New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION

Use of Learning Contract and Problem-Based Learning in a Metabolic Biochemistry Course for Undergraduates in Biology

Ángel Luis García-Ponce[1], Ángel Blanco-López[1], Ana Mª Rodríguez Quesada[2] Francisco J. Alonso Carrión[2], María Fernanda Suárez[2], Miguel Ángel Medina Torres[2]

Abstract

Metabolic Biochemistry is a subject that is perceived as particularly challenging by our undergraduate students in Biology. In fact, all the contents of its syllabus should be properly interconnected by our students throughout their study of the subject in order to get a global insight of the complex regulatory features controlling metabolism as a whole and each metabolic pathway within the metabolic network under different physiologic and pathologic conditions. Due to these objective difficulties, a high percentage of our students face the study of this subject as a very hard task beyond their forces and capacities. This perception leads to high rates of premature dropout. In fact, in the academic years 2011/12-2014/15 less than 40% of all the registered students attended the examinations of Metabolic Biochemistry in the second year of the studies to achieve the Degree of Biology at our University. Even worse, less than 25% of our students passed the exams.

In the academic year 2015/16, we have begun an innovative teaching project (PIE15-163) aimed to increase our student loyalty to the subject (and hence to increase their attendance to exams) and to help them to learn more effectively metabolism and its regulation. This innovative teaching project is mainly based on the use of two powerful tools: a learning contract and problem-based learning within the framework of group tasks promoting an actual collaborative learning.

The present communication will show the implementation of the PIE15-163 project and the first results obtained from it.

1. The *Metabolic Biochemistry* Course within the Grade in Biology at the University of Málaga (Spain)

The Grade in Biology at the University of Málaga (Spain) is organized around 8 semesters along with students must complete a total of 240 ECTS, among compulsory and optative subjects. Regarding the contents of a General Biochemistry, this Grade offers two compulsory courses on biochemistry: *Biochemistry I* and *Biochemistry II*. *Biochemistry I* is offered for the first semester of the second year and comprises the contents of a general structural biochemistry, a basic enzymology and the principles of the low of genetic information as an introduction to molecular biology. *Biochemistry II* is offered for the second semester of the second year and comprises the contents of a general metabolic biochemistry, with a special emphasis on metabolic regulation and metabolic integration.

The syllabus of our *Metabolic Biochemistry* course has the following contents:

Unit 1: Introduction. From the gene to the protein and from the protein to metabolism.
Unit 2. General principles of metabolic regulation.
Unit 3. Biosignaling.
Unit 4. Transport through biological membranes.
Unit 5. Membrane bioenergetics (I). Chemiosmotic theory and its application in cell respiration. electron transport chain and biosynthesis of ATP.
Unit 6. Membrane bioenergetics (II). Photosynthetic energy transduction and photosynthetic chemiosmotic coupling.
Unit 7. Photosynthetic assimilation of carbon, nitrogen and sulfur into organic material.

[1] Universidad de Málaga, Andalucía Tech, Departamento de Didáctica de la Matemática, de las Ciencias Sociales y de las Ciencias Experimentales, Facultad de Ciencias de la Educación, Málaga (Spain).
[2] Universidad de Málaga, Andalucía Tech, Departamento de Biología Molecular y Bioquímica, Facultad de Ciencias, Málaga (Spain).

Unit 8. The central core of oxidative metabolism.
Unit 9. Carbohydrate metabolism.
Unit 10. Lipid circulation and metabolism.
Unit 11. Metabolism of amino acids and other nitrogen organic compounds.
Unit 12. Integration of metabolism. Metabolic systems biology.
The complete contents of this syllabus should be properly interconnected in order to get a global insight of the complex regulatory features controlling metabolism as a whole and each metabolic pathway within the metabolic network under different physiologic and pathologic conditions. The contents do not follow one specific textbook but instead takes viewpoints from several main textbooks [1-5], but also first hand information from recently published articles. More than 200 students are recruited every year.

2. Our Educational Innovation Project PIE15-163

The conceptual contents within units 1-5, the bioenergetics calculations throughout the whole course, the great number of metabolic pathways revised within units 6-11 and the need of continuous integration of this information within a framework to understand the principles of metabolic regulation contribute to the perception of our undergraduate student of this course as a particularly difficult and demanding subject within the grade. This perception leads to high rates of premature dropout. In fact, in the academic years 2011/12-2014/15 less than 40% of all the registered students attended the examinations of *Biochemistry II*. Even worse, less than 25% of our students passed the exams.
PIE15-163 is the reference of the Educational Innovation Project entitled "*Learning-teaching of biochemistry. An initiative based in collaborative learning and learning contract*" we launched in the academic year 2015-16 and that will be developed up to the end of the academic year 2016-17.
The project has the following aims:

- To increase our student loyalty to the course by signing a learning contract.
- To reinforce the knowledge of students regarding the essential physicochemical principles for biochemistry
- To promote the confidence of students in their own capabilities.
- To promote procedures of collaborative learning.
- To promote the own creativity of students.
- To boost the knowledge of the main metabolic pathways and their regulatory features.
- To promote the capacity of our students to integrate metabolic information within physiopathologic contexts within the framework of group tasks.

3. The Learning Contract

The learning contract is a tool that has been shown to be effective for the loyalty of students. Essentially, a learning contract is a free agreement established between the student and the professor that specifies:

- The objectives and goals of the contract.
- The deadline to fulfil the terms of the contract.
- The obligations of both student and professor assumed with the contract sign.
- The criteria to determine whether the conditions of the contract have been met on time or not.

4. Problem-Based Learning

Problem-based learning has been described as "*the learning that results from the process of working toward the understanding or resolution of a problem*" [6]. Student are guided by their professors to enquire and search for information (either individually or forming part of collaborative groups) needed to solve problems. Here problems should be understood in an open sense, including cases, projects or actual problems, among others. This learning methodology is central to many Northern European universities but is still unfrequent in the Spanish university system.

5. Implementation of the Educational Innovation Project PIE15-163

Once our students enrolled in the *Biochemistry II* course for the second semester of the academic year 2015/16 were informed, volunteers were enrolled to participate in the project among those students that had failed to pass the examinations of the course in previous academic years. The

enrolled volunteers were informed that the score system for the evaluation of their work in the course would be as follows:

- Their performance in practical classes would score up to 15% of the final student score.
- Their performance in the final examinations would score up to 65%.
- Their performance in the voluntary tasks assumed within the project would score up to 10%.
- The fulfilment of the contract would score 10%.

Students taking part in the project were arranged in groups of up to 5 members and each group was assigned one out of 8 "problem/case situations":

- Metabolic adaptation to different kinds of stress.
- Regulation of cholesterol metabolism in health and disease.
- Redox homeostasis and metabolic regulation.
- Bioenergetics interdependency of mitochondria and chloroplasts in light and in the dark.
- Metabolic adaptation to diets.
- Central role of AMPK in metabolic regulation.
- Kinetic properties, distribution and regulatory mechanisms of glucose transporters. Their involvement in metabolic "specialization".
- Acetyl-CoA as a crossroad metabolite.

Three groups were assigned to each "case". Each group should work independently of the rest. Within each work, a collaborative work should produce 3 deliverable items within two months:

- A written essay fully documented and referenced on the topic.
- A visual summary in the form of a poster of the main messages to take home from the topic.
- A collection of questions regarding the contents of the topic.

Once the tasks were delivered, they were submitted to cross-evaluation (i.e.: members of each group evaluated the work delivered by 7 other groups working in different "cases"). This cross-evaluation was a component of the final evaluation of the task along with the evaluation carried out by the professor and according to a predefined rubric. An individual test with questions selected from the collections submitted by the different groups was also used for the final score of the task in the project.
In parallel to this main task, students were invited to suggest creative and playful tasks oriented to help in the study of metabolism. The suggested tasks were voted by students and those 5 with the highest vote numbers were selected to be carried out to the end with the participation of the rest of the students. The performance of these selected tasks helped to tinge the final score of each participant in the project.
The contract was considered fulfilled in all the cases in which the student would had participated in all the tasks and would had significantly contributed to the deliverable items submitted by their group before the deadline.

6. First Results of the Educational Innovation Project PIE15-163

- In the first year of implementation of the project PIE15-163 more than 100 students were enrolled.
- With the exception of two students, the rest of enrolled students fulfilled the contract and most of them received a score equal or higher to a 5% in their tasks associated with the project.
- Up to an 80% of the volunteers enrolled in the project attended the final examination, as compared with only a 53% of the rest of students attending the final examination.
- A 66% of the students that took part in the project and attended the final examination passed the course, to be compared with only a 20% of success among students not enrolled in the project that attended the final examination.
- The results of a satisfaction poll reveal that most of the enrolled students were satisfied with the experience.
- We also carried out polls on the perception of the course by the students at the beginning and the end of the course. We are currently analyzing them.

Summarizing, the first implementation of our project PI15-163 has allowed to achieve two of its main goals: to increase the percentage of students attending the final examination and to increase their success rate.

7. Components of the team

Ángel Luis García-Ponce is a Ph.D. in Chemistry currently involved in a second Ph.D. Thesis, focused on the teaching of biochemistry at the University. He is also serving as an external observer of the PIE15-163 project, being besides in charge of the polls. Ángel Blanco is full professor at the Faculty of Education and an expert in science didactics. Ana Mª Rodríguez Quesada is full professor of biochemistry and has been in charge of the course *Fundamentals of Biochemistry* for the last four academic years. María Fernanda Suárez is associate professor and Francisco J. Alonso Carrión and Miguel Ángel Medina Torres are full professor of biochemistry, and the three are in charge of the three groups of the *Biochemistry II* at the Faculty of Sciences.

8. Acknowledgements

We thank all our colleagues at the Department of Molecular Biology and Biochemistry their support to this initiative. This work was supported by funds granted to PIE15-163, University of Málaga, Spain

References

[1] Nelso, DL, Cox, MM. "Lehninger Principles of Biochemistry" (6th ed). Ney York, Worth Publ Inc, 2012
[2] Berg, JM, Tymoczko, JL, Gatto Jr., GJ, Stryer, L. "Biochemistry" (8th ed). New York, WH Freeman and Co, 2015
[3] Voet, D, Voet, JG. "Biochemistry" (4th ed). Hoboken, NJ, Wiley, 2011
[4] Newsholme, E, Leech, T. "Functional Biochemistry in Health and Disease". Chichester, Wiley, 2010
[5] Chandel, NS. "Navigating Metabolism". Cold Spring Harbor, CSH Laboratory Press, 2015
[6] Barrows, HS, Tamblyn, RM. "Problem-Based Learning. An Approach to Medical Education". New York, Springer, 1981