

From Case-based Reasoning to Problem-based Learning

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ABSTRACT

Many medical schools today are questioning whether they should implement a problem-based learning (PBL) curriculum. Educators have raised serious questions regarding the efficiency of PBL and therefore recommend learning more about the cognitive processes developed by PBL before implementing it broadly. In addition, it is important to determine whether PBL best matches the human reasoning process. The authors' theoretical discussion examines the relationship between the case-based reasoning (CBR) model and the PBL model. CBR indicates that the knowledge source one

uses while solving a new problem includes not only generalized rules or general cases, but often a memory of stored cases recording specific prior episodes. CBR enables the reasoner to recommend solutions to problems quickly and to propose solutions in domains that are not completely understood, such as medicine. The authors' analysis reveals a strong association between the CBR and PBL models, and thus it can be argued that PBL is a successful teaching method that should be encouraged by medical schools.

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In a recent study review, Colliver¹ reached the conclusion that there is no convincing evidence, that problem-based learning (PBL), despite the additional investments in time, money, and manpower, improves the knowledge bases and clinical performances of medical students, as perhaps might be expected. In response, Norman and Schmidt² have raised serious issues concerning curriculum assessment research. First, they argue that in educational interventions it is impossible to attribute success or failure solely to the intervention, and that teachers' and students' behaviors may have a great impact on the outcome. Second, they claim that students in medical schools, who are selected based on high standards, all have the approved prerequisite skills, regardless of the curriculum they are in, to succeed in their studies. Third, PBL is practiced very differently in various institutions,^{2,3} with some demonstrating positive effects and others

demonstrating negative ones. According to Norman and Schmidt,² averaging the effects of those different PBL curricula is not justified because it cannot be assumed that the results are additive or that the effects should be equally weighted. In their opinion, Colliver's conclusions are thus somewhat dubious.

Albanese,⁴ also responding to Colliver's review analysis, argues that the comparison process between novel and old curricula uses measuring tools that were designed for the previous curriculum and are not necessarily fit to measure other objectives existing only in the novel curriculum. In addition, he argues that the effect sizes (ESs) of 0.8–1.0 that were used to compare the PBL effect on knowledge and clinical skills with that of the traditional curriculum are unreasonably high. Albanese claims that many commonly used and accepted medical procedures and therapies are based upon studies with ES scores below 0.5, and therefore educational interventions that result in ES scores of 0.5 are significantly beyond the expectations one might have. Moreover, it is difficult to distinguish between the PBL curriculum and the so-called traditional curriculum. Students in the traditional curriculum are also exposed to case-based methods. For instance, during the clinical years, the traditional curriculum frequently exposes students to bedside teaching, discussing a patient's medical problem in

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small groups. Evaluating the differences between the PBL and traditional curricula with inappropriate tools might blur the real essential differences.

Considering the overall limitations of educational intervention assessment research—manifested in the comparisons of PBL with other methods—in the present article we suggest shifting the focus of the discussion from the question of whether PBL improves the knowledge base and clinical performance to gaining an understanding of whether PBL takes into account the reasoning processes involved in medical problem solving. In particular, the present analysis examines whether and how PBL and lecture-based instruction fit into rule-based and case-based reasoning, which are natural modes of the human reasoning processes.

To better understand what kind of reasoning is used, one should first understand the complexity of determining the nature of the medical problem.

THE COMPLEX NATURE OF THE MEDICAL PROBLEM

Medical problem solving is considered a highly complex phenomenon.⁵ In many cases, physicians work in uncertain situations that may result from any of the following circumstances:

- The problems are often poorly defined.⁶
- The problems that patients present can be confusing and contradictory, characterized by imperfect, inconsistent, or even inaccurate information.⁷
- Not only is much irrelevant information present, but also relevant information about a case is often missing and does not become apparent until after problem solving has begun.⁸
- The basic pathophysiologic mechanisms that underlie medical problems are often not completely understood.⁹
- Even if the mechanisms of an isolated system's contribution to the problem are understood, their interactions with other systems may cause their behaviors to vary.⁹

TYPES OF REASONING USED IN MEDICAL PROBLEM SOLVING

Physicians have to diagnose and treat illnesses despite the uncertainty and variations that characterize real medical problems. In order to do this, physicians may use different types of reasoning. For the purpose of this article, the following are discussed: rule-based reasoning and the use of personal knowledge in reasoning, which leads to case-based reasoning.

Rule-based Reasoning

The use of diagnostic rules for diagnosing illnesses demands rule-based reasoning (RBR). This is the process of drawing conclusions by linking together generalized rules, starting from scratch.^{10,11} RBR models are rooted in the philosophical belief that humans are rational beings and that the laws of logic are the laws of thoughts.¹⁰ According to Kolodner,¹² although some rules are very specific, the goal is to formulate rules that are generally applicable. An important advantage of rules, in general, is the economy of storage they allow.¹² However, the following are some disadvantages of RBR:

- The problem of applicability, i.e., bringing some general piece of knowledge to a particular situation.¹³ When rules are expressed too abstractly, the terms tend to be unintelligible to the novice and tend to mean a variety of specific things to the expert.
- Ill-defined domains. In domains that are not completely understood, the rules do not encompass all the situations they are asked to cover or are assumed to cover, may admit tacit exceptions, or can be contradicted and annulled by other rules.¹⁴
- The limitation of mental capacity. RBR requires that the problem solver take into account all the domain rules. However, in many real-life situations the problem solver is not capable of doing that, under the pressure of time, as the number of rules required for solving a problem may be unmanageably large.¹¹

These characteristics of rules and RBR indicate that a physician should use more than RBR when solving authentic medical problems. Moreover, an underlying assumption in RBR is that abstract information is important in problem solving, while the value of knowledge of a specific event and specific experiences is neglected. This view is challenged by the personal-knowledge point of view, which sees in knowledge of specific episodes a key to successful problem solving.^{11,12,15}

Use of Personal Knowledge in Problem Solving

Personal knowledge is defined as the unique frame of reference and knowledge of self, is central to the individual's sense of self,¹⁶ and is a result of the individual's personal experiences.¹⁷ Much of the knowledge a practitioner uses in problem solving and making clinical judgments is tacit and individual.^{18,19} The following citation demonstrates this:

A staff member discussed a case of his with a small class. After presenting the case he had them ask questions. A

number of his answers were along these lines: "What I do in such-and-such a case is so-and-so. Don't ask me why it works or why I do it, because I'm not real sure. I just know that it does work and I have a feeling that it ought to."²⁰

Becker et al.²⁰ emphasize that clinical experience is important for preparing medical students for practice. According to these authors, book learning, which usually presents general knowledge, has several disadvantages as compared with learning from experience:

- It may contradict the knowledge acquired from experience.
- It is not always available.
- It does not always exist, yet a decision on care must be made.
- It ignores the basis of learning by using one's senses.
- It does not take into consideration all the other factors that doctors encounter within their daily lives.

In recent years, there has been increasing concern about the growing gap between research-based knowledge taught in professional schools and the practical knowledge and actual competencies required of practitioners in the field.²¹ In this regard, Schon²¹ argues that in order to deal with the crisis in professional knowledge, we need to recognize that outstanding practitioners do not have more professional knowledge, but have more "wisdom," "talent," "intuition," or "artistry."

Case-based Reasoning

Case-based reasoning (CBR) takes the idea of personal knowledge one step further. In CBR the primary knowledge source is not generalized rules or general cases, but a memory of stored cases recording specific prior episodes.¹¹ A case, which records knowledge at an operational level, represents specific knowledge tied to a context.¹² Cases may cover large or small time slices, associating solutions with problems, outcomes with situations, or both.¹² CBR can mean adapting old solutions to meet new demands, using old cases to explain new situations, and using old cases to critique new solutions. It can also require the use of reasoning from precedents to interpret a new situation or to create an equivalent solution to a new problem.¹² Advantages of CBR include the following:

- It allows the reasoner to propose solutions to problems quickly, avoiding the time necessary to derive these answers from scratch.²²
- It allows the reasoner to propose solutions in domains that are not completely understood.²² In such situations

rules are imperfect. Thus, solutions suggested by cases also increase the quality of the solutions.

- It allows the avoidance of previous mistakes.^{11,12,15,22,23}
- Reference to previous similar situations is often necessary to deal with the complexities of novel situations.²²

These characteristics of CBR are particularly applicable to medical problem solving in instances where the pathophysiology of the illness is not completely understood and the problems are ill-defined. Such difficulties are common for illnesses in many domains. The term for CBR used in medical reasoning literature is "instance-based recognition." According to this model, a new case is classified by its resemblance to a case encountered previously, and is therefore given the same diagnosis.^{24,25} This model is supported by the fact that clinical diagnosis is strongly affected by the context of events (for example, the location of a skin rash on the body).²⁶ When this context is not part of the diagnostic rules, it may appear irrelevant (e.g., as the same rash may appear in the same location in another disease).²⁶ According to Elstein,²⁶ these contextual effects suggest that clinicians are matching a new case to a previous case, not to an abstraction from several cases, since the abstraction may not include these "irrelevant" features.

RBR or CBR?

Reminding is the process by which CBR takes place.²³ When we attempt to understand anything, we do so by attempting to find something in our memories that looks sufficiently like it to be helpful in processing. The use of rules also requires reminding of the appropriate rules. The argument that CBR, in many situations, is more efficient than RBR leads to the idea that reminding of cases, in some situations, is more efficient than reminding of rules. This means that CBR, which is more expensive in terms of storage, may be more economical in terms of processing.¹⁵ It is our understanding that reminding has to do with *indexing* and *retrieval*. "Indexing" means taking an experience and giving it a label or name.²³ It seems that there are situations where indexing a large chunk of a more specific knowledge (e.g., cases) might result in a more efficient retrieval of that knowledge from memory, rather than retrieval of small pieces of abstract knowledge (e.g., rules). In other words, occasionally the reminding process of cases is efficient. One reason may be that cases record knowledge at an operational level¹² and thus are more meaningful to the reasoner than is abstract knowledge of a rule. Case knowledge may also contain richer mental representations, verbal and non-verbal. This is very important in medical cases, where visual, auditory, tactile, and olfactory information is relevant to the

problem and may be ignored by the rules. These kinds of presentations may also be used as both indexing and retrieval items for the case. For instance, a unique shape, location, or tactile characteristics of a body rash or a secretary odor that has not been described in the literature, but that contains the features of what a patient may have, may be used as an index for this case that can be elicited from memory and be used while solving a new case. In other words, the reasoning process involved in solving a new problem may fail to retrieve and elicit the abstract small piece of knowledge—i.e., the rule—from memory. However, in those situations, the rich information that belongs to the new case may elicit the indexed information of a previous case or cases from memory.

INSTRUCTION AND CLINICAL REASONING

The characteristics of medical problems, the limitations of RBR, and the advantages of CBR suggest that physicians in many daily situations use both RBR and CBR when encountering patient cases. Does teaching take these two types of reasoning into account? To address this question, we now discuss traditional lecture-based instruction and PBL-based instruction.

Lecture-based Instruction

In the standard North American medical school curriculum, students spend two years (and more than four years in many other countries, where medical studies may include undergraduate programs) listening to lectures on basic science concepts and memorizing this information. This is followed by two years of clinical work in which students learn to apply the concepts to the treatment of patients.⁹ Lecture-based instruction emphasizes two views. The first is the view that disease is a scientific phenomenon—a deviation from a biological norm.⁹ Disease is thought to result from a determinate cause or set of causes that doctors can discover through observation and tests, and whose effects they can cure or alleviate through surgery or medication.⁹ The second is that if humans, who are logical, are equipped with basic principles, they will be able to apply them in novel situations. With these two assumptions, it is believed that students who learn the rules (e.g., the pathophysiology of illness) through lectures will be able to transfer these rules to patients and to treat them by the use of RBR.

Both views are inaccurate or, at best, incomplete. First, disease is much more than a deviation from a biological norm, and the diagnosis and treatment of medical problems are related to many factors other than pathophysiologic knowledge.²⁷ Second, it is clear now that we humans do

not—as was once thought—reason by the use of an abstract mental logic, but instead seem to be highly influenced by the content and context of the problems that we face, and are subject to many systematic errors and biases in our thinking.²⁸

In addition, it has been found that much of what is learned in lectures will be forgotten before students reach the clinical part of their training.²⁸ This is not surprising, considering the limitations of RBR. The above considerations may lead to the conclusion that lecture-based instruction is suited to and promotes the RBR mechanism, while neglecting the CBR mechanism, although CBR is widely used in medicine.

Problem-based Learning

Recently, medical curricula have been in the process of shifting from passive acquisition of knowledge to active learning, and from transmission of information without context to problem solving.²⁹ Problem-based learning (PBL) at its most fundamental level is an instructional method characterized by the use of the records of actual patient problems as a context for students to learn problem-solving skills and to acquire knowledge about the basic and clinical sciences.³⁰ The basic outline of the PBL process is³¹:

1. encountering the problem;
2. problem solving with clinical reasoning skills;
3. identifying learning needs in an interactive process in small groups;
4. self-study;
5. applying newly gained knowledge to the problem; and
6. summarizing what has been learned.

PBL stresses the acquisition of patient cases. The underlying assumption of PBL is that the closer the resemblance between the situation in which something is learned and the situation in which it will be applied, the more likely it is that transfer of learning will occur, a phenomenon known as “encoding specificity.”³² One might find similarities between CBR and PBL. Both methods assume that a large chunk of knowledge, which also contains the context of the case, will be effective in problem solving. In addition, each patient case usually contains rich sensory clues that might be ignored in books and lectures. PBL designers also believe that these data representations may assist in problem solving.

Another assumption of PBL is that abstract rules will be more meaningful for students because they can see how these rules are applied in the specific patient case they are learning about. It means that, for the students, a specific case contains the patient’s physical characteristics as well as

rules explaining the deterministic mechanisms that account for the behavior of the biological system. In such a way, rules may also be indexed in relation to the case. In other words, memory of a case may also elicit the appropriate rules, and vice versa. PBL provides the students with both rules and case knowledge and thus increases the ways one can index the new knowledge he or she learns and enables the students to index more efficiently. This may lead the students to more efficiency in retrieving the knowledge when needed.

However, there are also disadvantages of PBL:

- Practitioners might be tempted to use old cases blindly, relying on previous experience without validating it in a new situation.¹²
- Practitioners might allow cases to bias them too much in solving a new problem.¹²
- Often practitioners, especially novices, are not reminded of the most appropriate sets of cases when they are reasoning.³³

In order for PBL to be efficient, the following should be taken into consideration:

- Cases should be presented in order of complexity.
- Any new case must violate expectations from prior cases.
- Cases should relate to actions.
- Cases should have the potential to change behavior.
- Cases should be presented in a variety of verbal and nonverbal representations.

CONCLUSION

The PBL adventure continues to flourish, despite the lack of evidence of its superiority. There is much evidence to support the claim that PBL provides a more challenging, motivating, and enjoyable approach to medical education.¹⁻⁴ For the reasons described in this article, we argue that to better understand this phenomenon it is useful to thoroughly examine the human reasoning process rather than to compare the traditional and PBL curricula. We agree with Norman and Schmidt² that "trials of curriculum level interventions, whether they show large, small, zero or negative effect sizes, . . . whether they are of sound or unsound methodology, are, in our view, a waste of time and resources. They are a waste because, by their very nature, they are doomed to examining one variable, or more likely an unspecified combination of many variables, at a time."

One possible explanation for the apparent victory of PBL, arising from our discussion, is that PBL is better suited to the human reasoning process. In our daily lives, as well as in

a variety of professions such as medicine, we humans find ourselves confronting ill-defined problems or problems that are not completely understood. CBR assists us to overcome the complexity of real-life situations. Cases, unlike rules, provide large chunks of knowledge tied to contexts. Cases may also contain a wide spectrum of knowledge, including sensory factors that may be ignored by the literature or by rules. It can be argued that cases, as opposed to rules, provide rich index items and thus may lead to efficient retrieval of relevant knowledge from memory, especially in ill-defined situations encountered by physicians.

PBL, as opposed to lecture-based instruction, encourages and promotes CBR. The cases provided by the PBL approach are indexed in the memory by rich index items describing both the case history and the rules relating to the illness. When encountered in a new situation, the index items efficiently assist in identifying a useful case that was dealt with previously.

The role and contribution of the rich index items that students construct, through their studies in a PBL curriculum, and apply to their problem-solving ability were probably not identified in the studies described by Colliver¹ that used the Medical College Admission Test as a source for comparison. We agree with Albanese⁴ that it is possible that, with the introduction in 1993 of the United States Medical Licensing Examination, in which the questions have increasingly taken on a clinical context, comparative studies will show better results for the PBL students.

We believe that our discussion provides a theoretical explanation that might, in contradiction to Colliver,¹ help to better tie together the psychological theory of reasoning and the power of PBL. It is our conclusion that PBL should be implemented in all medical schools, to provide students with a rich learning environment that promotes the cognitive processes best suited to the medical profession.

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