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A PROBLEM/CASE-BASED LEARNING APPROACH AS AN USEFUL TOOL FOR STUDYING GLYCOGEN METABOLISM AND ITS REGULATION

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Abstract

Metabolism and its regulation is one of the most complex and difficult topics for students learning biochemistry. A problem/case-based learning approach can be useful to help biochemistry students to fulfil the goal of acquiring an integrated view of metabolism and its regulation. The present article describes our experience enrolling volunteer students to learn glycogen metabolism making use of a design-based research methodology to develop teaching learning sequences focused on a problem/case-based learning approach. Enrolled undergraduate students had better final scores than those students that did not participates. Furthermore, enrolled students were satisfied with the experience, finding it interesting, formative, and challenging.

Keywords: Glycogen metabolism regulation; problem-based learning; case-based learning; teaching learning sequence; design-based research

Introduction

Metabolism is a dynamic network with high levels of plasticity that is able to rewire, allowing for its adaptation to environmental and internal changes [1]. The complexity of this dynamical metabolic network, its multiple levels of regulation and its integration make metabolism one of the most difficult and complex study subjects for biochemistry students [2,3].

At the University of Málaga (Spain), metabolism is a topic covered by mandatory courses Biology (*Bioquímica II*, devoted to the study of *Metabolic Biochemistry*), Biochemistry (*Regulation of Metabolism*) and Chemistry (a course entitled *Biochemistry* that is completely dedicated to the study of metabolism) degrees. *Regulation of Metabolism* and *Metabolic Regulation* are perceived by many of our second year students as a difficult subject demanding study efforts far beyond their forces. This perception yielded high rates of premature dropout in previous courses. In the case of *Metabolic Biochemistry*, in the academic year 2014/15 less than 40% of enrolled students finally attended exams and less than 25% of enrolled students passed them. From the academic year 2015/16 on, three consecutive innovative teaching projects[1] have been devoted to help and overcome these difficulties and to increase the previously mentioned percentages. These projects are aimed at improving the experience of the teaching-learning process by using a design-based research (DBR) methodology [4] to develop teaching learning sequences (TLS) focused on a problem/case-based learning approach (PBL) [5-8].

Another important target of these projects was to change certain attitudes of students, decreasing their competitiveness and increasing their cooperativity by stimulating their engagement with procedures of cooperative study in a flipped classroom [9]. These

[1] PIE15-163, PIE17-145 and PIE19-057) have got financial support from the University of Málaga.

objectives contributed to overcome the main difficulties found by students in their study of Metabolic Biochemistry and to increase the percentages of students attending and passing the examinations.

In this work, we show and discuss the results obtained with the first application of an extended PBL approach for the study of glycogen metabolism under a learning contract [10,11] and using procedures of less hierarchical and more horizontal cooperative study [12,13], with the professor in the role of a facilitator/guide in a flipped classroom [14].

Research questions

This paper attempts to answer the following questions:

A. What impact does participation in the TLS focused in a PBL approach have on the acquisition of students' knowledge regarding glycogen, its metabolism, regulation and integration?

B. What is the students' perception of this PBL approach after their participation in the TLS?

Research methodology

The origin of the DBR methodology dates back to the 1990s when, under the term "design experiments", it was used by some researchers to collect the generation of knowledge from previous research, with the aim of checking and perfecting educational designs, studying their application and evaluation [4,15,16]. This concept has evolved over time under different approaches, nuances and a varied terminology, as detailed in a recent review of this research strategy applied to educational technology [17], reaching the most current term of design-based research. Following the methodological guidelines set by Rianudo and Donolo [18], the following stages are established in

DBR: (i) Design of teaching resources. (ii) Implementation of the design experiment. (iii) Retrospective analysis, leading to improvements in the design of the teaching resources and to the beginning of a second round of stages.

In the present study, the first stage led to the TLS described in the following section. The stage of retrospective analysis is included below as the main results obtained from the first implementation of our PBL on glycogen with our students.

Design of the TLS

The term 'teaching–learning-sequence' (TLS) is now widely used "*to denote the close linkage between proposed teaching and expected student learning as a distinguishing feature of a research-inspired topic-oriented sequence*" [5]. These authors consider that a TLS is both an object and a product of research that is constituted by a set of sequenced teaching-learning activities, which are considered adapted to the students' knowledge and reasoning ability, and that is submitted to research processes to analyze and improve its effectiveness with respect to the learning objectives.

Figure 1 shows the TLS applied in this study as a flow chart of suggested tasks. The whole extended PBL for the study of glycogen metabolism and its regulation was designed during the academic course 2017-18. This PBL included 57 guided tasks organized around five topics, as indicated in Table I. Many of these tasks were selected from available textbooks and student's guides on biochemistry [19-22] as well as cases and patient profile cases contained in the instructor's resources of Voet and Voet Biochemistry [19] and Marks' *Basic Medical Biochemistry* [23], respectively. These guided tasks were designed to stimulate the interaction among the members of the different teams/groups of students, their cooperative behavior during learning and their critical thinking. Furthermore, some tasks were designed to encourage the reading of

scientific papers and the use of very useful biological databases and online resources (see Tables II and III).

Participants

We presented the activity and enrolled volunteer students of both *Metabolic Regulation* and *Regulation of Metabolism* courses to a system of continuous evaluation under a learning contract. In *Metabolic Regulation*, 20 volunteer students who signed the learning contract were split in 5 groups. In *Regulation of Metabolism*, 32 students signed the learning contract and were split in 8 groups.

Data collection

To monitor the learning process, before PBL presentation to the students and after the submission of their final reports (Figure 1), they answered anonymously the questions of a test to analyze the impact of the PBL work on their acquisition of knowledge regarding glycogen, its metabolism, regulation and integration (included -as its English translation- in Supplementary material SM1).

Before the final examinations of the subjects, enrolled students anonymously filled in a post course mixed questionnaire, elaborated by using the 1 to 4 Likert scale for most of the questions, complemented with some open questions (the questionnaire is included -in its English translation- in Supplementary material SM2). This questionnaire was designed to evaluate students' perception of this PBL methodology. Finally, the impact of this methodology on the students' performance in the final examinations was evaluated.

Implementation of the TLS

The TLS was implemented in the second semester of the academic course 2017-18. All the groups received the instructions and rules to solve the "case" and a written document with all this information, along with the 57 tasks of the PBL (included -in its English translation- in Supplementary material SM3). Each group freely decided how to organize the work and how to share the tasks. Groups had two months to prepare a final report with the description of the response provided for each task and a public declaration of engagement, with mention of the specific work carried out by each member of the group in the resolution of the overall PBL. Throughout the whole procedure groups were allowed to demand tutorial sessions and guidance from their professors.

Before the final examinations of the subjects, enrolled students had a final meeting in which, under the instructors' supervision, the different groups discussed their answers to the different tasks included in the PBL.

Results and discussion

A) Knowledge acquisition

Regarding the answers to the 10 multi-option questions in both the pre-test and the post-test on the topic by the enrolled biochemistry students, in 9 out of the 10 questions there was an increase in the percentage of correct answers in the post-test as compared with the pre-test (see Figure 2). Altogether, correct answers increased from 31% to 54%. In the case of the enrolled biology students, there was a more modest increase in the percentages of correct answers, from 29% to 37%.

This PBL had a real impact not only in the overall knowledge of glycogen metabolism but also on the study of the course on metabolic regulation as a whole for most of the enrolled students in both groups of the Biochemistry and Biology Degrees. In fact, the percentages of students attending and passing the final examinations of both the *Metabolic Biochemistry* and *Metabolic Regulation* courses were higher among enrolled students to the PBL under learning contract. Specifically, in *Metabolic Biochemistry* (Biology Degree) course, 63% of the enrolled students passed the final exam, compared with only 37% of students passing the final exam among those not enrolled in the study. In the *Regulation of Metabolism* (Biochemistry Degree) course, the figures were 79% and 50% for students attending the final exam previously enrolled in the PBL activity or not, respectively.

B) Students' perceptions about PBL approach

Most of the enrolled students (74% of the students in the Biology Degree and 87% of the students of the Biochemistry Degree) declared that they had no previous knowledge of the PBL methodology and very few had previously used this methodology (14% of the students in the Biology Degree and 13% of the students of the Biochemistry Degree). Regarding the perception and the satisfaction of students with the PBL methodology, students of both courses considered this methodology useful (scores 3.6 and 2.8 in a Likert scale for Biochemistry and Biology students respectively), believed that they had learned more (75% of both Biochemistry and Biology students), but almost 100% of them declared that they had to work more and harder than for the preparation of other kinds of tasks in the same or in other subjects. Overall, 83% of Biochemistry students and 75% of Biology students enrolled in this study declared to be "very satisfied" or "satisfied" with their experience.

Limitations and perspectives

An obvious major limitation of the study described here was the small number of enrolled students (20 students of the degree in Biology and 32 of the degree in Biochemistry). However, these numbers represented almost 25% and 45% of the respective numbers of students attending both courses. In our experience, these percentages are relatively high for a voluntary activity demanding an additional effort and carried out under a learning contract. A second limitation is the fact that this activity, while providing the student with comprehensive training in the covered topic, focuses on a relatively small portion of the extensive content of a metabolic biochemistry course.

These limitations will be overcome in the near future. On the one hand, as this volunteer activity continues to be offered in the coming academic years, the cumulative number of students enrolled will gradually increase. This will make it possible to carry out a comprehensive retrospective analysis in a few years' time, the conclusions of which will have greater statistical power. On the other hand, in subsequent academic years we have introduced and will continue to introduce new PBLs that will cover increasing portions of the total contents of the subjects.

Final considerations

The use of the PBL designed to study glycogen and its metabolism within the framework of a collaborative learning in a flipped classroom has contributed to improve the experience of our students learning metabolism and its regulation. Furthermore, they had the opportunity to learn that cooperation is a better strategy to study than competition. It should be underscored that this didactic/pedagogical strategy is easily

exportable and adaptable to other academic disciplines in the same and other areas of knowledge.

Acknowledgements

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Conflicts of interest

No potential conflicts of interest were disclosed.

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TABLE I. Guided tasks and topics covered by our PBL on glycogen.

Topics covered	*Number of guided tasks*
On the structure and properties of glycogen	13
Historical issues regarding the scientific study of glycogen metabolism and its regulation	5
On glycogen metabolism and its regulation	24
Glycogenosis. Biochemical foundations of clinical cases	10
Integration of glycogen metabolism	5

TABLE II. List of scientific articles that students had to consult to fulfill the tasks included in the PBL.

Articles	*Topic covered*
Bolto et al. J Cheminformatics 3: 32 (2011)	PubChem3D tool
Meléndez-Hevia et al. Biochem J 295: 477-483 (1993)	Theorical studies of glycogen structure
Meléndez et al., Biophys J 77: 1327-1332 (1999)	Fractal structure of glycogen
Navas-Delgado et al., Database 2015, 1-11 (2015)	Kpath tool
Jope and Johnson. Trends Biochem Sci 29: 95-102 (2004)	GSK3 functions
Whelan. Trends Biochem Sci 1: 13-15 (1976).	Glycogenin
Testoni et al., Cell Metabolism 26: 256-266 (2017)	Glycogen synthesis can be initiated without glycogenin as a primer
Rodríguez-López et al., BMC Bioinformatics 15: 375 (2014)	PhenUMA tool

TABLE III. List of biological databases and online resources that students had to consult to fulfill the tasks included in the PBL.

Databases and online resources	*Topic covered*
pubchem.ncbi.nlm.nih.gov	PubChem
nobelprize.org	Nobel prize (1947) to Gerty and Carl Cori
wikipathways.org	Wikipathways
browser.kpath.khaos.uma.es	Kpath tool
ebi.ac.uk/pdbe	PDB
omim.org	OMIM
orpha.net	Orphanet
phenuma.clinbioinfosspa.es	PhenUMA tool

Figure legend

Figure 1. Flow chart of the teaching-learning sequence (TLS) adopted in the present study.

Figure 2. Results of the knowledge acquisition as revealed by the comparison of pre-test and post-test scores by the enrolled biochemistry students. Scores are depicted as percentages of correct answers for each of the 10 questions. Pre-test scores in brown. Post-test scores in blue. Dashed lines indicate the mean values of scores for the whole set of 10 questions in both the pre-test and the post-test.

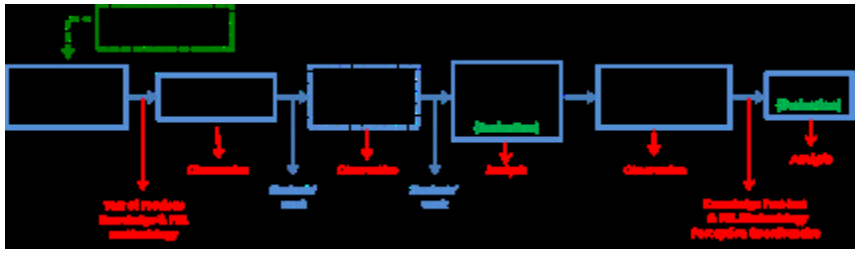

Figure 1

149x43mm (72 x 72 DPI)

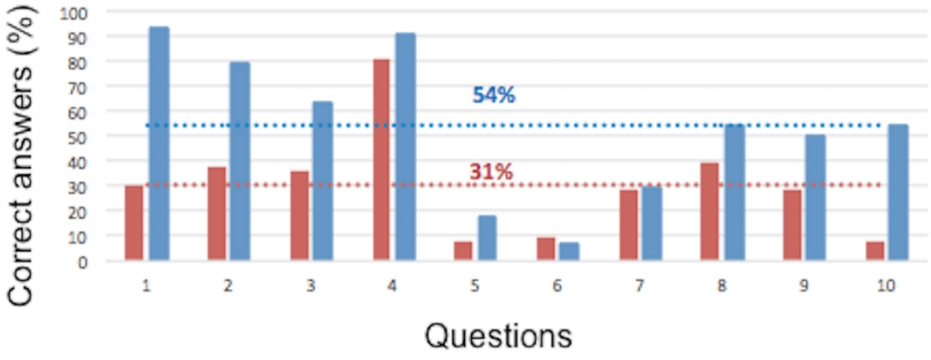

Figure 2

150x62mm (300 x 300 DPI)