

## Foundational Sciences Through PBL - Process & Learning Principles

PBL, or problem based learning, is an evidence-based educational strategy aligned with a constructivist philosophy of learning. Our approach acknowledges that clinical reasoning is knowledge-based; for this reason, we support students in initiating their own learning and building mental models of disease that integrate foundational science knowledge within a clinical framework. These foundational sciences include not only the traditional basic biomedical sciences (i.e., anatomy, physiology, biochemistry, pathology, histology, pharmacology) but also the social and behavioral sciences. In our program, PBL looks like this:

PBL process	Learning principles
On Monday, a group of 8 students meet for 3 hours. They are presented with a clinical case from real-life medical practice.	The goal of working around medical cases is for students to create rich and elaborated causal networks that explain the clinical case in terms of the underlying, social, psychological, biological, and pathophysiological processes.
The case is disclosed progressively, one page at a time.	Students live the evolution of the case. The clinical context enhances motivation to learn foundational sciences and it provides a scaffold to build integrated knowledge.
All students participate in the initial analysis of the case scenario and problem(s) definition by voicing their thoughts, previous knowledge, intuitions, and ideas (i.e., brainstorming).	Students engage in collaborative learning around medical cases. The group has an expanded working memory capacity, thus overcoming the known limitations of individual working memory.
Students assume rotating roles including facilitator, time-keeper, scribe, researcher, and participant.	Students learn skills of team work, collaboration, non-judgmental communication, and feedback.
The scribe organizes information on a white-board. The essential information to collect includes facts given in the case, hypotheses (possible diagnoses), additional information needed, and learning issues (gaps in knowledge).	The use of representations provides opportunities for knowledge building and integration.
Students refine learning issues (LIs) by formulating them as “why” or “how” questions in the context of a synthesis of the problem as understood thus far and a commitment to top diagnoses.	The group's discussions reveal areas of disagreement or limited understanding that need to be investigated. This process also contributes to developing the important clinical skill of decision making with incomplete data.
Students select the most important LIs to be researched after agreeing on the interrelated phenomena that need to be explained. Students feel that they are in charge and have an impact on the learning situation.	LIs cover the subject matter underlying the problem and are hence related to the learning objectives of the case. These objectives are known by faculty tutors; they use them to guide students through questions without affecting their self-determination.
Individual students take charge of one LI to be researched at home. They find and	Students learn and apply information seeking skills and reference management. They interact with the learning

evaluate appropriate resources, take a critical stance, and then select the best ones to post for other members of the group to read. These materials are known as learning objects (LOs).	material more than in an information-gathering or theoretical approach because they relate the new concepts to the problem and everyday experience. These are features of the deep approach to learning possible through PBL. Also, this approach to decision making is critical for clinical practice.
Students post LOs and read each other's LOs in preparation for the next PBL session.	Students learn to assume responsibility for the learning of every member of the group. At the same time, this responsibility is shared.
Students return on Wednesday ready to engage in a rich discussion. This is the most important and exciting step in PBL. Students begin by re-examining their hypotheses and understanding of the case in light of the new knowledge provided by LOs. The task of the group of students is to explain the phenomena presented in the problem in terms of underlying processes.	Group discussions confront learners with alternative ideas and viewpoints they would not have come up with themselves, helping them establish additional meaningful relationships between presented information elements. Unlike simple teach back, the process at this point is about knowledge-building discourse in which there is construction, refinement, and transformation of knowledge. Explanations produced in the context of discussion result in better learning with enhanced long-term memory.
The progressive disclosure of the case continues after the end of the discussion, and the PBL process described until this point repeats itself.	Students reinforce learning processes and principles mentioned above. Furthermore, they use questions to help with goal setting, guiding cognitive processing, activating prior knowledge, focusing attention, promoting cognitive monitoring, and promoting displays of knowledge.
Students return on Friday for their last 3-hour PBL session of the week, which usually closes the case. The discussion leads to synthesis and establishment of general principles.	Students organize prior and new learning around the problem scenario. This aids retrieval of what has been learned when a similar problem or situation is encountered later in professional practice. Students aim to achieve cognitive conceptual coherence by systematizing and integrating the information from the foundational sciences around the clinical case. The organizational cognitive framework provided by the foundational sciences anchors the student's incipient clinical knowledge and is the basis of clinical reasoning.
Lastly, students engage in self and group evaluation of progress and process.	Students are trained to cooperate and communicate their knowledge in a clear and logical manner. They also learn to give and accept feedback from each other.

After 7 weeks, students prepare for a summative written knowledge exam and a formative oral exam, known as triple jump, that focuses on how individuals engage in learning through PBL.

Evidence from the educational research literature shows that medical students that learn through PBL perform just as well in USMLE step 1 as their counterparts in non-PBL curricula; however, they gain considerable advantages in other domains such as critical thinking, knowledge organization, and social skills. Besides, PBL is just fun; even at three hours per session, students and faculty just love it.