__Pearls on Educational Principles__ bring relevant educational research topics to educators for application to teaching and curriculum design/development.

Why teach foundational concepts rather than facts?

The number of biomedical facts that a medical student is asked to learn has increased exponentially since the Flexner report. In addition, the rate at which these facts change has accelerated dramatically, as is indicated by the fact that the majority of positive findings in today's biomedical literature are eventually disproven.

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At the same time, the science knowledge necessary for the 21st century physician is no longer limited to anatomy, biochemistry, pathophysiology, pharmacology and other branches of biomedicine. Today, the medical student must learn content from other sciences, including population health; complex adaptive systems, human factor engineering and reliability sciences (that inform the domains of quality improvement and patient safety); social and behavioral sciences; healthcare financing; and health policy and epidemiology. This raises important questions about how to teach this expanding content, and whether to focus on teaching foundational concepts.[1-8]

What are the educational underpinnings of expertise development?

Theories of expertise tend to belong to one of two categories:

- **Processing theories** focus on how experts process clinical information. These theories postulate that experts use hypothetico-deduction, whereby an expert generates a hypothesis early in the encounter and then tests this hypothesis against data subsequently gathered.
- **Structural theories** focus on underlying knowledge structures that produce diagnostic hypotheses. These theories employ constructs such as schemas that organize information in long-term memory into chunks that are readily accessible.

Research on clinical reasoning has demonstrated that **knowledge structures** (i.e., how well knowledge is organized in memory) are more important to expertise than general reasoning skills.[9] The organization of knowledge in long-term memory can be represented in numerous ways such as:

- **Prototypes,** or abstractions of numerous cases accumulated over time and stored in semantic memory (Bordage[9,10])
- **Exemplars** of a specific patient encounter experienced in the past and stored in episodic memory that functions as the embodiment of a specific disease (Norman[11])
- **Illness scripts** that format each disease in three dimensions – causal factors, disease mechanism, and signs/symptoms (Schmidt and Boshuizen[6])

Importantly, these constructs encapsulate foundational knowledge, such as the underlying pathophysiology of a disease, which may no longer be consciously accessed by the clinician, but nonetheless plays an important role in supporting accurate and efficient clinical decision making. In assessing a specific patient, clinicians look for which prototype, exemplar, and/or illness script best matches the patient's presentation.

> Kahnemann's work represents an important set of concepts in modes of cognition:
>
> - **System 1:** pattern recognition as a product of well-organized knowledge structures
> - **System 2:** conscious, deliberate, means/end analysis
>
> Recent discussion has focused on how expertise requires not only well developed System 1 and System 2 modes but also the ability to know when to shift between these modes.[12]

What evidence supports teaching of knowledge structures?

Clinicians with better organized **knowledge structures** generate superior solutions to problems,

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perceive and recognize cues that others do not perceive, analyze problems qualitatively, show more accurate self-monitoring, choose better problem-solving strategies, opportunistically use available information, and spend less cognitive effort.[13]

Learning facts is important but insufficient. Rather, foundational knowledge, even if not consciously used, is important to learn and does predict clinical performance. One study found that as expertise increases, the physician is able to reflect on a case and more quickly classify and recognize biomedical concepts. In another study, structural equation modeling found positive links between biomedical knowledge and diagnostic accuracy. Students who learn with causal explanations have better recall of disease features one week later. Similar studies have found that causal understanding leads to more coherent understanding of clinical conditions and is associated with increased speed at performing a given task.

How can I use this approach in my educational practice?

Instructional techniques that can facilitate the formation of robust **knowledge structures** in early learners include:

- Less is more: prototype formation improves when the curriculum utilizes fewer diseases on the differential with more intermediate level complexity;
- Advanced organizers, aids, and scaffolds;
- Part-task practice;
- Task simplification;
- Integrating basic science with clinical experience so that foundational knowledge is encoded with and triggered by problems presented by patients.

What are some specific examples and steps?

As we design medical school curricula to develop future physicians who are not only outstanding clinicians but also effective leaders of systems, teams, and continuous quality improvement, there is an urgent need to:

- Identify the foundational knowledge that is sufficient but also practical to learn in medical school for population health, patient safety, quality improvement, team leading, etc.
- Develop the exemplars or prototypes that are real-world-based and can provide a scaffold on which students can build knowledge that transfers to future problem solving, i.e., will be readily accessible when they encounter systems proglems in the future.

References

1. **Charlin B, et al.** Scripts and clinical reasoning. Med Educ. Dec 2007;41(12):1178-1184.
2. **Rikers RM, et al.** The role of encapsulated knowledge in clinical case representations of medical students and family doctors. Med Educ. Oct 2004;38(10):1035-1043.
3. **Schmidt HG, et al.** A cognitive perspective on medical expertise: theory and implication. Academic medicine : journal of the Association of American Medical Colleges. Oct 1990;65(10):611-621.
4. **Woods NN.** Science is fundamental: the role of biomedical knowledge in clinical reasoning. Med Educ. Dec 2007;41(12):1173-1177.
5. **Schmidt HG, et al.** On acquiring expertise in medicine. Educational Psychology Review. 1993;5(3):205-221.
6. **Schmidt HG, et al.** How expertise develops in medicine: knowledge encapsulation and illness script formation. Med Educ. Dec 2007;41(12):1133-1139.
7. **Schauber SK, et al.** On the role of biomedical knowledge in the acquisition of clinical knowledge. Med Educ. Dec 2013;47(12):1223-1235.
8. **Boshuizen HPA, et al.** On the role of biomedical knowledge in clinical reasoning by experts, intermediates and novices. Cognitive Science. Apr 1992;16(2):153-184.
9. **Bordage G.** Elaborated knowledge: a key to successful diagnostic thinking. Academic medicine : journal of the Association of American Medical Colleges. Nov 1994;69(11):883-885.
10. **Bordage G.** Prototypes and semantic qualifiers: from past to present. Med Educ. Dec 2007;41(12):1117-1121.
11. **Norman G, et al.** Non-analytical models of clinical reasoning: the role of experience. Med Educ. Dec 2007;41(12):1140-1145.
12. **Eva KW.** What every teacher needs to know about clinical reasoning. Med Educ. Jan 2005;39(1):98-106.
13. **Chi MTH.** Two Approaches to the Study of Experts' Characteristics. In: Ericsson KA, ed. The Cambridge handbook of expertise and expert performance. Cambridge: Cambridge University Press; 2006:21-30.

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