


# Learning Metabolism by Problem-Based Learning Through the Analysis of Health or Nutrition Articles from the Web in Biochemistry

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**Abstract:** Problem-based learning using authentic material from the web was used to teach metabolism in a biochemistry course. In place of traditional lectures, students' analyzed health or nutrition articles from newspapers and magazines, which were debatable from a scientific point of view, following the principles of problem-based learning. A mixed method was used to assess the students' perception, use of sources of information and web services while performing the task, and changes in self-directed learning. Students' perception was particularly positive. The majority stated that the methodology helped them to apply knowledge to real life and that they learned about the topic analyzed by their group. The perception that problem-based learning promotes the ability to solve problems, critical thinking, and collaborative work is noteworthy. Tutors considered that teams identified the problem and concluded correctly, noticing students' enthusiasm and motivation. The methodology also promoted scientific reading. More importantly, a significant improvement in self-directed learning of the 2014 cohort was detected. This intervention suggests that this methodology is a valuable alternative to motivate and promote self-learning; representing an opportunity to shift the focus of instruction from the teacher to the student. The design of the activity and materials are described in detail. Also, limitations and solutions are discussed.

**Keywords:** authentic material, biochemistry, metabolism, problem-based learning, self-directed learning

## Introduction

Students from different backgrounds and undergraduate programs have problems understanding metabolism in introductory biochemistry courses, often focusing on memorizing pathways rather than on applying concepts to relate the physiological and pathological conditions to nutrition and health (Anderson & Grayson, 1994). It has been discussed that students are not trained to develop intellectual abilities, promoting superficial knowledge (Valdés de la Rosa, Álvarez, Valls, Valle, & Fajardo, 2001). Therefore, it is a necessity that teachers provide new environments in

the classroom that can stimulate students to engage in the learning process to acquire specific and meaningful knowledge as well as generic skills in order to prepare them for their future workplace.

The need to address teaching differently has been widely discussed. Nevertheless, this has not necessarily transferred into the classrooms (Uslu, 2017). The adoption of any instructional innovation in public education is a complicated undertaking. In the past years case, project and problem-based learning (PBL) methodologies have gained ground; all of them are considered excellent learner-centered instructional strategies. Nevertheless, cases and projects tend to diminish the learner's role by setting clear goals and outcomes, while in PBL the questions to answer are not explicit, and students need to identify and understand the issues to be addressed before preparing themselves and attempting to solve the problem (Bergstrom, Pugh, Phillips, & Machlev, 2016; Savery, 2006). Thus, in this paper, we report a descriptive study of the implementation of PBL using authentic material as problems, specifically news articles from the internet. This instructional intervention was designed in order for students to learn metabolism by applying contents in real-life contexts, by focusing on the process and not the outcome, expecting that careful choosing of the problems could guide discussion to higher thinking levels.

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Table 1—Web articles selected as problems for teaching metabolism by problem-based learning.

Articles	Main topic
<b>First round</b>	
The strange disease that prevents climbing stairs and heavy lifting <a href="http://www.abc.es/20120814/sociedad/abci-enfermedad-ejercicio-mcardle-201208131606.html">http://www.abc.es/20120814/sociedad/abci-enfermedad-ejercicio-mcardle-201208131606.html</a>	Metabolic disease related to glycogen metabolism
Should legumes and cereals be combined? <a href="http://www.vidasana.bio/por-que-combinar-legumbres-y-cereales/">http://www.vidasana.bio/por-que-combinar-legumbres-y-cereales/</a>	Essential amino acids and the contribution of vegetables to animal metabolism
Good and bad cholesterol <a href="http://www.vitonica.com/enfermedades/colesterol-bueno-y-colesterol-malo">http://www.vitonica.com/enfermedades/colesterol-bueno-y-colesterol-malo</a>	Lipoproteins, fat mobilization, and health
The benefits of daily consumption of Yacón <a href="https://www.colombia.com/vida-sana/nutricion/sdi/100957/los-beneficios-del-consumo-diario-de-yacon">https://www.colombia.com/vida-sana/nutricion/sdi/100957/los-beneficios-del-consumo-diario-de-yacon</a>	Glycemia regulation and diabetes
<b>Second round</b>	
Lose up to 3 kilos per week <a href="http://www.agenciaderf.com/despachos.asp?cod_des=151972">http://www.agenciaderf.com/despachos.asp?cod_des=151972</a>	Healthy diet and interconversion of biological macromolecules in mammals
What does the fantastic swimmer Michael Phelps eat? <a href="http://www.directoalpaladar.com/otros/que-come-el-genial-nadador-michael-phelps">http://www.directoalpaladar.com/otros/que-come-el-genial-nadador-michael-phelps</a>	Use of energy in aerobic and anaerobic exercise
New diet proposes banquets five days and fasting other two <a href="https://lta.reuters.com/article/worldNews/idLTASIE95C04C20130613">https://lta.reuters.com/article/worldNews/idLTASIE95C04C20130613</a>	Fast metabolism, the relationship between nutrition and health
Miners resist with mouthfuls of tuna and one glass of milk every two days <a href="http://www.elespectador.com/articulo-220626-mineros-resistieron-dos-bocados-de-atun-y-un-vaso-de-leche-cada-dos-dias">http://www.elespectador.com/articulo-220626-mineros-resistieron-dos-bocados-de-atun-y-un-vaso-de-leche-cada-dos-dias</a>	Fast metabolism, the relationship between nutrition and health

## Problem-Based Learning in the Classroom

PBL has been implemented in several educational scenarios around the world (Barrows, 1996; Kumar & Refaei, 2017). It has been reported to be more effective than conventional classrooms (Strobel & Barneveld, 2009) and has been well received in the universities because of its emphasis on active learning, the ability to transfer learning to other contexts, and its great potential to raise student motivation (Hmelo-Silver, 2004; Newhouse, 2017). Students can also develop critical thinking, creativity, decision making, self-directed learning, communication skills, collaborative teamwork, and problem solving (Savin-Baden, 2016).

Hung, Jonassen, and Lui (2008) identify the main characteristics of PBL: (1) It is problem focused, such that learners learn by addressing an authentic, unstructured problem. (2) The content and skills to be learned are organized around problems, rather than as a hierarchical list of topics. (3) Knowledge building is stimulated by the problem and applied back to the problem. (4) It is student centered. (5) It is self-directed, such that students individually and collaboratively assume responsibility for generating learning issues and processes through peer and self-assessment.

PBL has been successfully used in teaching sciences, mathematics, law, and medicine (Merritt, Lee, Rillero, & Kinach, 2017; Uden & Beaumont, 2006). Students are engaged in carefully chosen and formulated unstructured problems, which do not explicit the questions to answer. Actually, identifying these questions is part of the task, allowing them to go beyond traditional learning about specific content (Savery, 2006). Instead, they are challenged to pose questions, to analyze in a collaborative way with different perspectives, because the core of the process is not to solve the problem, but to learn from it. Therein lies the difference between problem solving and PBL. The first one is focused on the algorithms and procedures for solving problems, whereas in the second the problem does not need to be solved. Students learn while analyzing, contrasting, and exchanging information.

The teacher's role is to facilitate student's learning. Students interact among them in groups six to eight members, while the

teacher guides their interaction and analysis (Boud & Feletti, 1999). The sequence in the sessions is essential. For the purpose of this study, seven steps were implemented: (1) clarifying terms, (2) defining the problem, (3) brainstorming, (4) structuring and hypothesis, (5) learning objectives, (6) searching for information, and (7) synthesis.

## The Use of Authentic Material in Education

The concept of authentic material has influenced language teaching in the past two decades. Numerous definitions are available to describe the concept of authentic material (Al Azri & Al-Rashdi, 2014). For this study, we consider authentic material as language produced by a real speaker or writer for a real audience, which is expected to express a real message that was not specifically produced for the purpose of teaching. Authentic materials have no limit, including instruction leaflets, journals, manuals, advertisement, inscription forms, demonstration videos, statistics, and job offers (Vahidbaghban & Pandian, 2011). The teachers can benefit from their use by breaking the routine and providing a welcomed variety of materials in the classroom, if chosen and used appropriately and judiciously. The nature of the materials can also support a more creative and critical approach in the classroom (Tungesh, 2012).

It has been proposed that using authentic material increases the learners' motivation and reflects positively on the learning process, preparing learners for real life by exposing them to problems and language they will face in the real world (Al Azri & Al-Rashdi, 2014). In addition, authentic materials are considered more challenging than artificial materials by relating more closely to students' needs, providing authentic cultural information, and giving them sense, as it serves a real purpose, more interesting and stimulating (Vahidbaghban & Pandian, 2011).

Importance has been given to internet as a source for authentic material being described as stimulating and interactive. The immediacy and scope of materials now available in the web is unprecedented in history (Vahidbaghban & Pandian, 2011).

Newspapers are the most easily available source of authentic material. The different sections: headlines, pictures, cartoon strips, advertisements, and the news articles can be exploited differently (Tungesh, 2012). There are innovative and valuable ways to include science-related news in science lessons with the desire to support higher order thinking and active learning by emphasizing the prominence of science in current events when relating articles to specific subject content (McClune & Jarman, 2012).

For a material to be authentic, there is a need for social interaction, pointing out that materials are interactive, whereas textbooks are instrumental (Vahidbaghban & Pandian, 2011). This interactivity and social environment is particularly provided by the PBL dynamics. We hoped that careful selection of the materials to be used as problems and the task of problem solving would offer a closer approximation to the world outside the classroom. In this learning environment, the participants would publicly share the problems, achievements, and overall process of learning together as a socially motivated activity (Vahidbaghban & Pandian, 2011). By contextualizing learning in real life and analyzing health or nutrition articles from newspapers and magazines, which were debatable from a scientific point of view; we hoped to focus the instruction to the student, promoting motivation, generic skills, and learning of metabolism. With this purpose, an intervention was designed and implemented.

## Materials and Methods

### Study population

The intervention was applied to all students from the biochemistry course for Bioengineering at Univ. de Concepción in 2013 and 2014 (27 and 25 students, respectively), with informed consent.

### Data collection tools and analysis

A mixed method design was used.

**Quantitative analysis:** The perception of the students of the experience regarding their effectiveness in promoting motivation, learning, and generic competences was assessed using a checklist created for this intervention, which included space for voluntary commentaries. Pre and post-tests to assess self-directed learning were applied to the cohort 2014 using the Fischer, King, and Tague's self-directed learning readiness scale, which was validated in Chilean medical students (Fasce, Perez, Ortiz, Parra, & Matus, 2011). Due to the small sample size, nonparametric statistics was used. The Wilcoxon Test for related samples was applied to analyze the difference between measurements. Finally, a survey was applied to the cohort 2014 to determine their preferred sources of information and web services while performing the task. Regarding sources of information, students had to select if they used internet pages, books, and/or scientific papers, as well as specifying any other resource used for acquiring knowledge that were not included as an option. The survey also inquired about the use of web services to organize teamwork or share material, having to select if they used Facebook, WhatsApp, and/or Dropbox, as well as specifying any other resource for this purpose that were not included as an option.

**Qualitative analysis:** Content of the voluntary commentaries of the checklist used for assessing the perception of the students was analyzed according to Krippendorff (1997). For segmentation criteria, positive and negative commentaries were coded and categorized.

Table 2—Example of one of articles selected as problems.

#### Lose up to 3 kilos per week

Extracted from [http://www.agenciaderf.com/despachos.asp?cod\\_des=151972](http://www.agenciaderf.com/despachos.asp?cod_des=151972)

**Main topic.** Healthy diet and interconversion of biological macromolecules in mammals

**Main question.** Is it possible to stimulate glucose synthesis in hypoglycemia?

**Associated contents.** Lipid and carbohydrate metabolism, glycemia regulation, fat mobilization, and macromolecules interconversion.

**Summary of the article.** In order to lose weight, this article recommends the elimination of carbohydrates from the diet so that glucose is obtained by gluconeogenesis from fat.

**Expected discussion.** Students are expected to determine that mammals do not have metabolic pathways to transform triacylglycerols into glucose, except glycerol and three carbons from odd-chain fatty acid. They should discuss that in hypoglycemia, fatty acids will be degraded, but to produce energy. In a low carbohydrate diet, initially, fatty acids from adipose tissue will mobilize and degrade causing weight loss. Nevertheless, glucose levels will not normalize. Moreover, with an unbalanced carbohydrate and lipid ingest, fatty acid degradation will be inhibited due to the lack of oxaloacetate, which in turn will induce the production of ketone bodies to nourish muscle and brain. If this situation is prolonged, it could produce metabolic acidosis. Therefore, they should conclude that a diet that lacks carbohydrates completely is not recommended and what is proposed in the article is not feasible.

### Intervention design

The analysis of web articles by PBL was included as a graded activity in the biochemistry course. Biochemistry is part of the 5th semester of the curriculum. It covers protein structure (30%), enzymology (30%), and metabolism (40%) with lectures, seminars, and laboratory sessions. The intervention was implemented in metabolism. Carbohydrate metabolism was revised as usual in order to introduce students to metabolic pathways and general concepts in a familiar way; while lipid and nitrogen metabolism and the integration of metabolism were covered only through PBL.

Four teams of six to seven randomly selected students worked on two rounds of PBL, each one during four sessions distributed in 2 to 3 weeks. PBL was the only task for students during these 5 weeks. Defining the teamwork rules can contribute to the development of transferable skills as well as students' satisfaction (Carvalho, 2016). Therefore, the group committed to the assignment through a learning contract (Anderson, Boud, & Sampson, 1998) which focused in attendance, punctuality, task compliance, and teamwork.

Problems consisted of articles available in newspapers and nutrition or health web pages covering the following contents of the course: (1) biological macromolecules structure and mobilization, (2) anabolic and catabolic pathways, (3) differential regulation and relationships between metabolic pathways, and (4) energy sources and metabolism in normal and pathological conditions. (1) and (2) were analyzed through the first round of PBL, while (3) and (4) by the second problem. General information about the articles is presented in Table 1 and one example in Table 2.

One tutor supervised two teams. They were introduced to PBL and their role by two reading assignments followed by a discussion session guided by an experienced colleague. Additionally, an instruction document with a general description of the role of the tutor and specific information for each problem was elaborated for them.

Each problem was analyzed in four sessions. In the first session, students were expected to engage in a brainstorming discussion in order to identify the problem and assign tasks for independent study. In the second session, they should report their findings, classify ideas, identify new questions, and define new tasks. In the third

session, they were expected to conclude after discussing their findings and analyzing new information. Finally, in the fourth session, students were asked to present their problem and conclusions focusing on the process that led them to the outcome, describing the related metabolic content. Global and specific feedback from the tutors was provided during group dissertations. Each session, they selected a leader, a moderator, and a secretary, roles that had to be switched each session ensuring a similar distribution of roles.

Students were expected to learn from the process by considering the opinion of their team members, as well their own perception of their performance. Therefore, a 360 degree assessment (Tee & Ahmed, 2014) was performed using a progress assessment chart shown in Figure 1, which included four dimensions: (1) identification and analysis of the problem, (2) interaction, (3) responsibility and commitment, and (4) presentation; each with several aspects to assess and four levels of performance to select from (Figure 1). Self-assessment should help students to think about and practice thinking-like-a scientist, as reported by Hendrich et al. (2018). This progress assessment chart was used for grading. Tutors evaluated the group in dimensions 1, 3, and 4 (50% of the grade), while students evaluated themselves and one randomly selected member of their team in the four dimensions (25% each). The average grade from both rounds of PBL represented 15% of the final grade of the course.

## Results

Students analyzed web articles by PBL during 5 weeks to learn metabolism in a biochemistry course. The tutors considered that the teams identified the problem and provided a correct and complete solution. Students seemed engaged, enthusiastic, and committed to the task. All students participated, whereas with traditional lectures in the preceding part of the course, low attendance and motivation was perceived. Actually, students arrived early to the sessions and worked independently, needing little guidance from the tutors. In some cases, they analyzed the problem further than expected, including physiological or pathophysiological contexts.

A progress assessment chart (shown in Figure 1) was used for grading by the tutors, peer, and self-assessment. A popular fear of including students' in assessment is the possibility that they assess themselves or their classmates with higher scores than they deserve. On the contrary, in this experience, most individual self-assessments and more than 50% of peer-assessments were harsher than the tutors' team evaluation. Besides particular exceptions, students were tougher when evaluating themselves than when they evaluated a team member. Final grades were in general 1 point above the grade of the examination performed previous years to assess the same learning outcomes and contents, ranging from 5 to 6.7, in a scale from 1 to 7. The average grade from the first round was 0.3 points lower than the average grade of the second round.

The perception of the students is presented in Table 3. Some students alleged that the time assigned for the activity was not enough (mainly cohort 2013) and stated having difficulties for identifying the problem (33% and 20% of cohorts 2013 and 2014, respectively). In all other aspects, the perception was very positive. Particularly, students' considered that the methodology motivated them to study biochemistry and promoted generic skills. It is noteworthy that all the students from both cohorts liked the methodology and reported that the analysis of web articles by PBL promoted critical thinking and learning about the topic analyzed

by their team. Most of them preferred PBL to traditional lectures and would rather be evaluated using the assessment chart than by a traditional examination, being willing to use PBL in other subjects. On the other hand, 67% and 84% declared having learned concepts presented by other teams. In general, they were satisfied with the guide of the tutors and the assessment.

From the content analysis of the students' commentaries, 11 codes emerged, which were organized in the following three categories considering the theoretical basis of PBL methodology and their nature and frequencies:

1. PBL properties and relationship with content learning: Referred to descriptions of specific characteristics of the methodology that promote better learning of the contents. This was the most represented category. Examples:

It is a very dynamic methodology that promotes interest for the content by relating it to daily life [Subject 10, female, 2013 cohort].

I consider that it is a good way to learn, mainly because we not only memorize contents, but we apply and explain them and we can extrapolate them to different situations [Subject 2, female, 2014 cohort].

I liked the methodology. It encourages to learn by our own means and to criticize what we read [Subject 8, female, cohort 2014].

2. PBL applicability: Related to the use and implementation of PBL in other courses. Examples:

Excellent methodology, I would like to see it applied in superior courses that require knowledge analysis such as molecular biology or genetics [Subject 10, male, cohort 2014].

I would be good that the following courses adopt this methodology in order to have continuity [Subject 22, male, cohort 2013].

3. Planning of PBL: Referred to the planning of the PBL in regards to time, organization, or assessment. Examples:

It was useful to adopt concepts more easily. I consider it very constructive. Unfortunately, it requires more time than traditional lectures. Therefore, broad implementation would be complex [Subject 10, male, cohort 2014].

I liked the methodology; but I disliked the fact that it was carried out at the end of the semester, when we have less time [Subject 19, female, cohort 2014].

Regarding the assessment of self-directed learning using the Fischer, King, and Tague's self-directed learning readiness scale (Fasce et al., 2011), the comparison between the scores in the pre and post-tests showed an increase of 0.28 points. In all the cases, the score in the post-test is higher than in the pretest. Wilcoxon Test for related samples determined that the difference between both assessments is statistically significant ( $P < 0.01$ ). If the standard deviation of the pretest is used as an indicator of the standardized size effect, the result is  $d = 0.9$ , implying that the difference is strong. Figure 2 plots the increase of self-directed learning in the post-test measurement in all students.

The use of resources by students in 2014 is presented in Table 4. Websites are the preferred information source, whereas books are the less used within the available options. Interestingly, most of the students used scientific papers in both rounds of PBL (92% and 88%). Regarding the use of web services, more than 90% of the students used Facebook for exchanging, organizing, and discussing material.



PROGRESS ASSESMENT CHART

Name: .....

Date: ..... Total score: 72 points

Dimensions and aspects to assess	Excellent 4	Good 3	Regular 2	Poor 1
<b>1. Identification and analysis of the problem</b>				
They/He or she are/is able to define the problem				
They/He or she identify/ies the topics related to the problem				
They/He or she recognize/s useful and relevant knowledge for solving the problem				
They/He or she develop/s models or hypothesis				
They/He or she identify/ies learning necessities and tasks for solving the problem				
<b>2. Interaction</b>				
He or she communicates effectively his or her knowledge and ideas to the team				
He or she avoids to contribute excessively to the discussion				
He or she incorporates knowledge and ideas from others				
He or she respects their team mates and helps them to clarify their doubts				
His or Her contribution supports the team to solve the problem				
<b>3. Responsibility and commitment</b>				
They/He or she assist/s punctually to all the sessions				
They/He or she research/es or study/ies independently for the next session				
They/He or she display/s enthusiasm getting involved with the task				
<b>4. Presentation</b>				
They/He or she describe/s the metabolic pathways related to the problem				
They/He or she transmit/s effectively the problem and the conclusions to their classmates				
They/He or she construct/s knowledge in every aspect related to the problem				
They/He or she elaborate/s a profound analysis of the problem from a biochemical point of view				
They/He or she are/is capable of answering questions related to the problem				
They/He or she use/s and appropriate language and formality				
Total score				

Comments:.....  
 .....  
 .....

Figure 1–Progress assessment chart for assessing students' performance in PBL. The evaluator chose one of four levels of performance for each aspect of the four available dimensions. The tutor only assessed dimensions 1, 3, and 4, while the student self-assessed and assessed one of his or her peers considering all dimensions. Space for voluntary positive or negative commentaries was also available.

**Discussion**

This experience presents PBL as a valuable methodology for motivating and engaging students, observing a positive attitude toward learning in the classroom. Actually, students' perception is much more optimistic compared to other methodologies previously used in same course, such as wiki and conceptual maps (Bruna, Bunster, Martínez, & Márquez, 2014a; Bruna *et al.*, 2014b). Moreover, when asked informally, students declared hav-

ing studied considerably more than for a traditional examination. More importantly, the general, and in some cases, total positive perception of promoting generic competencies is extremely relevant, given that the development of a scientific perspective and the workplace require them. This proposal is consistent with the increasing tendency of not focusing on the content when teaching in higher education. Delaney, Pattinson, McCarhy, and Beecham (2017) have shared an experience of the use of PBL for

Table 3–Perception of the students of PBL-based analysis of web articles in biochemistry.

Evaluated aspect	2013			2014		
	%YES	%NO	%NA	%YES	%NO	%NA
It motivated me to study biochemistry	89	11	–	96	4	–
It encouraged self-directed learning	100	–	–	96	–	4
It helped me to work cooperatively	100	–	–	100	–	–
It promoted critical thinking	100	–	–	96	–	4
It promoted my problem-solving skills	96	4	–	84	16	–
It motivated me to commit to my own learning	93	7	–	92	8	–
Team work facilitated analysis and problem solving	78	18	4	96	4	–
Using real articles motivated me to study biochemistry	93	7	–	92	8	–
Using real articles helped me to apply knowledge to daily life	63	33	4	76	20	4
It was easy to identify the problem and topics that needed to be studied	44	56	–	84	16	–
The time assigned for the activity was enough	93	7	–	96	4	–
The guide of the tutor helped my team	100	–	–	100	–	–
I learned about the topics analyzed by my team	67	22	11	84	16	–
I learned about the topics analyzed by other teams	82	11	7	92	4	4
The progress assessment chart seemed appropriate to assess my performance	96	4	–	92	4	4
I consider appropriate to evaluate myself and one of my classmates	7	93	–	–	100	–
I would rather be evaluated by a traditional examination	100	–	–	100	–	–
I liked using PBL	4	96	–	4	96	–
It demanded too much time and hindered my performance	78	18	4	92	4	4
I prefer PBL over traditional lectures	92	4	4	96	–	4
I would like to use PBL more frequently in this and other subjects		<i>n = 27</i>			<i>n = 25</i>	

NA, no answer.

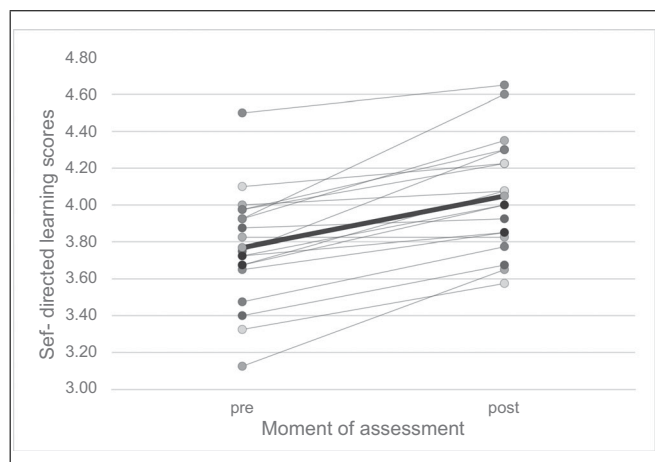


Figure 2–Effect of PBL in self-directed learning in the 2014 cohort. Chart of the students' pre and post-tests self-directed learning scores. Both measurements are connected for each student, showing an increase in all cases. The mean values are presented in a bold line.

Table 4–The use of resources by cohort 2014.

Resources	First round (%)	Second round (%)
<b>Information sources</b>		
Websites	96	92
Books	68	60
Scientific papers	92	88
Other <sup>a</sup>	8	4
<b>Web services</b>		
Facebook	96	92
WhatsApp	8	–
Dropbox	36	20
Other <sup>b</sup>	28	20

*n* = 25.

<sup>a</sup> Meeting with health professional or advanced classmate.

<sup>b</sup> Google drive.

transitioning from traditional education in management education. Nevertheless, no details as to how actually implement it, such as examples of problems, how to assess students' performance, time and other requirements, were included. Thus, this experience can be of value for the staff when introducing PBL in a course.

PBL has been reported to be more effective than conventional classrooms (Strobel & Barneveld, 2009). Studies are consistent in demonstrating its superior efficacy for longer term knowledge retention and in the application of knowledge (Yew & Goh, 2016). Consistently, content analysis of the commentaries of the students focuses on the perception that the methodology promotes learning, on its advantages, and its applicability in other courses. Students also acknowledge that it requires more time and dedication.

One of the key results suggested by this intervention is an increase of motivation. Motivation is regarded as a key element in the success of learning in general. It has been found to be a crucial process or mechanism for enhancing student learning outcomes in science and engineering (Lazowski & Hulleman, 2016). Research findings suggest that promoting learning based on motivation requires complex interventions to have high impact, but simple interventions, such as the one presented in this work, have also proven effective (Bernacki, Nokes-Malach, Richey, & Belenky, 2016; Rosenzweig & Wigfield, 2016). Instructional methods that nurture and draw upon the curiosity of students have the best chance to motivate students to learn science (Silverman, 2015).

Empirical studies have concluded that authentic materials have a positive effect on learners' motivation; teachers need to have a clear pedagogical goal in mind while selecting them (Al Azri & Al-Rashdi, 2014). In this context, it has been declared that teachers need to understand the nature of the students' subject area; using appropriate strategies, making tasks authentic, bringing the real world into the classroom, motivating through variety and relevance, and providing environments that encourage idea sharing, awareness, and curiosity (Vahidbaghban & Pandian, 2011).

Using real articles from the web in a PBL environment agree with these ideas. Consequently, 78% (2013) and 96% (2014) declared being motivated to study biochemistry and 93% (2013) and 92% (2014) stated that it helped them to apply knowledge (Table 3). Accordingly, the qualitative analysis of the students' commentaries suggests an increase in motivation, being the majority related to the properties of PBL and how to promote learning of the content. Pre- and post-test motivation measurements with a validated instrument would have provided more information, and it would be interesting to inquire the effect on motivation of this methodology in the future. In this experience, the fact that most students voluntarily studied from scientific papers supports the claim that using PBL and authentic material in class promotes motivation for learning biochemistry. The preferential use of websites as a source of information (Table 4) evidences the need to emphasize critical reading and the vast use of Facebook represents an opportunity to explore in education.

Despite there is no information in this study regarding learning gain, one could hypothesize that students will be able to easily find and apply content to metabolic issues in the future. Instead, with traditional lectures, no training for these abilities is pursued and the content may be forgotten if it is not regularly used.

Unfortunately, no objective data were collected from the tutors. Their subjective perception is that students seemed more engaged, committed and autonomous, and performed a deeper analysis of the contents.

Despite the very positive perception of PBL from the students, some limitations need to be addressed:

- 1) Planning the activity and select/construct appropriate problems is time-consuming. Nevertheless, the activity can be reproduced or used as a base for designing new learning environments, significantly decreasing time requirement for succeeding attempts.
- 2) Need for spaces for collaborative work. Many universities are including spaces that fulfill this requirement. Even so, this is a strong restraint when working with numerous groups.
- 3) Need for tutors. One tutor per group is recommended. However, in this experience, one tutor successfully guided two groups, actually one tutor per three groups could have been feasible. Thus, it depends on the level of the students and the problem complexity. Engaging postgraduate students to participate in exchange for credits or a teaching experience certificate could be a solution to this problem.
- 4) Providing effective feedback. Feedback is central to the development of student learning. Nevertheless, several studies have reported feedback as one of the most problematic aspects of the student experience. It should support students in self-monitoring their own work independently of the tutor (Carless, Salter, Yang, & Lam, 2011). It should go beyond teachers informing students about their strengths and weaknesses. Feedback and analyzing exemplars could help make sense of the information and help them use it to enhance their work and/or learning strategies (Carless & Boud, 2018).
- 5) Time for reviewing contents with this methodology is higher than with traditional lectures. On the other hand, students develop other competences rather than only acquiring knowledge, which is consistent with what is usually

declared in the professional profiles to which courses must contribute.

- 6) The perception of this experience suggests that students do not learn from topics covered by other teams (67% and 84% for 2013 and 2014, respectively) as much as from topics analyzed by their own team (100% for both cohorts). Thus, evidencing the need of a careful design when selecting and assigning problems, including relevant topics in all problems when using different material for each team.

The use of authentic material in PBL environments provides a meaningful context that encourages students to read further. Newspapers and the internet are presented as a rich source for extracting materials for analyzing biochemistry, genetics, microbiology, and other subjects, representing an opportunity to also discuss ethics, social responsibility, and promote critical thinking. One interesting idea is to use common material in related subjects; for example, biochemistry, physiology, and physiopathology to analyze the material from different points of view, integrating contents and subjects as a final task. This should be feasible considering that according to Chua, Tan, and Liu (2016), "looking from different perspectives" is one of the dominant cognitive functions displayed during PBL. The use of authentic material in metabolism could also contribute to promote health literacy, which has been reported as insufficient in university students (Sukys, Cesnaitiene, & Ossowsky, 2017).

This methodology has been also used in other biochemistry course the following years. Moreover, workshops to introduce PBL based on this experience in the university community have resulted in successful implementations. For example, university colleagues have used it to teach urinary system in a clinical biochemistry course and genetic diagnosis in a vegetal biotechnology course (unpublished data).

As mentioned previously, none other methodology used in this course in the past has been perceived as positive as the experience presented in this paper. On the other hand, students' perception and content analysis revealed that they liked the methodology, are willing, and in some cases eager to use it in other subjects. Moreover, a quantitative improvement in self-directed learning over a short period was detected. Thus, if difficulties can be overcome, analyzing authentic material by problem-based learning is a valuable alternative to traditional lectures, consistent with the pressing need of providing active learning and innovating in the classroom while teaching science (Waldrop, 2015). This proposal can be applied to other subjects and disciplines and contributes to the transition from teacher to student centered-education.

## Conclusion

This study describes an intervention in the classroom based on the analysis of health or nutrition articles from newspapers and magazines from the internet by PBL, in order to learn metabolism by applying contents to real-life contexts. A positive perception of the students, an increase of self-directed learning, and a voluntary use of scientific papers as a source of information, is reported. This experience is transferable to other contents and emphasizes the need to innovate in the classroom, in order to engage students in their learning process by providing more authentic tasks that relate to the real world. The design and analysis of this intervention is in accordance to the movement of scholarship of teaching and learning, by assessing teaching practices in order to improve the learning of the students.

## Author Contributions

C. Bruna was responsible of the design, implementation, and assessment of the intervention and drafted the manuscript. N. Valenzuela participated as a tutor in the implementation phase and collected the data. D. Bruna analyzed and interpreted self-directed data, and revised the manuscript critically. A. Lozano contributed to the design of the intervention and the drafting of the manuscript. C. Márquez was responsible of training the tutors and performed the qualitative analyses.

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