraduate students when cursing the Biochemistry discipline, several works have been suggesting new methodologies, namely, games, problem-based learning classes, models, videos among others, to call the students attention and improve their comprehension of the Biochemistry subjects [10-12,15-24]. On the other hand, to our knowledge few studies were carried out evaluating the opinion of the undergraduate students about the discipline [13, 25-28].

In this work, we evaluated the perception of undergraduate students about the Biochemistry discipline. Two hundred thirty-one students (231) from 12 undergraduate courses from a Brazilian University answered a questionnaire divided into four parts (Table 1); the undergraduate courses were separated by area, namely, Natural Science, Health Science and Rural Science (Table 2).

In the first part of the questionnaire, the students answered about their perception of the Biochemistry course. Two semesters after they finished the discipline, the majority of the students (from Health and Rural Sciences) answered that they missed a correlation between the subject that was taught and the practice in their undergraduate course (Question 1, Figure 2).

Curiously, when the Natural Science students answered the question number 1, 50 % of the students responded that there was a correlation and 50 % said that there was not a correlation.

This ambiguous result may be directly correlated with the affinity of the students by the theme, we have to take into consideration that in our study 92 % of the Natural Science representatives are Biology students; and, Biology students have different areas of affinity (Botany, Zoology, Molecular Biology, Biochemistry among others) which, perhaps, influenced their answer in the Question 1.

Figure 2. Percentage of answers by Science areas to Question 1 “During the Biochemistry discipline, do you think your Professor failed to relate theory to the practice in your course?”

Usually, the Biochemistry discipline is offered in the 1st semester of the undergraduate courses. Although the students started their life in the University with a complex discipline, the great majority of the students answered that the semester in which the discipline is offered is adequate (Question 2, Figure 3). Moreover, the majority of the students consider the credit hour of the discipline sufficient, but badly used (Question 3, Figure 4).

Figure 3. Percentage of answers by Science areas to Question 2 “How do you consider the semester in which the Biochemistry discipline is taught?”

Figure 4. Percentage of answers by Science areas to Question 3 “How do you consider the credit hour of the Biochemistry discipline?”

When students were asked about their perception of the Biochemistry course two semesters after they finished it, the majority of them report that Biochemistry is an important course. On the other hand, there is a small difference among the Rural Science students and the Natural and Health Science students. Rural Science students stated that the discipline needs to be redesigned to better meet the needs of the professional in the specific areas of Rural Science; distinct from students from Natural and Health Sciences that punctuated that the discipline should address more topics related to human health (Question 4, Figure 5). The need of Rural Science students that the discipline covered the subjects related with their professional area can be explained because the textbooks that usually are suggested as bibliography are directed to animal and human metabolism, and vegetal Biochemistry is rarely mentioned (except for photosynthesis).

Figure 5. Percentage of answers by Science areas to Question 4 “Nowadays, what is your vision of the Biochemistry course?”

The students also indicated disciplines that they consider correlated with the Biochemistry discipline (Question 5, Table 3). The students of Natural Science, Health Science and Rural Science said that the Biochemistry is correlated with 9, 16 and 22 disciplines, respectively. Among the 35 different disciplines cited, Physiology is the only discipline cited by all the areas. The most cited discipline in Natural Science was Molecular Biology (32%), to the Health Science and Rural Science was Physiology (46% and 36%, respectively). Due to the high variation in the students' answers to the question 5, it is possible to observe the importance of the Biochemistry disciplines to the development of the undergraduate courses.

Table 3. Percentage (%) of disciplines cited by the students as correlated with the Biochemistry area.

	Natural Science	Health Science	Rural Science
No answer	6	5	4
Anatomy	3	0	0.5
Animal Nutrition	0	0	2
Biology	0	1	1
Biomechanics	0	0.7	0
Botany	2	0	0
Bromatology	0	0	10
Caryology	0	0.7	0
Cellular Biology	16	0	0
Chemistry	5	6	4
Clinic Pathology	0	0	0.5
Clinics	0	0	1
Entomology	0	0	0.5
Exercise Physiology	0	4	0
Experimental Biochemistry	0	0.7	0
Fertility	0	0	5
Genetics	5	2	0
Histology	3	0.7	0
Immunology	0	0	4
Microbiology	0	0	11
Molecular Biology	32	0.7	0
Monogastric	0	0	0.5
Nutrition	0	3	7
Organic Chemistry	3	6	0
Pathology	0	2	0
Pharmacology	0	20	2
Physicochemical	0	0	0.5
Physiology	25	46	36
Plants	0	0	0.5
Polygastric	0	0	0.5
Reproduction	0	0	0.5
Soil	0	0	2
Sports Biochemistry	0	0.7	0
Sports Nutrition	0	0.7	0
Technology	0	0	2
Vegetal Physiology	0	0	1

In the second part of the questionnaire, the students answered about their perception about the Professors. The majority of the Health and Rural Science students recognized that Professors from other courses highlight topics that are from Biochemistry subjects; on the other hand, the majority of the students from Natural Science said that their Professors only explain the topics without mentioned if it is or not a Biochemistry subject (Question 6, Figure 6). Therefore, when we asked if the Biochemistry Professors correlated the Biochemistry subjects with other courses/subjects of their undergraduate course (Question 7), there was a discrepancy among the respondents. The majority of the students from Rural and Natural Science answered that the Professor correlated the topics, but almost 70% of the students from Health Science answered that the Professor did not make correlations (Question 7, Figure 7).

Figure 6. Percentage of answers by Science areas to Question 6. “When you are taking classes in another discipline and the contents are about Biochemistry, what the Professor does?”

Figure 7. Percentage of answers by Science areas to Question 7. “During the Biochemistry classes, did the Professor correlate the topics covered with other subjects/disciplines of your course?”

In relation to the performance of the Biochemistry Professor (Question 8, Figure 8) and the way that he/she prepared the tests (Question 9, Figure 9), the opinion of the students differed among the three Science areas. The majority (40%) of the students from the Health Science judged the performance of the Professor as reasonable and the tests were classified as reasonable to good (30%). The majority of the students from Rural Science affirmed that the Professor performance and the test organization were good (45%). As observed in the Question number 1, the students from Natural Science presented a divergence in their opinion; approximately 29% of the students judge the Professor performance as bad and approximately 25% judge the performance as excellent. Again, we believe that this discrepancy of opinion from the same course students (92% of the respondents of Natural Science are from the Biology undergraduate course) is directly related with the students' affinity by the Biochemistry area.

Figure 8. Percentage of answers by Science areas to Question 8. "How you evaluate the performance of your Biochemistry Professor during the explanations of the Biochemistry subjects?"

Figure 9. Percentage of answers by Science areas to Question 9. "How you classify the way of how the content taught in Biochemistry classes was evaluated in the test?"

The third part of the questionnaire was directed to the perception on the monitors of the course. The monitors are undergraduate students that facilitate the teaching-learning process. They are extremely important once they can be helpful in the process of knowledge construction [29, 30]. In our study, a great number of students said that they did not know about the monitors (Question 10, Figure 10). However, the students considered necessary monitor in the Biochemistry course (Question 11, Figure 11). Moreover, the few students that went to the monitoring assistance affirm that the monitors satisfactorily clarified their doubts (Question 12, Figure 12).

Figure 10. Percentage of answers by Science areas to Question 10. “Was it mentioned during the Biochemistry classes the existence of monitoring?”

Figure 11. Percentage of answers by Science areas to Question 11. “In your opinion, monitoring in Biochemistry is...”.

Figure 12. Percentage of answers by Science areas to Question 12. “How were the monitors?”.

At the last part of the questionnaire, the students answered questions about their dedication to the Biochemistry course. Study hours are fundamental to the construction of knowledge and fixation of the content [31]. In the question 13, the students evaluated the importance of the Biochemistry course, the majority of the students from Natural Science and Health Science consider it as an important discipline but the students from Rural Science considered Biochemistry as a necessary discipline (Figure 13).

Figure 13. Percentage of answers by Science areas to Question 13. “In your opinion, to study Biochemistry is ...”.

The students from Natural Science represented the highest percentage of students that study periodically, they are followed by the Health Science students and at the last place the students from Rural Science, actually, the majority (60%) of the Rural Science students affirmed that did not study periodically (Question 14, Figure 14).

Figure 14. Percentage of answers by Science areas to Question 14. “Do you study periodically?”

Approximately 60% of the students from the three evaluated areas affirmed enjoy to study Biochemistry topics (Question 15, Figure 15A) and justify it because they have affinity by the theme or because they can make a correlation between the Biochemistry topic and the needs of their undergraduate course (Question 16, Figure 15B). Interestingly, they affirm that they enjoy study Biochemistry, but only 40–55% of the students revise the Biochemistry subjects (Question 17, Figure 16).

Figure 15. Percentage of answers by Science areas to Questions 15 and 16. Do you enjoy studying Biochemistry? (A) Why? (B)”.

Figure 16. Percentage of answers by Science areas to Question 17. “Do you revise Biochemistry topics?”

Figure 17. Percentage of answers by Science areas to Question 18. "Could you satisfactorily understand the Biochemistry contents taught in the classroom?"

Figure 18. Percentage of answers by Science areas to question number 19. "How you evaluate your chemistry skills based in your high school knowledge?"

Although the students appreciate study Biochemistry, the majority of them presented a reasonable comprehension of the Biochemistry subjects (Question 18, Figure 17). Perhaps, this difficulty to understand the Biochemistry subjects is involved with a lack of chemical skills. As affirmed by the students in the question 19, their chemical knowledge from high school is reasonable to bad (Figure 18). The knowledge of chemical concepts (mainly general and organic chemistry) is essential to understand the biochemistry concepts [32]. In fact, the analysis of the undergraduate curriculum of each course showed that the Health Science undergraduate courses (with the exception of Pharmacy) do not have basic chemical disciplines in their curriculum.

In general, the differences in the students' answers can be related to the Professor teaching methodology. In fact, one of the major criticisms highlighted by the students was the lack of correlation between the Biochemistry subjects and the student future career. In

addition, was observed that the students present different affinity by the theme. In this way, the Professors must increase the student's motivation and improve their interest in the classes [33-37].

Furthermore, the lack of chemistry skills of the students is a factor that must be taken into consideration in the Biochemistry course. The responsible who will be developing a given undergraduate course curriculum must adequate it to the student's weakness (learning difficulty and lack of skills), with the purpose of fix it. For example, a revision of main chemistry topics could be presented to the students before the biochemistry course. The Brazilian secondary school is frail [38-41], and the students that start in a given undergraduate course might not have the necessary skills to understand the complexity of the Biochemistry subjects.

The most important thing is the student learning and for this, it is essential that they understand the subjects along the semester. In this way, the time used in an essential topic revision is more important than to "teach" all topics of the course curriculum (in this last situation, the students will not learn, only memorize the content [42-47]). In addition, we propose that the responsible for each undergraduate courses promote a periodical meeting with the professors aiming to discuss the student's weakness, skills, and the student professional career, as well as the topics approached in the course, the period that the course is offered, and how the course is taught. The interdisciplinary curriculum must be encouraged to help the students to associate areas and to avoid to understand each discipline separately.

Conclusion

In general, this study showed that the students evaluated the Professor performance as reasonable to good, but in some cases, specific classes that correlate the subject of the course with the professional practice of the undergraduate course are necessary. It was observed also that the students present a reasonable comprehension of the Biochemistry subjects, but an increase in the monitoring assistance would be helpful to the students. Although the students classified the semester, in which the Biochemistry is offered as adequate, we think that this complex and multidisciplinary course has to be offered after the basic and essential disciplines, such as the Chemistry and Cellular Biology. In fact, Beckhauser et al. [23] demonstrated a lack of chemical and biology skills and a knowledge heterogeneity of the freshmen students. This study shows that the biochemistry classes need to be rethought for the professional area of each undergraduate

course, especially the courses from Rural Sciences that involve plant metabolism, due to the lack of specific textbook available. Although this study is simple, this type of research is very important because summarize the opinion of the students about a given course. This work can be used as an example to other Universities to analyze the students' perception about a given course.

References

- [1] Berg JM, Tymoczko JL, Stryer L. Bioquímica. 5 ed. São Paulo: GEN. 2014.
- [2] Champe PC, Harvey RA, Ferrier DR. Bioquímica Ilustrada. 5 ed. Porto Alegre: Artmed. 2012.
- [3] Nelson DL, Cox MM. Princípios de Bioquímica de Lehninger. 6 ed. Porto Alegre: Artmed. 2014.
- [4] Santos AP, Moura MF, Barbosa NL, Nascimento MM, Oliveira HD. Biochemistry Questions Analysis From National Exam Of Student Performance (ENADE). Rev Ens Bioq. 2016;14(2):9.
- [5] Vella F. Unity and Diversity in Biochemical Education. Biochem Educ. 1984;12(1):120–123.
- [6] Shaw LG. An Australian's Impression of Biochemistry Education in North American Medical Schools. Biochem Educ. 1984;12:39–41.
- [7] Reys MVT, Mendoza EMT. Biochemical Education in the Philippines. Biochem Educ. 1988;16(3):128–129.
- [8] Zancan GT. Biochemical Education in Brazil. Biochem Educ. 1985;13(4):167–168.
- [9] Vella F. Biochemical Education in Brazil. Biochem Educ. 1988;16(3):130–132.
- [10] Dórea FC, Rodrigues HS, Lapouble OMM, Pereira MR, Castro MS, Fontes W. Biochemical View: A Web Site Providing Material for Teaching Biochemistry Using Multiple Approaches. J Biochem Educ. 2007;84(11):1866–1870.
- [11] Cicuto CAT, Torres BB. Implementing an Active Learning Environment To Influence Students' Motivation in Biochemistry. J. Chem. Educ. 2016;93(6):1020–1026.
- [12] Silva T, Galembeck E. Developing and Supporting Students' Autonomy to Plan, Perform, and Interpret Inquiry-Based Biochemistry Experiments. J. Chem. Educ. 2017;94(1):52–60.
- [13] Pinheiro TDL, Silva JA, Souza PRMS, Nascimento MM, Oliveira HD. Ensino de bioquímica para acadêmicos de fisioterapia: visão e avaliação do discente. Rev Ens Bioq. 2009, 1, Artigo C.
- [14] Arini GS, Cicuto CAT, Torres BB. Analysis of Motivation, Expectations Attainment and Satisfaction of Graduate Students of The Department of Biochemistry, University of São Paulo. Rev Ens Bioq. 2016;14(2).
- [15] Dods RF. A problem-based learning designing for teaching Biochemistry. J. Chem. Educ. 1996;73:225–228.
- [16] Macaulay JO, Van Damme M-P, Walker KZ. The use of contextual learning to teach Biochemistry to dietetics students. 2009;37:137–142.
- [17] Sears DW. Using inquiry-based exercises and interactive visuals to teach protein structure/function relationships. Biochem Mol Biol Educ. 2002;30:208.
- [18] Whitehead JP, Pence HE. Using computers to teach Biochemistry. Biochem Mol Biol Educ. 2002;30:206–207.

- [19] Roberts JR, Hagedorn E, Dillenburg P, Patrick M, Herman T. Physical models enhance molecular three-dimensional literacy in an introductory Biochemistry course. *Biochem Mol Biol Educ*. 2005;33:105–110.
- [20] Sé AB, Passos RM, Ono AH, Hermes-Lima M. The use of multiple tools for teaching medical Biochemistry. *Adv Physiol Educ*. 2008;32:38–46.
- [21] Pereira HABS, Pereira TM, Magalhães AC. Protein Synthesis "The Game". *Rev Ens Bioq*. 2017;15:40–48.
- [22] Oliveira CS, Schmitz GL, Nogara PA, Rocha JBT. Insulin as a model to teach three-dimensional structure of proteins. *Rev Ens Bioq*. 2017, 15(2):114-130.
- [23] Silva T, Oliveira ML, Garzon JCV, Galembeck E. Diabetes Mellitus: Generating Issues for The Teaching Of Biochemistry. *Rev Ens Bioq*. 2016;14(2).
- [24] Mestana PE, Ribeiro SHD, Moura EC, Freitas V, Grosche VR, Espindola FS, Rodrigues RS, Tudini KAGY, Ávila VMR. From Amino Acids to Enzymes: A Proposal Using Didactic Games to Review the Content of Proteins. *Rev Ens Bioq*. 2016;14(2).
- [25] Tarhan L, Ayyildiz Y. The views of undergraduates about problem-based learning applications in a Biochemistry course. *J Biol Educ*. 2014;49:116–126.
- [26] Garrido RG, Araújo FO, Oliveira TH, Garrido FSRG. O lugar da Bioquímica no processo de cuidar: visão de graduandos em Enfermagem. *Rev Ens Bioq*. 2010. Artigo C no 1.
- [27] Beckhauser PF, Almeida EM, Zeni ALB. O Universo discente e o ensino de Bioquímica. *Rev Ens Bioq*. 2006;2(6):Artigo B.
- [28] Silveira JT, Rocha JBT. Avaliação da qualidade de ensino de Bioquímica em cursos de Nutrição. *Rev Ens Bioq*. 2018.
- [29] Haag GS, Kolling V, Silva E, Melo SC, Pinheiro M. The contributions of monitoring in the teaching-learning process in nursing. *Rev Bras Enferm*. 2008;61:215–220.
- [30] Assis F, Borsatto AZ, Silva PDD, Peres PL, Rocha PR, Lopes GT. Academic monitory program: perceptions of Student monitors and mentors. *R Enferm UERJ* 2006;14:391–397.
- [31] Kember D, Jamieson QW, Pomfret M, Wong ETT. Learning approaches, study time and academic performance. *Higher Educ*. 1995;29:329–343.
- [32] Taber RL. A biochemistry course for non-science majors. *Biochem Educ*. 1977;5:53–54.
- [33] Kittrell DL and Moore GE. Student Motivation, *Nacta Journal*, 2013;94-95.
- [34] Maehr ML and Midgley C. Enhancing Student Motivation: A Schoolwide Approach, *Educ. Psychol*. 1991;26: 399-427.
- [35] Schiefele U. and Schaffner E. Teacher interests, mastery goals, and self-efficacy as predictors of instructional practices and student motivation. *Contemp. Educ. Psychol*. 2015;42:159–171.
- [36] Brophy J. Synthesis of Research on Strategies for Motivating Students to Learn. *Educational Leadership*, 1987;45:40-48.
- [37] Han J and Yin H. Teacher motivation: Definition, research development and implications for teachers. *Cogent Education*, 2016;3:1217819.
- [38] Mesquita SSA and Lelis IAOM. Cenários do Ensino Médio no Brasil. *Ensaio: Aval. Pol. Públ. Educ*. 2015;23(89):821-842.
- [39] Madeira V, De Lima, ALS, Mello AJR, Melo JAVB, Afonso HCAG, Camara MK, Peixoto A. The Lack of Preparation of Students that Enter Engineering Courses in Brazil, *EDUCON*, 2018;1360-1363.

- [40] Muri AF and Ortigão MIR. The Brazilian scientific literacy in the PISA, J Sci Educ. 2017;2(18):80-84.
- [41] OECD Programme for International Student Assessment (PISA). Results from PISA 2015: Brazil. Available: <http://www.oecd.org/pisa/pisa-2015-Brazil.pdf>
- [42] Bunce DM. Teaching Is more than Lecturing and Learning Is More Than Memorizing: 2007 James Flack Norris Award. J. Chem. Educ. 2009;86(6):674-680.
- [43] DeHaan RL. The Impending Revolution in Undergraduate Science Education. J. Sci. Educ. Tech. 2005;14(2):253-269.
- [44] Camargo ALC. O discurso sobre a avaliação escolar do ponto de vista do aluno. Rev. Fac. Educ. 1997;23:283-302.
- [45] Klemm WR. What Good Is Learning If You Don't Remember It? JET. 2007;7(1):61-73.
- [46] Ausubel DP. Educational Psychology: A Cognitive View. New York: Holt, Rinehart & Winston. 1968.
- [47] Novak JD. Meaningful Learning: The Essential Factor for Conceptual Change in Limited or Inappropriate Propositional Hierarchies Leading to Empowerment of Learners. Sci. Ed. 2002;86:548-571.

Acknowledgments

CNPq, CAPES/PROEX (nº 23038.005848/2018-31; nº 0737/2018; nº 88882.182123/2018-01), FAPERGS.