

# The use of multiple tools for teaching medical biochemistry

Alexandre B. Sé,<sup>1,2,\*</sup> Renato M. Passos,<sup>1,2,\*</sup> André H. Ono,<sup>2</sup> and Marcelo Hermes-Lima<sup>1</sup>

<sup>1</sup>Oxyradical Research Group, Departamento de Biologia Celular, and <sup>2</sup>Faculdade de Medicina, Universidade de Brasília, Brasília, Brazil

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**Sé AB, Passos RM, Ono AH, Hermes-Lima M.** The use of multiple tools for teaching medical biochemistry. *Adv Physiol Educ* 32: 38–46, 2008; doi:10.1152/advan.00028.2007.—In this work, we describe the use of several strategies employing the philosophies of active learning and problem-based learning (PBL) that may be used to improve the teaching of metabolic biochemistry to medical and nutritional undergraduate students. The main activities are as follows: 1) a seminar/poster system in a mini-congress format (using topics of applied biochemistry); 2) a true/false applied biochemistry exam (written by peer tutors); 3) a 9-h exam on metabolism (based in real publications); 4) the Advanced Biochemistry course (directed to peer tutors, where students learn how to read and criticize real medical papers); 5) experiments about nutrition and metabolism, using students as volunteers, and about free radicals (real science for students); 6) the BioBio blog (taking advantage of the “web age,” this enhances out of class exchanges of information between the professor, students, and peer tutors); 7) student lectures on public health issues and metabolic disorders directed to the community and lay people; and 8) the BioBio quiz show. The main objective of these activities is to provide students with a more practical and interesting approach to biochemistry, such as the application of theoretical knowledge to real situations (diseases, experiments, media information, and scientific discoveries). In addition, we emphasize the importance of peer tutor activities for optimized learning of both students and peer tutors, the importance of a closer interaction between students and teaching staff, and the necessity to initiate students precociously in two broad fields of medical activity: “real” basic science and contact with the public (also helping students—future doctors and nutritionists—to be able to communicate with lay people). Most activities were evaluated by the students through written questionnaires and informal conversations, along various semesters, indicating good acceptance and approval of these methods. Good student scores in the biochemistry exams and seminars indicated that these activities are also working as valid educational tools.

problem-based learning; medical education; metabolism

THE PROBLEM-BASED LEARNING (PBL) philosophy adopted in many universities throughout the world, especially in North America and Western Europe, has become in recent years an important tool to enrich the learning of science and medicine (20, 22, 28). Many authors are convinced that students learn more effectively if the knowledge and skills they acquire are inserted and contextualized in relevant real-life, problem-based situations (8). Also, PBL is generally regarded as an effective learning strategy and an active process of personal cognitive construction. This implies that the individual students are ultimately responsible for their own learning,

while professors (or preceptors) play the role of “learning facilitators” (7). The participation of well-prepared and PBL-committed professors is also a key factor for the excellence of learning (9).

Inserted in this philosophy, the course of Basic Biochemistry (BioBio), mandatory for first-semester medicine and nutrition students at the University of Brasilia, has been developing, in the last 10 years, a series of strategies and alternatives for the teaching of metabolic biochemistry.

Until 1996, the BioBio course was inserted in the classical “lecture” format. The teaching process consisted mostly of traditional classes, and the evaluation method was based on conventional exams, relying on memorization of facts and concepts. Since then, instead of reproducing textbook information during class time, we decided to use a PBL-like approach, based on recent scientific publications and former BioBio exams (see *The 9-h Exam of Metabolism*). Students have to study theoretical subjects at home and bring their books to class prior to the discussions. For example,  $\beta$ -oxidation is not intensively taught during class time. Instead, we discuss whether or not obesity could be related to a lower activity of  $\beta$ -oxidation muscle enzymes. Thus, the so-called active learning philosophy (14, 17) is also applied.

In addition to this change in the basic structure of the course, several parallel activities were created to complement and integrate its practical approach. The main activities, mostly in active learning and PBL-like styles, are listed below. They make the BioBio course an intense and unique experience that must be shared. Moreover, at the end of the semester, students are required to answer questionnaires to evaluate the importance of these activities to their academic and professional lives. Likert 5-point scales (scores from 0 to 4) and “yes” or “no” questions were employed to assess students’ satisfaction about each activity.

The contents, chronogram, and activities adopted in the BioBio course, a 90-h course, have been fully explained in a previous article (10). In general, the initial 2/3 of the BioBio course (introduction to biomolecules, bioenergetics, and carbohydrate metabolism) is taught in a more traditional way by two other professors. Exams for this initial part cover 45% of the final grade of the BioBio course. The other 1/3 of the course (covering lipid and nitrogen metabolism as well as integrated metabolism) is taught with the use of PBL-like and active learning philosophies.

The Advanced Biochemistry course, directed mostly to former BioBio students, is also discussed in this article. This course, which is integrated into the BioBio course by means of peer tutor activity, has also a unique format and is discussed in detail in *The Advanced Biochemistry Course for Peer Tutors*.

Address for reprint requests and other correspondence: M. Hermes-Lima, Oxyradical Research Group, Departamento de Biologia Celular, Universidade de Brasília, Brasília DF 70910-900, Brazil (e-mail: m\_hermes\_lima@yahoo.com.br or hermes@unb.br).

\* A. B. Sé and R. M. Passos contributed equally to this work.

### The Seminar/Poster System: the "BioBio Meeting"

This system has the major objective of presenting topics of clinical/practical interest to students (future physicians and nutritionists). Students are divided into groups of four to five, and, at the beginning of the semester, groups must choose one from a list of topics related to applied biochemistry. Present topics are shown in Table 1. Initially, this activity was based on oral seminar presentations by the groups and written monographs, as previously described (10).

In 2003, the seminar system was changed to an alternative format: panel presentations, simulating a scientific congress. The monographs were abolished, since many sections of several monographs were "copy and paste" from the internet (plagiarism became evident in 2001 and 2002 in ~10–15% of the monographs), reflecting its poor didactic value. After groups have chosen the topic, which is oriented by a peer tutor, each group elaborates and prints two to five panels, using a step-by-step guide (5), on the chosen topic. Details on how students select topics for presentation have been previously explained (10). The panels used for presentations have the basic format of professional biomedical conference posters. Using the panels as a didactic tool, students usually make 2 or 3 presentations for audiences of 10–30 people, including the professor, peer tutors, BioBio students, and former BioBio students or former peer-tutors that show up to see specific presentations. The audience is free to walk around and watch other simultaneous presentations, in a closer and dynamic fashion. This activity lasts for 5–6 days of class. Peer tutors, which are second- or third-semester students (10), play a key role in this activity.

We consider this panel presentation activity, nicknamed the "BioBio Meeting," an important introduction to the students' scientific lives, considering that real scientific meetings are the main opportunity for academic update and exchange of experiences. In addition, since the panels have only the most relevant written information and illustrations from each chosen

topic, instances of plagiarism plummeted to nearly none from 2003 to date. Students are also stimulated to present recent novelties from the literature, making some presentations an opportunity to learn about new discoveries.

During the years, some topics have been substituted to others of greater clinical relevance, sometimes by the students' suggestions. Generally, the list of subjects is predetermined by the professor and peer tutors, but occasionally a group may demonstrate an interest for a new topic, in which they are encouraged. Some examples are metabolic syndrome, physiology of human extremes, prions, and vegetarianism. Most of the present themes were introduced in the BioBio course between 2001 and 2006 (see Table 1 and Ref. 10).

When students were asked whether the presentations (questionnaires from 1998 to 2000) are valid tools for the learning of biochemistry, 81% ( $n = 150$ ) of the students answered "yes." Among students who provided written comments ( $n = 53$ ), 55% of them thought that the seminars were relevant links between theory and clinical applications (10).

For the class of 2006-2, we gave new questionnaires to reevaluate if BioBio students ( $n = 62$ ) still approved the activity, since the last student evaluation was done several years ago. For that semester, 87% and 79% of the students answered 3 or 4 when asked about 1) the content of the panels and 2) the content of the oral presentations, respectively (where 0 = poor and 4 = very good; Table 2). The following written comment from a BioBio student summarized the general feeling about the seminar/poster system: "The use of posters stimulates the student in his/her capacity of synthesis and expression."

Regarding the clarity of oral presentations, 43.5% of the students answered 3 and 37% of the students answered 2 (nobody marked 4; see Table 2). This indicated that peer tutors and the professor still have to work harder for the improvement of the didactical aspects of the presentations. Students are supposed to practice with the peer tutors before the official

Table 1. Student panels and seminars (all related to biochemistry)

| Presentation Themes                                  | Panel Style | When Activity Started | Public Health Presentation |
|--|-------------|-----------------------|----------------------------|
| 1. Diabetes  | A           | Before 2000           | Yes                        |
| 2. Cholesterol and Health                            | A           | Before 2000           | Yes                        |
| 3. Obesity   | A           | Before 2000           | Yes                        |
| 4. Free Radicals in Medicine                         | A           | Before 2000           | No                         |
| 5. Corticosteroids and Thyroid Hormones              | A           | Before 2000           | No                         |
| 6. Neurotransmitters (Plus Mental Disorders)         | A           | In 2000               | Yes                        |
| 7. Aging   | A           | Between 2001 and 2005 | No                         |
| 8. Sports and Exercise                               | A           | Between 2001 and 2005 | Yes                        |
| 9. The Extremes of Human Tolerance                   | A           | Between 2001 and 2005 | No                         |
| 10. PKU and Galactosemia                             | B           | Before 2000           | No                         |
| 11. Vegetarianism                                    | B           | Between 2001 and 2005 | Yes*                       |
| 12. Prions   | B           | Between 2001 and 2005 | No                         |
| 13. $\omega$ -3 and -6 and <i>Trans</i> -Fatty Acids | B           | Between 2001 and 2005 | Yes*                       |
| 14. Medicine and Nutrition Dot Com                   | B           | In 2006               | No                         |
| 15. Metabolic Syndrome                               | B           | In 2006               | No                         |
| 16. Hypertension                                     | No          |                       | Yes                        |
| 17. You Are What You Eat                             | No          |                       | Yes                        |
| 18. Molecules of Life                                | No          |                       | Yes                        |

Style A consisted of groups of 4–5 students and 45- to 60-min presentations; style B consisted of groups of 2–4 students and 15- to 25-min presentations. Seminar 9, The Extremes of Human Tolerance, included conditions such as diving, starvation, and extreme cold (it was also named "Discovery Channel for BioBio Students"). Seminar 13,  $\omega$ -3 and -6 and *Trans*-Fatty Acids, concerned a popular health issue in the Brazilian media. Seminar 14, Medicine and Nutrition Dot Com, was about the misinformation abuse of the media (from the internet to fashion magazines) on health issues. \* Topics presented as part of seminar 17, You Are What You Eat.

Table 2. Questionnaire for BioBio students of the class of 2006–2

|   | Answers     |
|---|-------------|
| Questions about the seminar/poster system   |             |
| 1. Evaluate the contents of the panels (written parts and illustrations). (0 = poor; 4 = very good)                             | 3.2 ± 0.64  |
| 2. Evaluate the contents of the oral presentations. (0 = poor; 4 = very good)   | 3.0 ± 0.74  |
| 3. Evaluate the clarity of the oral presentations. (0 = poor; 4 = very good)  | 2.2 ± 0.83  |
| 4. Are seminars a relevant stimulus to participate in professional meetings? (0 = totally disagree; 4 = totally agree)          | 3.4 ± 0.10  |
| Questions about the true/false exam   |             |
| 5. Evaluate the overall technical quality of the exam. (0 = poor; 4 = very good)  | 3.15 ± 0.72 |
| 6. Evaluate the relevance of using health-related media texts as a part of a formal exam. (0 = no relevance; 4 = very relevant) | 3.68 ± 0.50 |
| 7. Do the true/false exams evaluate well the contents of the seminar/panel system? (0 = not at all; 4 = yes, totally)           | 2.73 ± 0.89 |

Values are means ± SD;  $n = 62$  student responses except for question 4, where  $n = 61$ .

presentations; however, not all groups followed this recommendation. On the other hand, most students agreed that the seminars were a good stimulus to participate in professional meetings in the near future (Table 2).

#### The True/False Exam on Applied and Clinical Biochemistry

This activity, started in 1999, has the objective of evaluating the students' comprehension of the topics contemplated in the seminar/panel presentations (see Table 1). The peer tutor(s) responsible for each topic elaborates four to six "true/false" statements about the respective subject (with close supervision by the professor, who acts as the editor of the exam). The exam is composed of 45–50 questions with 10–12 topics. The peculiarity is that the students themselves elaborate the exam (after all, the tutors were BioBio students the semester before), creating a cycle of learning (27). They learn as students in the BioBio course and later as peer tutors, helping with the correction of BioBio exams and participating in other activities (see below). The relevant role of peer tutors in an active

learning-teaching process has been discussed by others (13, 23).

In recent years, the true/false exams on applied and clinical biochemistry have been acquiring an interesting approach. Students do not enjoy memorizing data or studying subjects without any practical applicability. Thus, when acting as exam writers (usually an exclusive job for the "official" teacher), they are stimulated to elaborate pertinent, intelligent, and coherent statements. Internet texts, media news, examples of daily life, clinical situations, scientific discussions, discoveries, and controversies are all more interesting alternative topics for learning and evaluating than just inquiring about details of metabolic pathways or enzyme regulation (27).

These exams have the rule that three incorrect answers invalidate one right answer. This is a way of reducing student "guessing." Students are supposed to leave blank those questions that they are not sure of the answers to. At the end of the exam day, students may bring home a copy of the exam and have access to the spreadsheet of correct answers. Thus, they can fix, at home, their mistakes on the exam and misconceptions on applied and clinical biochemistry. This could be viewed as a similar way of application of the immediate feedback assessment technique [used for multiple-choice exams (6)], but without the "answer-until-correct" procedure.

The exams made up from 1999 to 2002 were mostly based on simple questions, such as the following: Lovastatin promotes noncompetitive inhibition of HMG-CoA reductase. True or false? (False; the mechanism is competitive). These types of simple questions might promote a right/wrong view of science and could encourage knowing answers at the expense of understanding answers. Therefore, more recent true/false exams (from 2003 to date) have incorporated more comprehensive questions, such as those shown in Table 3.

These new types of questions are *level 3* and *4* (*application* and *analysis*), according to the well-known Bloom's taxonomy (1). In fact, our current goal with these true/false exams is to evaluate not only *knowledge* of applied medical biochemistry but to encourage *evaluation of knowledge* (Bloom's *level 6*). In very recent exams (starting in 2006), we used short health-related articles (from the internet and magazines) and asked students to mark whether those texts are true or false. This is also a way to help future doctors and nutritionists to pinpoint mistakes that are abundant in health-related Brazilian websites

Table 3. Example of a question in a true/false exam (from the 2003–2 exam)

The following is an excerpt from "Pleasures of the Flesh," by Dr. Dráuzio Varella:

"As many other doctors, I have spent years advising my patients to decrease cholesterol levels through a dietary plan. It was a frustrating experience.

With the exception of a few cases, only extremely disciplined patients had succeeded to decrease these levels in 10% to 20%. Meanwhile, other patients not at all disciplined did not present any increase. Once I saw a man who used to eat a dozen eggs everyday for over thirty years and had total cholesterol of 160 (it is recommended that one keeps its value under 200). I met a forty-year-old woman with cholesterol of 250. When I told her she needed to cut down the animal fat from her diet, she answered me she had been a vegetarian for twelve years."

Using your knowledge acquired from the cholesterol metabolism lecture along with the information contained in the text above, judge the following questions:

1. \_\_\_ A possible explanation for the normal cholesterol level of the man in the text is a higher capacity for cholesterol excretion through its elimination in the form of biliary acids, which is the main form of cholesterol excretion of the organism.
2. \_\_\_ Assuming that the woman in the text is an exclusive vegetarian with high levels of cholesterol, it can be considered normal, as lots of vegetables are also sources of cholesterol.
3. \_\_\_ We can infer from the high cholesterol levels of the woman in the text that both HDL and LDL levels are probably increased. Thus, the woman has a great chance of developing atherosclerosis.

Medical student Juliana Janner selected Varella's text and prepared the questions. Dr. Varella is a well-known physician in Brazil and the host of a nationwide television program. Answers to the questions are as follows: *question 1*, true; *question 2*, false; and *question 3*, false.

and fashion magazines, which are sources of miss-education to lay people (future patients of our BioBio students).

In a survey of true/false exams from the classes of 2001-1 to 2003-2, BioBio students were asked, at the end of the exam, about the technical quality of the exam; 92% of the students answered 3 or 4 (mean  $\pm$  SD:  $3.4 \pm 0.6$ ,  $n = 337$  exams; where 0 = poor and 4 = very good; see Table 4). When students were asked if it was a positive experience to be evaluated by an exam like that, 96% of the students answered "yes." The mean score for these true/false exams (from the classes of 1999-1 to 2003-2, 10 different exams) was  $6.0 \pm 1.3$  out of 10.

In another survey, we interviewed former BioBio students from the third to the seventh semesters about true/false exams regarding technical aspects, which included 1) clarity of questions, 2) clinical applications, and 3) reasoning abilities demanded, as opposed to memorizing. The answers (scores of 0 to 4; means  $\pm$  SD;  $n = 95$ ) for these questions were as follows: 1)  $3.24 \pm 0.78$  (where 0 = unclear and 4 = totally clear), 2)  $2.95 \pm 0.88$  (where 0 = no application and 4 = very good application), and 3)  $2.69 \pm 1.13$  (where 0 = memorization only and 4 = full reasoning). The story of the true/false exam was presented in a Brazilian biochemistry meeting in 2004 (27).

In a more recent evaluation of the true/false exam, applied to the class of 2006-2 (the average score of this particular exam was  $6.4 \pm 1.5$ ,  $n = 62$ ), we asked students about the overall technical quality of the exam, the relevance of using health-related media texts as part of a formal exam, and whether the exam evaluated well the contents of the seminar/panel system. The majority of answers were quite positive (Tables 2 and 4), indicating that the present format of our true/false exam constitutes (in the students' opinion) a good evaluation method for applied and clinical biochemistry. We also asked 2006-2 and 2007-1 students ( $n = 125$ ) whether it was valid to be evaluated by an exam prepared by peer tutors, and 89% of the students marked "yes."

The weight of the true/false exam in the total grade of the BioBio course is 10%. The poster presentations have a 15% value. The final exam (see *The 9-h Exam on Metabolism*) has a value of 30% on the final grade. Students need to obtain a final grade of 5.0 out of 10 to advance. Unfortunately, this a university regulation for all courses, allowing students to pass if they retain/learn at least half of the contents of a specific course.

#### *The 9-h Exam on Metabolism*

In the end of the BioBio course, students are evaluated through a quite original and distinct model of exam, designed to work on the higher levels of Bloom's taxonomy: *application, analysis, synthesis, and evaluation* [levels 3–6, respectively (1)]. The exam is elaborated based on one or two scientific articles (mostly from the *American Journal of Physiology*) concerning general metabolism or metabolic disorders (see examples in Table 5). The main parts of the articles are edited and translated into Portuguese, and actual data are shown in a simplified way. The questions (from 8 to 12) are focused more on the interpretation of the authors' results and conclusions instead of just theoretical questions about metabolic concepts and pathways. To emphasize this methodology, students are allowed to work in pairs and to bring any bibliography and class notes to the exam day except for laptops that connect to the internet. Pairs are made up of students with similar scores in a previous BioBio exam. Moreover, students have almost a whole day to work on the exam (~9 h), thus disposing of a great deal of time to reflect on and discuss the exam. During the test, students are allowed to eat and rest outside the exam room for as much time as they need (peer tutors keep an eye on the students!).

Student interviews (on 7 different 9-h exams, from 2001-1 to 2004-1) have shown very positive feedback about the quality and relevance of such an exam. The following student comment summarizes the general feeling about the 9-h exam: "Although this is a difficult exam it is the best way to learn Biochemistry. We think and discuss about metabolic pathways

Table 4. Summary of student questionnaires

|   | Student Class Years | Answers            |
|---|---------------------|--------------------|
| Questions about the seminars (for BioBio students)                      |                     |                    |
| Seminars are tools for the learning of biochemistry.                    | 1998–2000           | 81% agreed*        |
| Evaluate the contents of the panels.                                    | 2006                | 87% marked 3 or 4† |
| Evaluate the contents of the oral presentations.                        | 2006                | 79% marked 3 or 4† |
| Evaluate the clarity of the oral presentations.                         | 2006                | 43.5% marked 3‡    |
| Seminars stimulate participation in professional meetings.              | 2006                | 82% marked 3 or 4† |
| Questions about the true/false exam (for BioBio students)               |                     |                    |
| Evaluate the technical quality of the exam.                             | 2001–2003           | 92% marked 3 or 4† |
|   | 2006                | 87% marked 3 or 4† |
| It is relevant to use media texts as part of a formal exam.             | 2006                | 98% marked 3 or 4† |
| The exam evaluates well the contents of the seminars.                   | 2006                | 61% marked 3 or 4† |
| It was a positive experience to be evaluated by this kind of exam.      | 2001–2003           | 96% agreed*        |
| It is valid to be evaluated by an exam prepared by peer tutors.         | 2006–2007           | 89% agreed*        |
| Questions about the 9-h exam (for BioBio students)                      |                     |                    |
| The exam made me reflect and discuss about metabolism.                  | 1999–2004           | 97% marked 3 or 4† |
| The exam was pertinent to what was studied in the BioBio course.        | 1999–2004           | 93% marked 3 or 4† |
| Questions about the BioBio quiz show                                    |                     |                    |
| The quiz show will be a relevant tool for learning.                     | 2005–2006           | 69% marked 3 or 4† |
| The quiz show was a relevant tool for learning.                         | 2005–2006           | 59% marked 3 or 4† |
| Questions about the Advanced Biochemistry course (for peer tutors)      |                     |                    |
| I was more prepared to read a science paper (at the end of the course). | 2005–2006           | 87% marked 3 or 4† |

Original questions and answers were modified to fit this summarized table and are detailed in the text. Answers were scored as follows: \* marked "yes"; † 0 = poor to 4 = very good; and ‡ 0 = totally disagree to 4 = totally agree.

Table 5. Example of articles discussed in the Advanced Biochemistry course

|   |
|---|
| <b>Blass EM, Anderson DR, Kirkorian HL, Pempak TA, Price I, Koleini MF.</b> On the road to obesity: television viewing increases intake of high-density foods. <i>Physiol Behav</i> 88: 597–604, 2006.<br><i>Comment:</i> interesting psychology study. It was discussed while the students and professor had pizza and soda!   |
| <b>Chen T, Smith W, Rosenstock J, Lessnau K.</b> A life-threatening complication of the Atkins diet. <i>Lancet</i> 367: 958, 2006.<br><i>Comment:</i> the discussion section of this article was removed to compare the authors' and students' conclusions.   |
| <b>Davidson GW, George L, Jackson SK, Young IS, Davies B, Bailey DM, Peters JR, Ashton T.</b> Exercise, free radicals, and lipid peroxidation in type 1 diabetes mellitus. <i>Free Radic Biol Med</i> 33: 1543–1551, 2002.  |
| <b>Fontana L, Meyer TE, Klein S, Holloszy JO.</b> Long-term calorie restriction is highly effective in reducing the risk for atherosclerosis in humans. <i>Proc Natl Acad Sci USA</i> 101: 6659–6663, 2003.<br><i>Comment:</i> relevant caveats were found in this article by our students.   |
| <b>Foster GD, Wyatt HR, Hill JO, McGuckin BG, Brill C, Mohammed BS, Szapary PO, Rader DJ, Edman JS, Klein S.</b> A randomized trial of a low-carbohydrate diet for obesity. <i>N Engl J Med</i> 348: 2082–2090, 2003.<br><i>Comment:</i> the study is about the famous Atkins diet.   |
| <b>Gresl TA, Colman RJ, Roecker EB, Havighurst TC, Huang Z, Allison DB, Bergman RN, Kemnitz JW.</b> Dietary restriction and glucose regulation in aging rhesus monkeys: a follow-up report at 8.5 yr. <i>Am J Endocrinol Metab</i> 281: E757–E765, 2001.  |
| <b>Hochachka PK, Clark CM, Matheson GO, Brown WD, Stone CK, Nickles RJ, Holden JE.</b> Effects on regional brain metabolism of high-altitude hypoxia: a study of six US marines. <i>Am J Physiol Regul Integr Comp Physiol</i> 277: R314–R319, 1999.  |
| <b>Kim JK, Zisman A, Fillmore JJ, Peroni OD, Kotani K, Perret P, Zong H, Dong J, Kahn CR, Kahn BB, Shulman GI.</b> Glucose toxicity and the development of diabetes in mice with muscle-specific inactivation of GLUT4. <i>J Clin Invest</i> 108: 153–160, 2001.<br><i>Comment:</i> also used in a 9-h exam.  |
| <b>Klein S, Fontana L, Young VL, Coggan AR, Kilo C, Patterson BW, Mohammed BS.</b> Absence of an effect of liposuction on insulin action risk factors for coronary heart disease. <i>N Engl J Med</i> 350: 2549–2557, 2004.<br><i>Comment:</i> also used in a 9-h exam.   |
| <b>Owen OE, Smalley KJ, D'Alessio DA, Mozzoli MA, Dawson EK.</b> Protein, fat, and carbohydrate requirements during starvation: anaplerosis and cataplerosis. <i>Am J Clin Nutr</i> 68: 12–34, 1998.<br><i>Comment:</i> also used in the preparation of a 9-h exam.   |
| <b>Stephoe A, Wardle J, Marmot M.</b> Positive affect and health-related neuroendocrine, cardiovascular, and inflammatory processes. <i>Proc Natl Acad Sci USA</i> 102: 6508–6512, 2005.  |
| <b>Vickers MH, Breier BH, McCarthy D, Gluckman PD.</b> Sedentary behavior during postnatal life is determined by the prenatal environment and exacerbated by postnatal hypercaloric nutrition. <i>Am J Physiol Regul Integr Comp Physiol</i> 285: R271–R273, 2003.<br><i>Comment:</i> the discussion section of this article was removed to compare the authors' and students' conclusions. |

used in real life situations and learn applied metabolism.” When students were asked if the exam made them reflect on and discuss the questions (where 0 = it did not and 4 = yes, very much), 97% of the students marked 3 or 4 (mean  $\pm$  SD:  $3.82 \pm 0.45$ ;  $n = 428$ ). When asked if the exam was pertinent to what was studied during the BioBio course (where 0 = not pertinent at all and 4 = totally pertinent), 93% of the students marked 3 or 4 (mean  $\pm$  SD:  $3.61 \pm 0.63$ ;  $n = 438$ ) (see Table 4). We also observed that the mean score for eleven 9-h exams, from 1999-1 to 2004-1, was  $6.6 \pm 1.8$  ( $n = 735$ )<sup>1</sup>. The high frequency of scores equal or above 6.0 (~70%) and of those equal to or above 7.0 (~48%) for the 9-h exams indicated a good level of learning and comprehension of metabolic biochemistry among BioBio students. These observations were presented in a Brazilian biochemistry meeting in 2005 (25).

These results from 1999 to 2004 are similar to those obtained in the most recent 9-h exam (class of 2006-2): 41 of 63 BioBio students had scores equal to or above 6.0 out of 10 (mean  $\pm$  SD =  $6.3 \pm 2.2$ ). We also observed in the class of 2006-2 a correlation between student scores of the second-term BioBio exam, given by Prof. Egle de Almeida (e-mail: eglemasi@gmail.com), and the 9-h final exam ( $r^2 = 0.27$ ,  $P = 1.2 \times 10^{-5}$ ,  $n = 63$ ). Since the second-term exam has a “classical” format (2-h exam about bioenergetics and carbohy-

drate metabolism; students resolve it alone without consultation), this suggests that the evaluation of learning of metabolism is achieved in both “classical” and “alternative” formats of exams.

The fact that students work in pairs is one the key strategies for the success of the 9-h exam. This allows students to exhaustively discuss the questions to prepare the best answers. This is in line with other strategies where peer instruction helps to enhance meaningful learning (4). Students are required to prepare concise answers and, if necessary, to quote the source of the information used for the answer.

Since 1999, 16 different 9-h exams have been provided to the BioBio course. For an actual example of questions provided in a 9-h exam, see Passos et al. (21). Usually, two peer tutors are coresponsible for the elaboration of the exam, closely supervised by the professor. Preparation of this exam takes ~2 mo of work.

Interestingly, a 3-h version of the 9-h exam has been applied since 2006 by Prof. Élide G. Campos (e-mail: elida@unb.br) to the Basic Biochemistry course for Biology undergrad students at the University of Brasilia. These students had a very good impression of the new exam, and this activity will keep going on indefinitely.

#### *The Advanced Biochemistry Course for Peer Tutors*

This course is offered to second-semester students (12–18 students) who have just finished the BioBio course plus one or two third-semester students who are taking the course for the second time, as “senior peer tutors.” This course is composed of two parallel activities: weekly meetings for scientific discussions and the peer tutor activity (described above). In

<sup>1</sup> The scores of 0–2.9, 3.0–3.9, 4.0–4.9, 5.0–5.9, 6.0–6.9, 7.0–7.9, 8.0–8.9, and 9.0–10.0 for the 9-h exams (from the classes of 1999-1 to 2004-1) show a Gaussian-type distribution of 2.7%, 5.4%, 7.2%, 15.0%, 21.9%, 21.8%, 18.8%, and 7.2%, respectively ( $n = 735$ ). A similar result was also observed for the 9-h exam applied to the class of 2006-2, with the highest frequency of scores between 7.0 and 7.9 (25.4%,  $n = 63$  exams).

addition, they also elaborate lectures directed to the community (see *Student Lectures Directed to the Community*). The selection of peer tutors is mostly based on their 1) class participation while BioBio students, 2) BioBio scores, and 3) capacity to read English. Usually 1/3 of candidates for peer tutoring are turned down.

In each meeting, one student presents an article suggested by the professor or of his/her personal interest, similarly to that reported by Rangachari and Mierson (24). These articles are mostly on metabolic biochemistry with clinical relevance; articles from areas that are outside biochemistry or physiology are also presented in some classes. The requisite is that the article was published in a recognized international journal and is adequate for group discussion (see list shown in Table 5). The emphasis of the discussion is greater on the methodology of science instead of on details about particular subjects. What did the authors want to prove? How did they do it? Were the conclusions valid? What were the experimental caveats and omissions? How could it be a better article? These are questions made in every class discussion, and students should be prepared to answer them alone at the end of the course. Also, it is a good opportunity to discuss statistics and methodology and to exercise the sense of criticism. Sometimes the professor selects a “bad” paper published in a “good” journal, just to see if students find the major caveats of the “bad” study. In recent years, the DISCUSSION section of a few articles has been removed to stimulate the students to figure out their own conclusions. We also introduced an activity called “How to read a paper abstract from PubMed,” since the understanding of abstracts of medical papers is not usually a simple task for undergrad students. Overall, the objective of these discussions is to teach undergrad students how science and medicine are constructed and the ability to exercise scientific criticism.

The second attribute of the course is the peer tutor activity. Each student is responsible for tutoring a BioBio group on the seminar/panel presentation and is coresponsible for evaluating the group, always closely supervised by the professor. In all cases, the “last word” for scoring the presentations is from the professor. Moreover, peer tutors must elaborate the true/false exam (which is closely supervised by the professor; see *The True/False Exam on Applied and Clinical Biochemistry*) and help with the other activities presented in this article: the 9-h exam, real-science experiments, the BioBio quiz show, and lectures to the community.

At the end of the course, peer tutors answered (from classes of 2005-1 to 2006-1;  $n = 30$ ) if they considered themselves more prepared to read and discuss a scientific article after the course. These tests showed 87% scores of 3 or 4 (where 0 = totally dull and 4 = prepared); nobody answered 0 or 1 (26). The advancing and grading of peer tutors is based on their overall participation in all activities. Since the first class of Advanced Biochemistry (back in 1999), over 95% of the peer tutors scored above 9.0 out of 10.

It is very important to make clear that peer tutors are not substitutes for the professor since senior and junior students are both being educated by an institutional curriculum. Peer tutors are not teachers in an institutional point of view. They are, however, coinstructors of BioBio students, being essential to the success of all activities, similarly to the descriptions of Rangachari and Crankshaw (23) and Lake (13).

### “Real Science” Experiments

In 2002, we elaborated and executed an experiment designed to improve the learning of metabolic biochemistry by nutrition and medical undergraduate students, as previously published in *Advances in Physiology Education* (21). Basically, we compared two groups of volunteer students (12 peer tutors in total): one group eating pasta (hyperglycemic lunch) and the other group eating pizza (hyperlipidic lunch). Blood parameters from students were determined (plasma glucose, triglycerides, and urea) before and after the meals, and the results were then applied in the 9-h exams (in 2002 and 2003). Interesting differences between the two groups were observed in plasma triglycerides and urea (21). Currently, these results have been used for PBL-like class discussions, using the philosophy of active learning.

In 2004, we designed a similar experiment, this time comparing a Brazilian-type breakfast (“high carbohydrate”: 87% carbohydrate, 5% lipid, and 8% protein) with an American-type breakfast (“high fat”: 37% carbohydrate, 45% lipid, and 18% protein). A certified nutritionist, Patricia Torsani, was responsible for preparing the meal contents and calculating the amount of meal for each student volunteer based on his/her body mass index and age. Blood glucose, triglycerides, total cholesterol, HDL-cholesterol, and uric acid were determined. Unfortunately, the results of the blood tests (except for blood glucose, which was used as a question in one 9-h exam) turned out to be too complex for our teaching purposes, as opposed to the first experiment. Both lunch and breakfast experiments were approved by the Ethics Committee of the University of Brasília.

In 2005, we planned an activity with the objective of inserting the peer tutors into the professional university laboratory (different from regular laboratory classes, which generally are based in standardized, oversimplified experiments). This activity may also serve as a stimulus for working with basic science. In any case, our future physicians will be requesting laboratory exams, and they should be aware of possible laboratory errors and their effects in recommending a treatment.

A laboratory specialized on free radicals was selected for this scientific initiation activity, taking advantage of the authors’ (M. Hermes-Lima) experience in the field. An experiment was designed to verify the *in vitro* efficacy of the classical antioxidant DMSO (11) in preventing hydroxyl radical-induced oxidation of 2-deoxyribose. We utilized the classical Fenton reagents to generate hydroxyl radical *in vitro* ( $\text{Fe}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{Fe}^{3+} + \text{OH}^- + \cdot\text{OH}$ ) (11, 15).

The students participated in all levels of the experiment, from weighing the reagents to obtaining data and discussing them. Students observed the *in vitro* antioxidant activity of DMSO with the same efficiency of a laboratory professional. An evaluation questionnaire was applied at the end, regarding the usefulness, interest, and organization of the activity; results were very satisfactory. This activity on free radicals was presented in a Brazilian biochemistry meeting in 2005 (2).

### The BioBio Blog

The BioBio course is also on the internet in a blog format. It was created in 2003 to make off-hours communication between the professor, peer tutors, and students simpler and faster (the

current URL is <http://www.biobio-unb.blogspot.com>; the previous URL was <http://www.biobio.weblogger.terra.com.br>. This is easier than sending e-mails to students, since the management of e-mail lists, every semester, is hard and sometimes frustrating. The huge amount of electronic messages we receive per week (professors and students) make e-mail a cumbersome tool for communication.

The BioBio blog allows a constant update on the progress of the discipline, displaying technical information such as news, dates, grades, results, and meetings. There is also a space dedicated to uploading articles, media texts, web videos, or links regarding metabolism and clinical news, serving as a complement to the discipline's basic table of contents. As discussed by Boulos and coworkers (3), blogs (like the BioBio blog), wikis, and podcasts can be excellent tools to enhance student learning in medical courses.

### The BioBio Quiz Show

One of the course's more recent activities (it was started in 2004), the "BioBio quiz show" is indeed a game, similar to television-type quiz shows. Here, classmates exchange questions and answers over biochemistry topics, mostly those contemplated in the panel activity described above (see *The Seminar/Poster System: the "BioBio Meeting"*).

Our game has two different phases. The first phase is a true/false selection exam (with 15 questions), as the class is too big for everyone to participate. Four groups of three to five students are selected for class confrontations (the second phase). During confrontations, one group must select five questions (out of 10–15 true/false questions on applied biochemistry, previously elaborated by peer tutors) for the opponent group to answer, and vice versa. The answering group must always justify their answers (not just true or false) and is generally complemented by the asking group. This generates a rich class discussion on applied biochemistry, in addition to the entertainment value. The winning group receives an extra 0.5 point in the final BioBio grade.

An example of a "student confrontation" in a BioBio Quiz-Show is shown in Table 6.

Student interviews about the BioBio quiz show have indicated that they have great interest in participating in this kind of activity. Students at the beginning of the semester were asked if the activity would be a relevant tool for learning (*question A*; where 0 = no, I would prefer a "regular day class" and 4 = yes, the show will be interesting). At the end of the semester, they were asked if the BioBio show was indeed relevant (*question B*; where 0 = no, I would rather had a

Table 6. Example of a "student confrontation" in a BioBio quiz show

|   |
|---|
| Item (selected by <i>group A</i> ): One of the characteristics of diabetes is the increment of liver gluconeogenesis, which contributes to increase plasmatic glucose levels even more, resulting in protein glycosylation. (Answer: true.)   |
| <i>Group B</i> affirms that the item is wrong, because gluconeogenesis is diminished during diabetes. <i>Group A</i> disagrees, saying that the item is true. Thus, <i>group B</i> loses 1 point and <i>group A</i> neither gets nor loses points. If <i>group B</i> had answered correctly, they would have scored 2 points. |
| Next, <i>group A</i> should answer an item selected by <i>group B</i> . At the end of the confrontation, the winning group is the one with the higher score.  |

"regular day class" and 4 = yes, the show was a total success). The answers for *questions A* and *B* (means  $\pm$  SD) were  $2.91 \pm 1.14$  ( $n = 178$ ) and  $2.53 \pm 1.23$  ( $n = 135$ ) (see Table 4), indicating good acceptance of the method. This activity was presented in a Brazilian biochemistry meeting in 2006 (19). The use of games to aid in the learning of medical physiology has also been reported elsewhere (12, 16, 18).

### Student Lectures Directed to the Community

This is the most recent activity executed by the BioBio peer tutors, starting in 2005. Its purpose is to practice students in what will be some of the most important abilities for them as future physicians and nutritionists: contact with the public and their educational role in society.

The topics chosen for this course (named "Chemistry of Health") are public health issues of major importance related to metabolism and endocrinology (see Table 1). These 50-min lectures are directed basically to the university community, specially the technical and administrative staff, which generally has a superficial and media-oriented knowledge of such themes.

We could clearly perceive that most people attending the course were satisfied with the contents of the lectures. To be sure of that, at the end of the course, participants were asked if they liked the lectures or not (where 0 = lectures were totally uncompressible and 4 = lectures were excellent). Twenty-three participants (out of 25 participants who answered the questionnaire) answered 3 or 4; nobody answered 0 or 1.

A true/false questionnaire (with 30 questions) was answered by the participants regarding some basic concepts they were suppose to learn. They obtained a good score ( $72 \pm 14\%$  of correct answers), indicating that most of them comprehended the contents of the lectures. The participants were able to understand, for example, why eating too much sugar could be a risk factor for diabetes Type II or why too much salt in meals is a serious preoccupation for the development of hypertension. Metabolic syndrome, obesity, and clinical depression are very relevant health issues in our university community. Therefore, we focused most of the seminars in such directions.

We are currently preparing a "slideshow" version for these lectures (with audio) to be displayed on the internet to gain wider visibility. This activity started in mid-2006 and has the cooperation of professors from the Movie and Medical Schools of the University of Brasilia to help with the video/audio quality and on the accuracy of medical-related material.

### Conclusions

These are some of the tools used to improve the teaching of biochemistry in this institution. Some have been employed for over 10 years and have very good acceptance among the students (10). Other activities have been created on recently and are still in a developing phase. Some of the activities, such as the discussion of scientific articles, scientific experiments, and the biochemistry exam, have a great emphasis on the importance of basic science and have the purpose of stimulating the students about it. Our major purposes are to provide a broad and dynamic view about the basic area of biochemistry and to show students its applicability in their respective pre-clinical areas.

As reported by Lujan (16), first-year students prefer multiple learning styles during a course. In the search to find new

activities, these are alternatives to expand learning styles and make it fun to learn and study, instead of simply boring.

It is possible to greatly improve the efficacy of the teaching-learning process with a “low tech and high brains” approach. There are more simple and efficient ways of doing that than relying on multimedia projections, three-dimensional simulations, complex software, and similar high-tech tools. This is of special relevance in the developing world, where resources for teaching are usually scarce. Some of these principles are as follows: 1) a greater emphasis on students’ active participation in their own learning, as in the pizza and pasta experiment and the “Chemistry of Health” course; 2) a well-supervised peer tutoring activity, which makes it possible to develop many different activities simultaneously and to execute tasks that would be “impossible missions” for a single professor; and 3) a constant focus on bringing theory to practice, making it interesting and (why not) enjoyable to learn biochemistry, generally considered “the King of Boring” among students.

It is important to make sure that we do not consider our methods as educationally or pedagogically better than any other format of medical teaching, including the classical ones. However, when analyzing the student scores on the 9-h and true/false exams (most students scored equal or above 6.0; see *The 9-h Exam on Metabolism* and *The True/False Exam on Applied and Clinical Biochemistry*), we may conclude that our teaching/evaluation methods seem to work well. Moreover, grades for the poster presentations have been also very good: 28 of 31 student groups from the classes of 2006-1 and 2006-2 had a group score above 8.0 (mean  $\pm$  SD:  $9.3 \pm 0.7$ ,  $n = 31$  groups). Whether the majority of students retain the medical biochemistry contents in the years following the BioBio class is a matter for further evaluation. In any case, former BioBio students (1/5 to 1/4 of them) enrolled in the Advanced Biochemistry course have a unique experience of direct contact with real science and publications—an opportunity that most students will have only in PhD programs—that should be relevant during their professional careers as doctors or nutritionists.

The combination of activities in a student-centered course (reported herein), with the experience acquired along the years, has made great improvements of the teaching of biochemistry for medical and nutrition students at the University of Brasília. These experiences could be, at least in part, replicated elsewhere, bringing multiple learning and low-tech approaches for undergrad students.

#### NOTE ADDED IN PROOF

The clarity of student poster presentations, which scored badly in the 2006-2 class (see *question 3* in Table 2), improved markedly in the 2007-1 class: 78% of the students marked 3 or 4, and the average score was  $2.87 \pm 0.61$  ( $n = 63$ ). Regarding the true/false exam in 2007-1, student interviews produced almost the same scores as in the previous semester (see *questions 5–7* in Table 2), even though the average score for the 2007-1 exam ( $5.4 \pm 1.5$ ,  $n = 64$ ) was significantly lower than in the 2006-2 exam ( $6.4 \pm 1.5$ ,  $n = 62$ ). This indicates that level of difficulty of the exam does not interfere with student evaluation of its quality or relevance.

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Present address of R. M. Passos: Ophthalmology Unit, Federal University of São Paulo, São Paulo, Brazil.

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