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Case/Problem-Based Learning in a Flipped Classroom and Under a Learning Contract as Didactic Tools for Collaborative Learning of Metabolic Regulation

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Abstract

It is a widely shared desire among most teachers of subjects in the area of biochemistry to achieve a relevant transfer of relevant knowledge to their students through an effective teaching-learning process. Many undergraduate students in biology, biochemistry and biomedical sciences find metabolism particularly difficult to learn. The very extensive contents of metabolic biochemistry and the need to integrate them in a way that gives them full biological meaning are essential causes of this difficulty appreciated by students. The transition from the traditional educational model focused on teaching to the EHEA (European Higher Education Area) model focused on learning and the acquisition of competencies by the student implies a change in the educational paradigm that makes it necessary to complement lectures with active methodologies that enhance the central role of the student in the learning process. Collaborative learning strategies can contribute to facilitate students' learning of metabolism, its regulation, and its biological integration. Among the active methodologies, case-, problem- and project-based learning methods, often developed under the "inverted" classroom model, stand out. These methodological tools and teaching strategies have been tested by the members of this educational innovation team as voluntary activities of continuous assessment under a learning contract in the framework of two subjects focused on metabolism and its regulation, in the second year of the Biology and Biochemistry Degrees at the University of Malaga. This communication will discuss these strategies, analyze their implementation and provide evidence of their impact on the teaching-learning process.

Keywords: *Case/problem-based learning; flipped classroom; learning contract; metabolic regulation; collaborative learning*

1. The *Metabolic Biochemistry* and *Metabolic Regulation* Courses in the Grades in Biology and Biochemistry at the University of Málaga (Spain)

In the Biology and Biochemistry degrees at the University of Malaga, topics related to metabolism are studied in the mandatory subjects: Biochemistry II and Regulation of Metabolism, respectively. Both subjects have a theoretical-practical teaching load corresponding to 6 European Credit Transfer and Accumulation System (ECTS) and are taught in the second year (2nd semester) of both degrees. The subject Regulation of Metabolism focuses on advanced aspects of regulation and integration of metabolic processes previously presented (1st semester) to students in the subject “Fundamentals of Biochemistry". On the other hand, Biochemistry II, deals with fundamental aspects of Bioenergetics and Metabolic Biochemistry. In both subjects, the main objective is to provide students an integrated vision of metabolism, its regulation, evolutionary plasticity, and adaptation to different physiological and pathological conditions.

2. Our Educational Innovation Project PIE22-118

The aims of our Educational Innovation Project PIE22-118 can be summarized as follows: 1) To improve the results of our students in terms of scores. 2) To increase their skills in: scientific information finding, scientific data management and understanding, science communication, and studying and working in small collaborative groups. 3) To analyze the effectiveness of the flipped learning pedagogical model in terms of student performance and learning with respect to the use of traditional master classes. This strategy will be applied only to selected metabolic topics. 4) All scheduled group activities will be carried out after signing a Learning Contract between the teacher and his students. In addition, formative evaluation criteria will be specially taken into account in the final grade of the students.

3. Case/Problem-Based Learning

The use of problem-based learning (PBL) was pioneered by Barrows and Tamblyn at the medical school at McMaster University in Hamilton in the 1960s [1]. PBL is a student-centered pedagogy in which groups of students learn about a subject through the experience of solving an open-ended problem. Through PBL, students not only strengthen their teamwork, communication, and research skills, but they also sharpen their critical thinking and problem-solving abilities essential for life-long learning. The role of the tutor in the PBL is to facilitate learning by supporting, guiding, and monitoring the learning process, acting as a falicitator [2]. Thus, PBL represents a paradigm shift from traditional teaching and learning philosophy [3], which is more often lecture-based, and responds to some basic principles of contructivist inspiration. Although the PBL approaches had their origin and greatest development in the area of health science [4], they have been extended to other natural and social sciences [5, 6]. PBL can be used as a powerful strategy of collaborative learning. However, the lack of a sufficient number of cases or projects to be applied to teaching by means of this methodology is a fact, accentuated in the case of one of the most complex topics of study for the student of Biochemistry such as the regulation of the metabolism and its integration [7]. This encourages not only collaboration in increasing the scarce teaching resources available to the educational community, but also the application of some of the guidelines of educational research focused on design with implementation and evaluation to be carried out withuniversity science students, through case studies [7-11]

4. Flipped Classroom

Flipped learning (FL) is a pedagogical model that encompasses a set of teaching methodologies that have the following points in common: a) The information to be learned by the student is taken out of the classroom (Individual Space) and transmitted by the teacher online as links to documents, presentations, videos, podcasts, etc. b) Class time (Goup space), instead of the traditional master classes, is dedicated to discussing what the students have not understood well, working on cases, projects and problems, collaborative work, etc. (active and inductive learning). All this takes place under the supervision and guidance of the teacher. The different strategies of FL differ, fundamentally, in the type of online communication before classes; in the way in which it encourages and checks the student's previous study, and in the tasks or specific activities that are carried out in the classes. With the FL model, not only the use of time and space in the classroom and outside is reversed, but also the role of teachers and students in the classroom is altered. In traditional classes the teacher is the protagonist, he or she is placed on the stand looking at the students and explains the lesson while they attend, take notes and occasionally ask questions. In reverse teaching, on the other hand, the students are the main protagonists, they work actively while the teacher observes how they do it, helping them when they have problems or when they are asked to do so. FL can be much more pedagogically effective than traditional master classes. Some of its strengths are: a) It stimulates the students' continuous study, avoiding the typical last minute binges. b) It makes it easier for all students to understand the information, since they can access it as many times as they want. c) It allows class time to be spent on activities led by the students without slowing down the pace of progress with the syllabus, since it is transmitted online. d) It allows the realization of formative evaluation activities and metacognitive reflection during class time. e) The tasks are done and corrected during the class, thus facilitating the management of the teacher's feedback on the work products of their students. The main weakness of the inverse model is that it gives more work to teachers, especially: a) In the preparation and design of the materials to be transmitted to their students. b) In the preparation of pre-study verification questionnaires, and the analysis of the students' answers. c) In the redesign of classes to respond to difficulties and to carry out new activities. The first well-documented model of a flipped classroom was carried out in 2007 by the chemistry teachers of Woodland Park High School in Colorado (USA), Aaron Sams and Jonathan Bergman [12]. Before that date, methods had been developed to check the previous study of the students using reverse methodology. Of these methods the Peer Instruction, the Just-in-Time-Teaching, and the Team Based Learning stand out [13-15]. Currently, there are many combined flipped learning methodologies that can be applied [17,18]. The interest in FL methodologies is growing day by day, as indicated by the almost 50,000 educators from all over the world already registered at the Flipped Learning Community Network. In the specific case of Biochemistry and Metabolism, the work done by Professor Brent Stockwell is especially noteworthy. Since he joined the Columbia Center for New Media Teaching and Learning (CCNMTL) in the summer of 2013, he has been teaching Biochemistry with inverted class methodology.

5. The Learning Contract

A Learning Contract (LC) [19,20] is a negociated agreement signed between a learner and a teacher,

lecture or staff adviser that an activity will be undertaken in order to achieve a specific learning goal. During the execution time of the contract, the student works autonomously, since he is responsible for his learning process. The teacher will be a guide, support and counselor when the student needs it. With the LC, a series of rights and duties of both the teacher and the student are established and discussed. And both must commit to them and comply with what is established and agreed upon. This type of contract have many benefits, among them, they encourage learners to take more responsability for their own learning needs, and to use their existing skills and experiences as basis for new learning. In our case, only students who sign the contract can enroll in the project.

6. Collaborative Learning

Collaborative learning (CL) refers to an instruction method in which learners at various performance levels work together in small groups toward a common goal. According to Panitz, T. [21], collaboration is a philosophy of interaction and personal lifestyle where individuals are responsible for their actions including learning, respecting members' abilities and their contributions. CL is grounded on social constructivism, which considers learning a social process that is built not only with the teacher, but also with peers, the context and meaning of what is learned. This learning approach not only favors the academic performance of students but also allows them to acquire important transversal competences that are very useful in their professional development. An efficient collaborative learning approach is characterized by the following five features [22]: a) Positive interdependence. b) Individual and group accountability, to avoid free-rider effects [23]. c) Promotive interactions. d) Appropriate use of social skills. e) Group processing, with critical self-evaluation of the work carried out within the group. In the specific case of the learning-teaching of Biochemistry, the opinion of teachers and students in relation to the implementation of collaborative learning methodologies is, in general, very positive [24-28].

7. Implementation of the Educational Innovation Project PIE22-118

Each year, a relevant part of the syllabus has been worked out using this course-based undergraduate research experience approach. With a flipped-learning strategy, volunteer students signing a learning contract were challenged to collaboratively solve a selection of guided problems/cases (the PBL of the year) in groups of 3-4 students. Four progress sessions were programmed throughout the semester to stimulates groups to contrast and share their doubts and their responses to the problems/cases. At the end of the course, each group had to submit a final report.

8. First Results of the Educational Innovation Project PIE22-118

Our previous Educational Innovation Projects PIE15-163, PIE17-145, and PIE19-057 yielded a remarkable scientific production, with a number or communications to science education conferences, several chapters of books, a PhD Thesis [29], and two articles published in science education journals included in Journal Citation Reports [30,31]. In the first year of implementation, PIE22-118 has yielded promising results yielding three communication to international scientific meetings [32-34]. A first manuscript will be submitted soon.

The impact of the implementation of our project on our students can be summarized as follows:

- In the first year of implementation of the project PIE22-118 38 volunteer students were enrolled.
- Up to an 84% of the volunteers enrolled in the project attended the final examination, as compared with only a 42% 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.

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References

[1] Barrows, Howard S. "Problem-based learning in medicine and beyond: A brief overview". New Directions for Teaching and Learning. 1996 (68): 3–12, 1996
[2] Schmidt, Henk G; Rotgans, Jerome I; Yew, Elaine HJ. "The process of problem-based learning: What works and why". Medical Education. 45 (8): 792–806, 2011
[3] Hung, Woei. "Theory to reality: A few issues in implementing problem-based learning". Educational Technology Research and Development. 59 (4): 529–552, 2011
[4] Dolmans, D.H.J.M., Loyens S.M.M., Marcq, H., Gijbels, D. "Deep and surface learning in problem-based learning: a review of the literature", Advances in Health Sciences Education, vol. 21, pp. 1087– 1112, 2016
[5] Ward, J.D., Lee, C.L. "A review of problem-based learning", Journal of Family and Consumer Sciences Education, vol. 20, pp. 16-26, 2002
[6] Tsai, C.W., Chiang, Y.C. "Research trends in problem-based learning (PBL) research in elearning and online education environments: A review of publications in SSCI-indexed journals from 2004 to 2012", British Journal of Educational Technology, vol. 44, pp. 185-190, 2013
[7] Megías, A., Oñaderra, M. "ABP-4 orientado al aprendizaje e integración del metabolismo. Charlas de gimnasio", Reduca (Biología). Serie Bioquímica y Biología Molecular, vol. 6, pp. 48-57, 2013
[8] Collins, A., Joseph, D., Bielaczyc, K. "Design research: Theoretical and methodological issues", Journal of the Learning Sciences, vol. 13, pp. 15-42, 2004
[9] Méheut, M., D. Psillos. "Teaching-Learning sequences: aims and tools for science education research", International Journal of Science Education, vol. 26, pp. 515-535, 2004
[10] Rianudo, M.C., Donolo, D. "Estudios de diseño. Una perspectiva prometedora en la investigación educativa", RED-Revista de Educación a Distancia, vol. 22, pp. 2-29, 2010
[11] Simons, H. "El estudio de caso: Teoría y práctica" (in Spanish), Madrid, Morata, 2011
[12] Bergmann, J., Sams, A. "Dale la vuelta a tu clase" (in Spanish), 3rd ed. Madrid, Santillana, 2016.
[13] Mazur, E. "Peer instruction: a user's manual". Upper Saddle River, NJ, Prentice Hall, 1997
[14] Novak, G., Gavrin, A., Christian, W., Patterson, E. "Just-in-time-teaching: blending active learning with web technology". Upper Saddle River, NJ, Prentice Hall, 1999
[15] Michaelsen, A.L.K., Knight, A.B., Fink, L.D. "Team-based learning: a transformative use of small group in college", Stylus Pb., 2004
[16] Medina, J.L. "La docencia universitaria mediante el enfoque de aula invertida" (in Spanish), Barcelona, Octaedro, 2016
[17] Prieto, A. "Flipped learning. Aplicar el modelo de aprendizaje inverso" (in Spanish), Madrid, Narcea, 2017
[18] Talbert, R. “Flipped learning. A guide for higher education faculty”, Sterlin, Virginia, Stilus Publishing, LLC, 2017
[19] Anderson, G., Boud, D., Sampson, J. “Learning contracts. A practical guide”. London: Routledge Falmer , 1966
[20] Stephenson, J. and Laycock, M. “Using learning contracts in Higher Education”. London, RoutledgeFalmer , 2002
[21] Panitz, T.(1996). “A Definition of Collaborative vs Cooperative Learning”. Deliberations, London Metropolitan University, UK. Retrieved Jan. 9, 2024, from: http://www.londonmet.ac.uk/deliberations/collaborative-learning/panitz-paper.cfm
[22] Johnson, D.W., Johnson, R.T., Holubec, E.J. "El aprendizaje cooperativo en el aula" (in Spanish), Barcelona, Paidós Ibérica, 1999
[23] Kerr, N.L., Bruun, S.E. "Dispensability of member effort and group motivation losses: free-rider effects ", Journal of Personality and Social Psychology, vol. 44, pp. 78-94, 1983
[24] Magnarelli, G., Quintana, M. M., García, L., Cabrera, L., Ruiz, L. " El trabajo en pequeños grupos facilita la enseñanza-aprendizaje de Bioquímica", Revista Brasileira de Educaçao Médica, vol.33, pp. 374-381, 2009
[25] Peters, A. "Teaching biochemistry at a minority-serving institution: an evaluation of the role of collaborative learning as a tool for science mastery", Journal of Chemical Education, vol. 82, pp. 571-574, 2005
[26] Gilmer, P. J. "Transforming university biochemistry teaching using collaborative learning and technology ", Heidelberg, Springer, 2010
[27] Fernández, M.L., Alap, A., Artolozaga, M.J., Calvo, L.A. Centeno, C., Gómez, G., Granados, K., Madrigal, M., Murillo, A.G., Pinto, A., Quesada, S., Salas, E., Somarribas, L.F., Vindas, L.A., Campos, D. "Aprendizaje cooperativo en un curso de Bioquímica: Opinión de los estudiantes y

efecto en su rendimiento académico", Actualidades Investigativas en Educación, vol. 12, pp. 1- 26, 2012

[28] Souza-Júnior, A.A., Silva, A.P., Silva, T.A., Andrade, G.P.V. "A proposal of collaborative education for biochemistry and cell biology teaching", Journal of Biochemistry Education, vol. 13, 2015

[29] García-Ponce, A.L. “Diseño, aplicación y evaluación de recursos didácticos que faciliten el aprendizaje de la Bioquímica por parte del alumnado universitario de ciencias”, Universidad de Málaga, Spain, 2022

[30] García-Ponce, A.L., Martínez-Poveda, B., Blanco.López, A., Quesada, A.R., Suárez, F., Alonso-Carrión, F.J., Medina, M.A. “A problem-/case based learning approach as an useful tool for studying glycogen metabolism and its regulation”. Biochem Mol Biol Educ, vol. 49, pp. 236-241, 2021

[31] Medina, M.A., García-Ponce, A.L., Blanco-López, A., Quesada, A.R., Urdiales, J.L., Fajardo, I., Suárez, F., Alonso-Carrión, F.J. “Turning around cycles: an approach based on selected problems/cases to stimulate collaborative learning about Krebs and his four metabolic cycles”. J Chem Educ, vol. 99, pp. 2270-2276, 2022

[32] Medina, M.A., García-Ponce, A.L., Blanco-López, A., Quesada, A.R., Urdiales, J.L., Fajardo, I., Suárez, F., Alonso-Carrión, F.J. “Contrato de aprendizaje, aula invertida y aprendizaje basado en casos/problemas como herramientas didácticas para el aprendizaje colaborativo del metabolismo y su regulación”. Oral communication to the 44th Congress of the Spanish Society of Biochemistry and Molecular Biology, Málaga, Spain, 2022

[33] Medina, M.A., Suárez, F., Alonso-Carrión, F.J. “Selected problems/cases to stimulate collaborative learning regarding the dynamic flexibility of metabolism”. Communication (panel) to the 47th FEBS Congress, Tours, France, 2023

[34] Medina, M.A., Suárez, F., Alonso-Carrión, F.J. “Use of a teaching-learning experience to stimulate collaborative learning of metabolism based on selected problems/cases”. Communication (panel in the format of a global virtual symposium) to the ACS Spring 2024 Meeting, New Orleans (Hybrid), USA, 2024