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ABSTRACT

A study was conducted on the cognitive processes involved in the steps of problem-based learning and the way this pedagogical approach is applied in the health sciences. The objective was to understand more deeply the cognitive process related to student comprehension and its connection with the work done when studying a medical discipline through problem-based learning (PBL). A case study was undertaken with a total of 30 students and an interdisciplinary team composed of a physician and two professionals in the field of education. After a video analysis process of face-to-face teamwork on PBL, it was decided to design and use an advanced organizer to systematize and ease the comprehension process while working with problem scenarios. From its initial application, the students were satisfied with its usefulness, and they provided feedback to improve its format and extend its applicability to other disciplines. It was concluded that not only is it possible to integrate hybrid models in problem-based learning, but also to include variants and auxiliary tools that arise from the cognitive demands and the information management needs of the students, thus favoring the study and the preservation of knowledge.

Keywords: comprehension, educational innovation, formative assessment, higher education, learning taxonomy, problem-based learning

Background

More than a century after the initiation of the medical education revolution (Flexner, 2002), we are again entering into a period of transformation at an international level. Future professionals in health sciences, particularly in medicine, should be educated to mobilize and apply knowledge, work collaboratively, manage their continuing self-learning, develop critical thinking and leadership skills, create knowledge, exercise their professions with social sensitivity, and show a professional attitude along with ethical and committed behavior in the care of their patients.

In response to the current educational needs of future health science professionals, various learning approaches have been implemented as formative strategies to guide students in developing the necessary competencies to practice their professions. One of these strategies involves the use of didactic techniques such as problem-based learning (PBL).

Since its introduction in the 1960s, this technique has mainly been extended to health disciplines. PBL's popularity arose when the McMaster University Faculty of Health Sciences inserted innovative educational strategies throughout its three-year curriculum (Barrows, 1996). Since then, PBL has been incorporated in class as a way for the learner to become active and engaged with the learning process. It was understood that individual and collective prior knowledge could ease learners to make sense of the phenomena involved in a complex health situation. Additionally, it was also possible to provoke engagement in peer learning through small-group discussions and consolidate their learning through reflective writing (Yew & Goh, 2016). However, PBL's most

Title and Authors	Theme	Method	Results	Discussion
The effects of problem-based learning during medical school on physician competency: A systematic review.(Choon-Huat Koh et al., 2008)	The effect that the use of PBL has on the development of medical student competencies after they graduate.	Five specialized databases and five medical education journals were searched. Studies were included in the review only if they met the following criteria: (a) PBL was a teaching method in the school of medicine. (B) Physician competencies were assessed after graduation and against a control group of graduates taught in curricula using traditional methods.	A selection process was carried out, arriving at a final analysis of 13 studies: four from the United States, three from Canada, three from Britain, two from the Netherlands, and one from Australia.	Evidence is provided that the use of PBL in medical school has positive effects on the development of post-graduation medical competencies, especially in the social and cognitive dimensions. After conducting a meta-analysis, there was little robust evidence that PBL would have an adverse effect on acquiring knowledge. However, strong evidence was found that such a method has positive effects on the application of knowledge.
The process of problem-based learning: What works and why (Kassab et al., 2019)	The process of PBL, its functioning, and description in medical education.	Two scenarios are proposed to explain how learning is promoted through the use of PBL: (a) Elaborative activation (b) Situational interest The effects of various support strategies used in PBL are analyzed, and a series of short studies are carried out using a micro analytical methodology.	Evidence about the influence of PBL when it is used in small groups in the recovery of previous knowledge is presented, allowing the elaboration of ideas when new elements are integrated into the situations studied. These activities facilitate the understanding of new information related to the problem and improvement of long-term memory.	It is stipulated that PBL seems to have substantial effects on learning and performance compared to methodologies that are not based on problem-solving and when students are not encouraged to use their previous knowledge. These findings seem to vary with those of comparative curricular studies that generally do not report PBL having better results than those of conventional training methods.

Table 1: The most cited research in the last decade about PBL in training processes (Choon-Huat Koh et al., 2008; Kassab et al., 2019; Srinivasan et al., 2007; Yadav et al., 2011)

Comparing problem-based learning with case-based learning: Effects of a major curricular shift at two institutions (Srinivasan et al., 2007)	The opinion of medical students and professors concerning the comparison of the use of PBL vs. case-based learning (CBL).	During three years, medical schools at the University of California, Los Angeles (UCLA) and the University of California, Davis (UCD) changed second- and third-year courses in PBL formats to case-based learning (CBL). Ten months later, students and professors who had participated in both curricula completed a 24-item questionnaire on their perceptions of PBL and CBL, as well as the perceived benefits of each format.	Students and professors overwhelmingly preferred the CBL method. It was identified that in this format they made comparatively better use of time, experienced fewer unfocused tangents, and decreased external work. According to the majority opinion of the teachers, it was thought that, while CBL offered the opportunity to apply the skills learned, PBL offered more opportunity for the application of problem-solving skills in the session. In comparison, most teachers considered that PBL was advantageous only in two areas: 1. It emphasized independent learning. 2. It fosters self-directed learning.	PBL has been promoted as the preferred method for promoting critical research. However, students and professors from both institutions preferred the CBL instruction method. Why do these students prefer CBL over PBL? The findings indicate that the determinants of this preference are not related to the opposition to open research, but to the perceptions of the efficient use of time.

Table 1(continued): The most cited research in the last decade about PBL in training processes (Choon-Huat Koh et al., 2008; Kassab et al., 2019; Srinivasan et al., 2007; Yadav et al., 2011)

Problem-based learning: Influence on students' learning in an electrical engineering course (Yadav et al., 2011)	Comparison between the use of PBL and traditional learning in engineering students.	Fifty-five students in an electrical engineering course at a Midwest university participated in this research. The design interspersed traditional classes with others using PBL in the experimental phase of the study. Participants completed the pre-and post-testing of the four topics covered in the study and also completed a student-assessment survey about successful learning.	Compared to conventional classes, PBL allowed students to conceptualize better and transfer their learning to problem scenarios. Students obtained equal or better scores with PBL compared to the conventional approach. However, although in the overall survey results the students commented that PBL allowed them to apply the concepts learned, most reported that they thought their understanding and learning were better under the traditional class method.	In this study arises a controversy about the benefits of the use of conventional methods versus PBL. It is known through previous research that engineering students tend to go through an initial phase of shock and denial when they are forced to take responsibility for their learning during a problematic approach. Further research is needed on the impact of PBL on STEM learning

Table 1(continued): The most cited research in the last decade about PBL in training processes (Choon-Huat Koh et al., 2008; Kassab et al., 2019; Srinivasan et al., 2007; Yadav et al., 2011) important value lies in the fact that, in addition to developing practical skills, it promotes self-management of learning, the development of collaborative work skills, and self-discipline and reflection about the formative process (Fan et al., 2018; Gómez Restrepo, 2005; Hincapie Parra et al., 2018; Khoo, 2003; Sutton & Knuth, 2017).

After a search was conducted in the Web of Science index with regard to publications on the use of PBL for training purposes in the last ten years, it was found that, worldwide, 988 studies have been published in which advantages and disadvantages of implementing PBL in the training processes are specifically discussed. Studies related to other student-centered techniques such as project-oriented learning or case-based learning in this same period comprised approximately 10% of the total number of publications related to PBL. It should be noted that, of the total number of articles published that refer to PBL, there are 226 reports focused on its use in health sciences. Table 1 depicts the information provided by some of the most cited research on the use of PBL; it includes methodological aspects, the principal results, and the discussion about the use of this teaching strategy.

The results and discussions presented in these reports confirm that PBL is a learning strategy that offers significant advantages and benefits. However, it is also important to reflect on other possible supports or variants of this strategy that could be incorporated to make its use even more efficient. Some examples of variants or modifications that can be introduced into the PBL learning framework were reported in recent studies (Gladman & Perkins, 2012; Grisham et al., 2015), which include some useful alternatives to work under a hybrid PBL model.

In the first study (Gladman & Perkins, 2012), some modifications to the traditional PBL structure were proposed for certain groups due to rural contextual variables; for example, the lack of human resources trained in the use of PBL. No significant difference was found among urban and rural groups after grades analysis. The second study (Grisham et al., 2015) sought to collect information from professors and public health students about the use of PBL. While it is true that, in terms of its impact on learning, the technique can bring valuable results, it was emphasized that the use of hybrid models of PBL could be a much more favorable and promising alternative to achieve effective learning. In summary, both studies

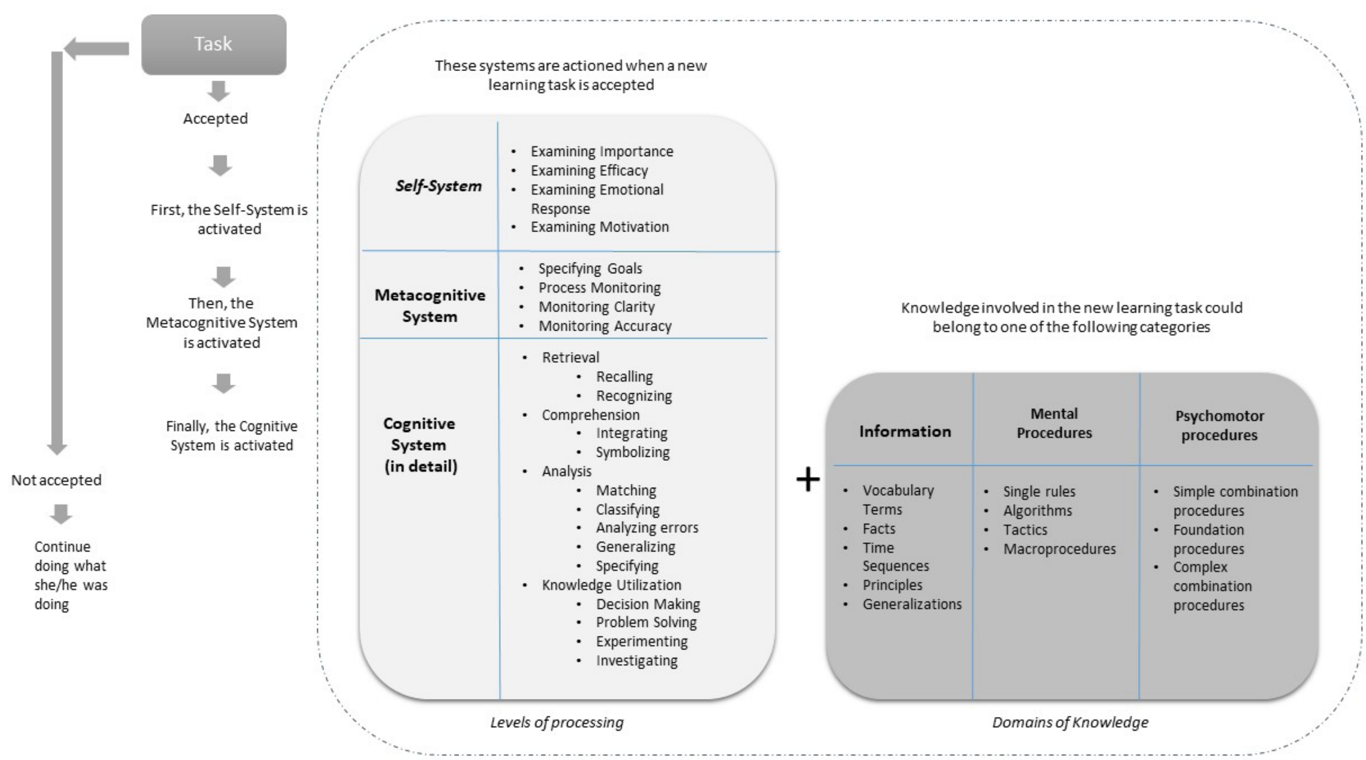

Figure 1: Integration of the systems, processing levels and domains of knowledge that the New Taxonomy (based on Marzano & Kendall, 2008)

reflect certain advantages in the application of modifications as well as complementary solutions that could allow working with PBL more efficiently.

Another case of using the PBL technique to foster learning among medical students with a variant in its methodology is reported (Wang et al., 2016). PBL in this particular learning situation was used from a coaching perspective. This approach considers personal qualities from a humanist perspective, emphasizing a sense of empathy and medical humanity. Thus, training with PBL paid particular attention to the emotional and motivational aspects of the students and found the emotional scaffolding, which implies establishing a trustful and supportive relationship with the students, to be an essential component of the learning processes as well as the cognitive scaffolding. The study was carried out with third-year students under an interpretative phenomenological approach. The results point towards achieving an improvement in doctor-patient communication in clinical scenarios, an improvement in the psychological well-being of the students, and the motivation to build a professional identity with higher sensitivity to clinical issues and a holistic view of patients.

Nevertheless, there are also other elements to consider when determining a formative goal. The thought processes required when working with PBL is one such element due to the fact that a poorly developed thought process can actually hinder work when using this teaching strategy.

In this sense, cognitive psychology has contributed for years to the teaching-learning process related to thought processes (Marzano & Kendall, 2008). The New Taxonomy defines a series of levels of mental processing, as well as their mechanisms; likewise, it defines a series of complementary systems that help systematize the learning process in a structured and progressive way. Figure 1 illustrates the integration of the systems, processing levels, and domains of knowledge that the New Taxonomy provides.

According to the New Taxonomy, one of the higher-order levels is the processing level called comprehension. Exercising processes of comprehension involves translating knowledge into the appropriate forms so that its storage in permanent memory is finalized; that is, it builds the structure and the format so that key information is preserved. Comprehension is supported by two sub-processes: integration and symbolization. The sub-process of integration has three steps:

1. Deletion: Given a sequence of propositions, any proposition that is not directly related to the next proposition in the sequence is cleared.

2. Generalization: This step replaces any proposition with one that includes information in a more general way.

3. Construction: This step replaces a cluster of propositions with one or more that includes the information contained in the previous cluster of propositions in a more general way.

The sub-process of symbolization is performed based on two elements of information processing:

1. Linguistic, which allows the integration of ideas and affirmations that are lodged in the permanent memory.

2. Imaginary, which leads to the generation of images or icons and sensations that enter through the five senses.

The characteristics of the problem scenarios that are worked through the steps of the PBL technique suggest that comprehension is the most frequent process when working with this technique. In Table 2 the mental processes that each step requires are described.

PBL Steps	Cognitive processing levels that are exercised
Clarification of concepts	Define concepts (Recovery level)
Definition of the problem	Describe the essential or key parts (Comprehension level)
Problem analysis: Brainstorming and systematic classification of topics to be reviewed	Make connections between concepts or elements (Comprehension level)
Definition of learning objectives	Define/explain how and why it is necessary to study specific issues related to the problem scenario (Comprehension level)
Problem resolution	Explain/interpret sustained relationships among elements in a given context (Comprehension level)
	Make associations of concepts or elements, classification, and detection of inconsistencies present in the situation studied (Analysis level)

Table 2: Processing levels identified at each step of the PBL technique

After understanding the connection that could exist between the problem scenarios worked through the PBL technique and the comprehension processes involved in doing so, some questions arose with regards to finding more practical strategies to help students in the phase of theoretical studies to strengthen their capacity of explanation while connecting symptoms' causes and effects within the body's multiple systems in a given situation. Thus, we developed the following research questions:

1. What kind of comprehension processes are involved in the work carried out by medical students when they are working with problem scenarios through the PBL technique?

2. What mechanisms could assist medical students to achieve and consolidate the learning goals and objectives when working through PBL?

Method

Design

We opted for a case study research design (Baxter et al., 2008). A case study is a valuable research tool in health sciences since it allows exploring a problem through multiple facets and capturing the essence of the studied phenomenon. This type of methodology is used to analyze the peculiarity and generality of a situation worthy of study and to understand the complexity of its contextual activities and interactions. It should be mentioned that in this study, we also decided to perform a phenomenological analysis to support the analytical process (Stake, 1999). An advantage in the use of this methodology is the possibility of performing a detailed inquiry that allows defining the characteristics of the comprehension processes involved in the study of medical basic sciences.

Context

This research was carried out at the department of basic sciences of a private medical school located in northeastern Mexico. The medical degree program has a duration of 14 semesters divided into four phases: theoretical (four semesters), pre-clinical (three semesters), clinical (five semesters), and social service (two semesters). The study was conducted specifically within the framework of a course called "Vital Processes." This subject is considered one of the most important in the theoretical phase because it includes contents related to cardiovascular, respiratory, and renal structure and function. As the academic development department of the institution promotes the use of the PBL technique in the classes, the instructional design of this course integrates the PBL technique into 45 sessions during the semester. Figure 2 illustrates the process of working with PBL.

Participants

A sample composed of 30 students enrolled in the last theoretical semester of medicine were registered in this study. For this course, students attend three sessions per week with a duration of two hours each session. The research process about using PBL in the classroom and the discernment of possible auxiliary mechanisms to strengthen the learning process became the responsibility of two medical professors, one educational researcher, and one PhD student in Educational Innovation.

Instruments

The instruments used were:

Video recordings: Video evidence was collected from the plenary and tutorial sessions where PBL was instituted to allow the researchers to analyze and understand the use of the different cognitive processes demanded when studying the discipline.

Semi-structured interviews: An interview was designed in order to know in greater detail aspects such as study habits, learning strategies, work with information organizers, and others.

Procedure

Two phases were implemented in the process of this study. The first was based on analysis of 480 minutes of video recordings of class sessions in which PBL was applied. The second phase involved designing an advance organizer that could allow working on the comprehension processes (Han-Chin & Hsueh-Hua, 2017; Shihusa & Keraro, 2009; Townsend & Clarihew, 1989). This came after the analysis of questions and statements contained on dialogs among groups of students while working on solving PBL situations. This advance organizer was named "Reasoning Procedural Map" (RPM). Once RPM was applied, the work carried out was analyzed.

The problems were presented in class to the students in a patient scenario format with their objective being to diagnose the described health condition. The group was divided into three teams of seven to ten students each. A total of three teams and three different scenarios were given for each class. Teams were provided with different PBL patient scenarios.

Of the two class hours, the first one was devoted to team discussion. In the second hour, the results for each problem were presented to the entire class by each team. Students used the blackboards to draw and explain their results. Two

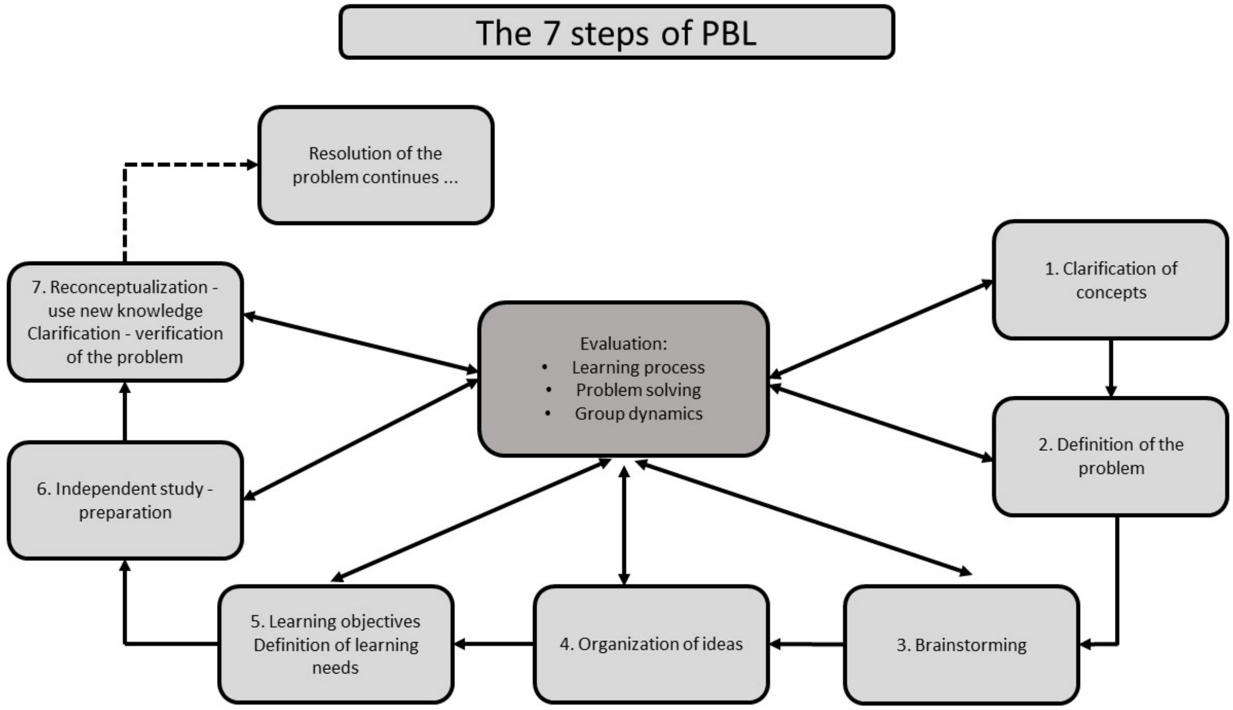

Figure 2: Process of working with PBL with medicine students

professors conducted the organization of teams as well as the feedback process. After the session, students completed the RPM individually and handed it to the professors for grading.

Finally, semi-structured interviews were conducted with four students to learn about their perceptions of the usefulness of this tool in the learning process. Consent for the use of the information for research purposes was requested. Once the verbatim transcript was completed, the ATLAS.ti program was used for the analysis of hermeneutic units. Finally, students' names were codified: A1, A2, A3, and A4 to safeguard their data.

Results

The analysis of the video recording minutes of the learning process using PBL led to designing an information organizer (RPM) that was provided to the students as a tool for the organization, interrelation, and argumentation of information when working on problem scenarios.

The characteristics of the RPM design were based on the following findings from the video recordings:

1. In this discipline, the exercise of the thought sub-process called integration, which is part of the comprehension process (see Figure 1), requires the formation of connections among elements involved in the problem scenario. These elements can be either primary or secondary. The sequence of physio pathological phenomena that lead to the set of signs and symptoms presented in the scenario of the problem can be explained through three types of cause-effect relationships: direct, indirect, and bidirectional.

2. In PBL, the scenario or problem contains a series of observable elements that, when presented sequentially, allow us to infer the conditions of the patient's health from the possible interconnections among different systems. Nevertheless, not only is it necessary to establish these interconnections but also to define critical elements that establish an organized and logical pathophysiologic process that leads to the development of the constellation of signs and symptoms presented in the problem scenario. The establishment or definition of cause-effect relationships makes it possible to explain what happened to the patient presented in the problem scenario (Figure 2, step 7).

Follow these directions to use this tool: Identify the primary node of the problem. Then determine if there is a second element involved in the situation. Write briefly the reason and argument for the definition of the element involved. Finally, draw arrows to illustrate the kind of relationship found among elements in the different health systems.

⊙MN= Main node/ O SN= Secondary node / Rs= Reasons, arguments/ →= Direct relationship/ --→ =Indirect relationship/ ←→ Bidirectional relationship

Reasoning Procedural Map (RPM)

		Observable and sequential elements involved in the problem or situation				
		The normal condition of the patient	*Valsalva* Maneuver	Maneuver finishes/additional noise can be perceived	Syncope	2-3 minutes later Recovery of consciousness Sweating Tachycardia Pallor
Non-observable elements	Arterial pressure	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*
	Cardio System	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*
	Nervous system	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*
	Brain activity	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*	⊙*MN:* O SN: *Rs:*

Figure 3: Example of the reasoning procedural map

Based on these two great findings, a premise was formulated: the process of integration could be strengthened if one works with PBL and an information organizer that intentionally captures the primary and secondary elements in any problem scenario in an orderly and hierarchical manner. Thus, the three types of cause and effect relationships and the integration of conceptual elements that are necessary to provide coherent explanations of the events presented in the problem scenario can be established. This information organizer, named the Reasoning Procedure Map, could help students work on the cognitive processes with a greater possibility of establishing pathophysiological connections and achieving long term knowledge. Figure 3 illustrates an example of the reasoning procedural map designed for this research.

The RPM was used for the resolution of two problem scenarios. Students were asked to resolve them preferentially by hand, although the use of Microsoft Word was also allowed (a resolved map is shown in Appendix A).

Following the first applications of RPM, four randomly selected students were interviewed in order to get to know them more in depth, to acquire information with regard to how they work through complex comprehension processes with the aid provided by the reasoning procedural map (including their experience with the process of establishing cause-effect relationships using this tool), to gather information concerning their study habits and/or reading strategies, to find out the amount of time they have to devote to this work (including individual work and teamwork), and to ask about their perception or personal experience with working through PBL.

The analysis of the students' interviews allowed establishing a series of topics about the comprehension process and understanding in greater detail some key aspects of the student work in the effort to appropriate knowledge. Figure 4 contains the topics and sub-topics analyzed in the interviews to understand the comprehension process.

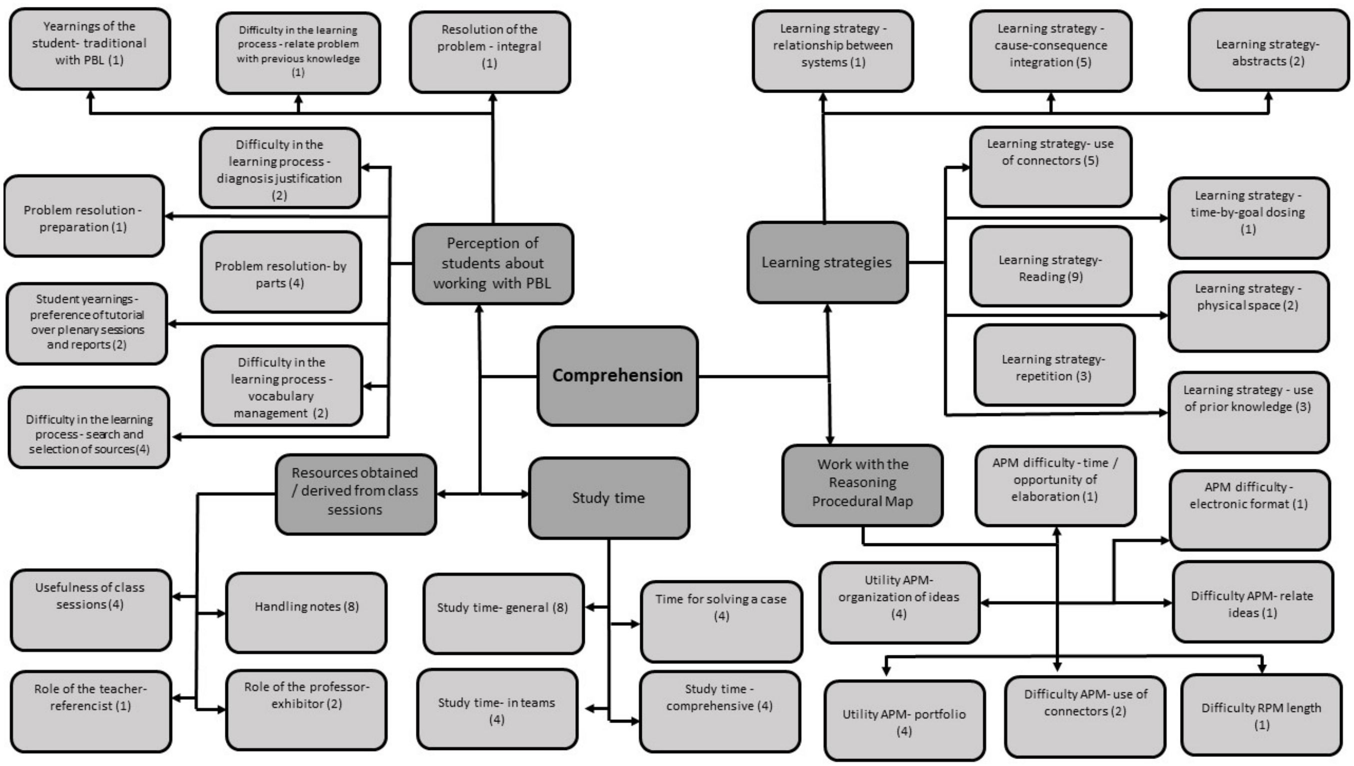

Figure 4: Analysis of topics that emerged during the comprehension process, the use of the RPM while working with PBL, and the number of citations collected by each topic.

After having conducted the discourse analysis of the interviews and the categorization of the topics, the main findings, accompanied by some quotes that illustrate the students' perception for each topic, were:

1. Study time: Most students agreed that, in order to study the contents and objectives that will be reviewed in the tutorial sessions, they usually need, on average, 25 hours of reading per week. In addition, they also spend a mean of eight hours in preparation for the discussion of the resolution of the problem scenarios corresponding to any given week.

> *"I think maybe 12 or 15 (hours)..." (A4)*

> *"Per week, let's say about six hours a day, minus one day that I don't study..." (A2)*

2. The information resources obtained in the classroom are classified into two types: On the one hand, notes or diagrams made by the students and, on the other hand, brief lectures and/or explanations provided by the professor. These resources are especially useful to deepen independent study on the issues addressed in the problem scenarios. Some students stated that, in this sense, the aid provided by the professor, when taking the research guide role, who recommends informational resources to facilitate the consultation of a precise bibliography, is crucial to achieve a good performance in the resolution of problem scenarios.

> *"If I can, before coming to the class, I read; I have my mental maps, in arrows, color lines, and all that, and in the notes, I do my summaries…" (A2)*

> *"...The professor sent me like 20 articles so as to be able to solve it…, well, to be able to put what we saw there; it was plenty of work." (A4)*

3. Learning strategies are varied: Whereas it is true that students agree that reading is essential for the preparation required in order to work with PBL, this is only the first step. From there, a series of processes are derived, namely: repetition to strengthen the new knowledge, recovery of ideas from previous knowledge, seeing the relationships among systems, and the establishment of cause-effect relationships among the main systems involved in a given problem scenario.

"Well, underlining in the books, and reading it again and again until I am clear." (A3)

"...I start looking for books that can serve to help me solve that case and go correlating each, every symptom; every data that we get, go relating it to why this is given, or rather, what is normal and then passing to what is abnormal, which is when you already suffer from a pathology." (A1)

4. Working with PBL leads students to confront some problems, for instance, the selection of information sources, the definition of certain terms and concepts, the correct use of medical vocabulary, and failures in recovering previous knowledge, among others. These problems sometimes make it difficult to arrive at solutions and appropriately justify the answers for a problem scenario.

"The doctor [professor] likes to define the terms, and I think that is the more complicated thing because he expects the precise, exact definition..." (A4)

"...It is that the doctor [Professor] sends us sometimes, sometimes sends us the cases but also sends us information; then when he does not send it to us, well, then I research, but it is difficult." (A2)

5. Likewise, working with the RPM as an auxiliary tool to define, organize, link, and justify the solutions of the problem scenarios was accepted by most students since it facilitated the ordering of ideas and the visualization of the three types of cause-effect relationships, thus strengthening the comprehension process. Nevertheless, difficulties arose owing to the designed format, apparently still somewhat rigid, which makes it difficult to work, in electronic format, with the establishment of links between the elements composing the RPM.

"…it helped me a lot to tabulate and organize all the information that I got, to place the information where it should be." (A1)

"Well, I liked it..., the positive characteristic that I liked is that it allows filling in the information, and then you got everything you need... summaries.... you can visualize that something happens as a result of something else... all the information regarding the case is orderly placed within the same scheme..." (A4)

"... it became very complicated to make the arrows, because, first, I did not know how to pass an arrow from one page to another, because, truly, it lengthened to two pages..." (A2)

Conclusions

The results obtained throughout the study have many similarities with some findings reported by other researchers concerning the application of PBL in health sciences. A first similarity is found with Srinivasan et al. (2007) regarding the time it might take the student to work with problem scenarios designed to be approached through PBL. In our study, although the students did not mention the preference for any other didactic technique, they did say that the number of hours devoted to work around a problem scenario could be higher than 12-15 hours, including individual reading time and the time of teamwork required to arrive at a solution for the problem scenario. In addition, students mentioned some difficulties that they have to face, such as the correct use of medical and technical vocabulary, as well as lack of expertise in searching for appropriate specialized references for approaching the problem scenarios. Therefore, they are clear that support by the teacher, such as the provision of key readings or explanation of difficult or complex topics during the class, eases their work and shortens their study time. This is in accordance with what was stated by Yadav et al. (2011) in relation to the difficulties that students have assuming the responsibility for their own learning, so that they continue to rely on the teacher to facilitate certain processes that involve the investment of time and effort.

However, one of the most important findings, in the opinion of the authors, is to have identified certain relevant peculiarities of the learning process through PBL which are related with the cognitive activity of Comprehension (Marzano & Kendall, 2008). A relevant theme was realizing that, for the most part, the steps of PBL demand comprehension-related processes, including the recovery of previous knowledge, the precise identification of primary and secondary elements included in the constellation of signs and symptoms presented in the problem scenario, as well as the interweaving of those elements so as to explain what happens in the different systems and establish the three possible types of aforementioned causal relationships. Certainly, this allowed us to understand the complexity reflected in the hours of study and the use of different learning strategies by the students.

Likewise, it was possible to understand, based on the review of the state of the art (Gladman & Perkins, 2012; Grisham et al., 2015) that certain variants or elements that enrich and facilitate the professional formation of students can be successfully integrated into PBL. In this sense, the most valuable contribution is the possibility of providing alternative tools aimed at supporting the development of comprehension processes in order to enable students to preserve and apply the newly acquired knowledge.

Future Research

It is deemed necessary to continue working on the application of the advance organizer RPM in different disciplines in which PBL is used as a didactic method within the field of health sciences, since it is a flexible tool that can be successfully adapted to the different needs of the comprehension processes. Likewise, it is recommended to study the different design variants of RPM that may be required in order to broaden its applicability in Health Sciences Education.

Abbreviations

In this article, the following abbreviations have been used:

CBL: Case-Based Learning
PBL: Problem-Based Learning
RPM: Reasoning Procedural Map
- MN= Main node
- SN= Secondary node
- Rs= Reasons, arguments

STEM: Science, Technology, Engineering, Mathematics

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APPENDIX A

A RPM solved by a student (presented in the original language for illustrative purposes only)

Mapa procedimental argumentado: caso #6

	Elementos observables en el Caso									
	Momento anterior a la admisión	Admitida para colecistectomía	Cirugía se prolongó	Disnea y fiebre	Signos Vitales y exploración física	Sospecha de infección	Sospecha de atelectasia	EKG/ Rx. Tórax	Respiración asistida PEEP	Ecocardiograma valorar V/Q
Elementos no observables en el caso Sistema respiratorio	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: Ventilación mecánica • PE: Rs: Mayor resistencia al flujo pulmonar - -	⊙ PP: Aumento de Carboxihemoglobina • PE: Rs: - Humo que se genera por los aparatos laparoscópicos (láseres) generan CO el cual es absorbido por el peritoneo-> desplazando la curva de disociación de la Hb a la derecha-> conduce a anoxia -	⊙ PP: Frecuencia respiratoria alta y Presiones arteriales: O2 baja (menor de 60 mmHg • PE: Rs: - Hipoxemia que estimula los quimiorreceptores periféricos que dan la FR alta. -	⊙ PP: Se descarta infección nosocomial • PE: Rs: - Dado que para ser considerada como tal deben pasar 48 horas a partir de la admisión del paciente. -	⊙ PP: HTA pulmonar • PE: Rs: Abolición del murmullo respiratorio - palpitaciones-> -	⊙ PP: Atelectasia • PE: Radiografía de tórax Rs: - Incremento de la densidad de la porción atelectasica pulmonar. - Hacinamiento de vasos pulmonares y bronquios en la región de la atelectasia.	⊙ PP: PEEP • PE: Rs: -Presión alveolar positiva al final de la espiración para prevenir atelectasia, provoca mayor resistencia en todo el ciclo en vasos alveolares y extra alveolares -	⊙ PP: Mayor desaceleración de la onda e • PE: Hipertensión pulmonar aguda causa insuficiencia ventricular derecha que causa la desaceleración de la onda e. Rs: - -

Sistema cardiovascular	⊙ PP: Dolor en hipocondrio derecho y sensación de pre síncope. • PE: Reflejo Cardiobiliar Rs: -Posible HTA-> Hiperinsulinemia -	⊙ PP: • PE: Rs: - -	⊙ PP: disminuye retorno venoso • PE: Rs: Trendlemburg inversa (aumenta presión hidrostática en pierna) - Neumoperitoneo (se insufla a 15mmHg de CO2) -Taquicardia y HTA	⊙ PP: Taquicardia • PE: Rs: - Reflejo de Quimiorreceptores periféricos -	⊙ PP: Presión arterial baja (90/60) • PE: Rs: - Disminución de Gasto Cardiaco (por insuficiencia ventricular derecha) y por desviación del tabique ventricular a la izquierda -	⊙ PP: • PE: Rs: - -	⊙ PP: Disfunción aguda del ventrículo derecho • PE: Rs: -Aumento de la presión tele diastólica del VD por arriba de 8 mmHg. - Elevación de enzimas cardiacas: CMKB, troponinas I y T. - Aumento de la mioglobina y BNP.	⊙ PP: EKG por Vasoconstricción y obstrucción de la arteria pulmonar. • PE: Disfunción aguda del VD Rs: -Inversión en Ondas T de V1-V4, desviación del eje a la derecha -Patrón S1Q3T3: Onda S en I y Onda Q y T negativa en III. -Taquicardia Sinusal -Patrón qR en V1 -Descenso del ST -Bloqueo incompleto o completo de la rama derecha	⊙ PP: Ventilada mecánicamente • PE: Gasto cardiaco disminuido Rs: -Ventilación con PEEP-> disminución del retorno venoso -	⊙ PP:Insuficiencia ventricular derecha Ingurgitación de • PE: vena yugular externa derecha, Signo de McConell, Movimiento anormal del tabique interventricular. Disminución de la desaceleración de la onda e. Rs: - Gasto Cardiaco disminuido - Aumenta poscarga para VD, dilatación e hipoquinesia.

Sistema digestivo	⊙ PP: Dispepsia • PE: Por falta de bilis Rs: Mayor secreción de colesterol (por obesidad)-> mayor actividad de Hígado -> mayor secre-ciónde bilis	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -

Sistema hematológico	⊙ PP: Coagulación aumentada. • PE: Posible triada de Virchow Rs: - Factor V Leiden o deficiencia de cofactor S, aumenta la probabilidad de desarrollar coágulos.	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: Tromboembolismo venoso Profundo • PE: Rs: -Posible triada de Virchow (estasis venosa, daño endotelial y aumento de la coagulación) --> trombosis venosa profunda en vena femoral o poplítea. -2: Estado de estrés de la cirugía --> proceso inflamatorio --> por liberación de IL-1, IL-6 y TNF-alfa - -	⊙ PP: Edema unilateral en miembro inferior. Doloroso • PE: Trombosis venosa profunda en vena femoral o poplítea. Rs: - Triada de Virchow -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -

Sistema endocrinolog.	⊙ PP: Obesidad • PE: 5ta década, ser mujer Obesidad Prevalencia Mujeres mexicanas: 37.5%. Prevalencia en mujeres de la 5ta década : 40.5% Rs: -La resistencia a la insulina en esta paciente es ocasionada por el aumento de metabolitos de ácidos grasos, principalmente diacilglicerol (ver explicación abajo). - Dicha resistencia conlleva a una estado de hiperinsulinemia con el propósito de mantener una normo glicemia, lo que lleva a un estado de hipernatremia (ver explicación abajo).	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: Hiperglucemia • PE: Rs: - Cirugía, conlleva a un estado de estrés, cortisol, hiperglucemia. -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -	⊙ PP: • PE: Rs: - -