The essential role of basic science in medical education: the perspective from psychology

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Introduction

Probably ever since the Flexner report1 endowed basic scientists with a central role in the education of doctors, the same basic scientists have been engaged in active, but circular, debates about why basic science really is essential to medical education. The arguments are generally at the theological level and can easily be dismissed by critics as self-serving. There is little evidence in the medical education literature to inform the issue; indeed, some studies, which I will review in more detail, suggest that clinicians rarely use basic science concepts. Of course, this does not imply that basic science might not have other roles in the educational process or that clinicians never use basic science concepts.

It would not be easy to bring direct evidence to bear on the situation. The definitive randomized trial, in which the experimental group's undergraduate preclinical education omits any contact with basic science, will likely never be done (although some might maintain that problem-based learning [PBL] is a close approximation). Consequently, if we are to bring evidence to bear on the question, the evidence must, of necessity, be indirect. That is the purpose of this paper — to review the evidence from education and psychology that might indicate whether there is an identifiable role for learning basic science in the education of physicians, and what form this learning might take.

I shall begin by briefly describing 3 possible roles for basic science in the armamentarium of a practising physician.

The roles

1. Some specialties are heavily rooted in basic science

If you examine what anesthetists, intensivists or nephrologists do on a day-to-day basis, it becomes rapidly evident that most of their thinking is not directed at reaching a diagnosis. For intensivists and anesthetists, the diagnosis was established much earlier in the process of care, and is, to large degree, irrelevant to the ongoing management of the patient, which takes place far more at the level of physiological tuning. For nephrologists, although traditional clinical diagnosis may be relevant early in the encounter, subsequent diagnosis and management are more at the physiological level.

I am not, in any way, suggesting that these specialties have exclusive rights to physiological reasoning. It is simply that I know these best, and it appears clear that for these physicians, and undoubtedly others I have not mentioned, some fairly sophisticated level of understanding of basic mechanisms is an essential component of competence. But this may not be viewed as sufficient cause to inflict so much basic science on so many.
2. All specialties need basic science occasionally

Two lines of inquiry have examined how clinicians use basic science by asking them to think aloud as they read a clinical case. Both studies concluded that clinicians rarely used basic science in developing an explanation. It should be noted that these conclusions were based on a very limited number of cases, and the clinician’s goal was always diagnosis, not management. Still, it is likely that most practitioners most of the time need not invoke basic science explanations to understand a patient’s problem. However, in relatively rare circumstances when things do not fit together, the clinician might go back to basic principles to reason it out. There is some evidence to support this hypothesis. Patel and associates found that specialists operating outside their specialty (where presumably the solution was less likely to be forthcoming) were more likely to invoke basic science. Another study suggested that specialists may use basic science concepts when working within their own specialty. In this study, nephrologists, second-year medicine residents and first-year family medicine residents were confronted with a series of 8 very difficult nephrology problems on paper and asked to “think aloud” as they reasoned their way through the problem. Diagnostic accuracy of the first-year residents was about 20%, of the second-year residents, it was about 50% and of the nephrologists, about 90%. More striking was that the process was very different in the 3 cohorts. The first-year residents seemed to have real difficulty generating hypotheses — they had few diagnoses and ordered few tests. Second-year residents had the most hypotheses and ordered the most tests but were unable to reach a conclusion. Nephrologists knew what they were dealing with and ordered relatively few, targetted additional tests. More striking was that, whereas the first-year residents rarely thought about basic mechanisms, this was the modus operandi of the specialists.

The mere fact that this is not a common situation makes it difficult to observe in any naturalistic setting. Still, it seems that this is a plausible role for basic science. However, the evidence to date is derived from only this study, and the cases were drawn from a specialty in which we expected to see a dominance of basic science reasoning. Whether this occurs in other specialties, and how often, is a matter of speculation.

3. Basic science is an essential underpinning for real understanding

One expects that, whether stated explicitly or not, this is the most common rationale for the teaching of basic science. That is, we share a collective view that medical practitioners should understand the mechanisms of diseases, rather than simply recognize and treat them (we should educate physicians not just train doctors). And the corollary is that students will be unable to understand diseases and their manifestations without a sound grounding in basic science. A related idea is that learning with understanding is superior to “rote” learning, and that understanding can only occur with some knowledge of mechanisms.

These are plausible, indeed powerful, ideas, which capture the heart of many educators. Certainly, the finding that students in PBL curricula report that they are much more likely to study for meaning rather than for memorization is viewed by many as a strong rationale for PBL.

(As an aside, this evidence from self-report may be misleading. Studies of performance of graduates of PBL and traditional schools related to understanding of mechanisms is far less persuasive. Patel and colleagues compared graduates from McMaster University and McGill University and found that McMaster graduates committed far more errors in their explanations than McGill graduates. Cunnington and associates showed that McMaster graduates’ performance relative to other Canadian graduates on factual recall questions and higher order questions from the national licensing examination was not significantly different.)

How might basic science enhance learning?

Returning to the main theme, I wish to review evidence from psychology that understanding contributes to learning. In brief, the perspective of psychology is that “people construct new knowledge and understanding based on what they already know and believe.” In a number of studies, Bransford and colleagues examined the effect of learning for under-
standing versus learning to remember. In one classic study, they showed 2 groups of students some text about learning to fly a kite. The text had sentences like “It works well on beaches....” One group had as the title of the paragraph, “flying a kite,” the other group did not. Not surprisingly, the first group was much better at recalling the specific information in the text. Thus, learning was enhanced by the meaning and understanding derived from the title. A more recent study more closely mimics the typical instructional situation. In this study, there were 3 groups who were all directed to learn a concept in psychology called “schema theory.” The first group read and summarized a text, then heard a lecture on the subject. (Read the text in advance? What ideal students!) The second group explored the concept using simplified data sets then heard the same lecture. The last group spent twice as much time as the second with the data sets, but never heard the lecture. Performance on a test was about 20% for groups 1 and 3, but 45% for group 2. Thus, active manipulation, combined with an organizing concept (from the lecture) was essential for optimal learning.

These experiments suggest that learning is facilitated by understanding. To the extent that basic science provides a basis for understanding clinical medicine, it might be viewed as a precondition for efficient learning. However, although basic science may provide the kind of prior knowledge that is necessary to assimilate new knowledge, there is no guarantee that students, once taught basic science, can or will use these concepts later.

How can we teach basic science so it will be used and not forgotten?

The preceding section argues that understanding is a precondition to maximizing initial learning. But this is, unfortunately, only part of the story. All we have established is that students will be better able to learn the knowledge of medicine if they have a clear understanding of relationships among the facts. And, of course, it is plausible that mastery of basic science concepts will assist in learning with understanding. But this presupposes that the basic science concepts learned (or taught) 1 or 2 years earlier will be available for application to a new problem or learning situation. Here the anecdotal evidence is disquieting. Teachers and students regularly express their frustration that concepts taught earlier (and presumably learned, if only for long enough to pass the examination) are seemingly forgotten when students try to apply this knowledge to clinical situations.

The phenomenon is known in psychology as transfer: applying a concept learned in one context to solve a problem in another context. Teachers may find solace from psychologists who have repeatedly demonstrated that it is notoriously difficult to achieve. Typically, after students have been shown a problem and solution, from 10% to 30% will think to use it to solve an analogous problem presented in a different context.

There are a number of factors that influence transfer. One is context, which involves everything from the specific examples in which the problem is learned to the location where learning took place. To the extent that the initial learning and the problem-solving take place in different contexts, transfer will be impeded. It is indeed hard to imagine 2 contexts that are more different than the biochemistry lecture room, where the various components of the Krebs cycle were taught one after another, and the inpatient ward 2 years later, where the critical elements must be applied to a patient with fatigue.

One factor that impedes transfer is to have the concept too tightly bound to the initial problem, which may occur when learners, for example, are encouraged to go over the examples used in class. This finding (closely tying a concept to a problem context) may have direct implications in medical education. Matching of context and concept is often hailed as an advantage of PBL. However, as usually taught, the concept is very tightly linked to the problem context, which may impede transfer.

Another factor that may influence transfer is the goal of initial learning. Problems are often used to illustrate a concept, for example, by presenting the problem and solution sequentially as part of instruction and instructing students to remember and review the problem so they can understand how the concept explains the problem. Needham and Bege contrasted this approach with a second, in which students were shown the problem and encouraged to arrive at their own solution (usually unsuccessfully), then pro-
vided with the solution. The first group, who were shown the problem and solution together, achieved about 60% transfer to a second problem. The group who actively attempted to solve the problem achieved about 90% transfer. Paradoxically, on a memory test, the first group remembered more of the initial problem. Although this study can appropriately be viewed as evidence for the advantage of active learning in facilitating transfer, the question really becomes what activities were being engaged. Presumably in the course of trying to solve the problem, subjects are led to discover the deep structure of the problem and then to create a more abstract representation. This strategy has also been shown to facilitate transfer.\textsuperscript{13}

Conclusions

To summarize, based on evidence derived from other domains, it is plausible that basic science learning may well serve an essential role in providing prior knowledge to facilitate understanding, and hence efficient learning, of clinical knowledge. This argument is not, of itself, either new or unique, and similar statements might well be retrieved from the Flexner report.\textsuperscript{1}

What is new is that the position is not simply rhetorical and is based on a substantive body of evidence about learning derived from studies in psychology. Second, one clear implication emerging from this literature is that the simple provision of basic science instruction is far from sufficient. A recurrent theme is that a number of factors will influence transfer, including context, representation and goals of learning. Against many of these yardsticks, the conventional approach to basic science instruction is almost precisely wrong. No attempt is made to match context to the problem situation, and often the context, in which particular concepts are taught in a sequence with other related concepts of the discipline, is vastly different from the application context. Instruction typically occurs at times removed in years from the application setting. Finally, the implicit goal of learning, to memorize the myriad facts of the discipline in order to pass the examination, is precisely the wrong goal to facilitate transfer.

PBL has frequently been advocated as a solution to some of these difficulties. This review indicates that PBL advocates have little cause for complacency, since they, too, have their own pedagogical skeletons. The constructivist position adopted by many PBL curricula, that the process of problem solving is of central importance, that students should be given free rein to generate solutions, and that teachers should never tell students the answer is not correct.\textsuperscript{14} And the common practice of teaching all concepts in the context of a single problem amounts to over-contextualization and can impede transfer.

I do not intend to venture a prescription for an ideal approach to basic science instruction. To do so would be presumptive rather than prescriptive. There are too many unknowns. The insights in this paper are based on many assumptions about the potential role of basic science in facilitating understanding. Although the literature does not, in my view, provide sufficient guidance for radical curriculum reform, it does provide models and metaphors for a solid program of experimental research into the potential role of basic science in medical education. If we can begin to achieve that, we will have progressed a long way toward marshalling real evidence, rather than rhetoric, to justify the central position of the basic sciences in medical curricula.

References


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