

Evidence-based expertise development: A round table discussion of research-informed best educational practices for veterinary pathology

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During the past 60 years, we transitioned from a society dominated by industrial workers to one abundant with knowledge workers.¹ Sixty years ago, knowledge was relatively scarce and challenging to acquire. Though libraries did their best to distribute information on paper media, a simple literature search typically involved many hours of combing through card catalogs and lengthy bibliographic print publications such as Index Medicus. Frequently, searches were delayed for weeks when the desired reference was sent out for binding or checked out by another patron. Innovations like Google, PubMed, e-journals and digital repositories changed everything. Now, information is not only available, it is overwhelmingly so. Currently, the challenge is less how to acquire knowledge, and more how to sort through the ever-burgeoning content to find relevant and reliable information.

Though our information paradigm has transformed dramatically, our education system remains largely unchanged. In the National Survey of Student Engagement (NSSE), administered annually at more than 700 colleges and universities, over 60% of college students reported in 2014 that *“memorizing facts, ideas, or methods from your courses and readings so you can repeat them pretty much in the same form”* was used either “quite a bit” or “very much.”² In other words, the majority of college students report that their courses emphasize rote memorization. Back when information was scarce, it was necessary for professors to distribute knowledge through lecture, and students to memorize facts and figures to recite on examinations. Now that information is readily accessible, it makes sense that our education system can loosen its grip on methods that promote memorization skills and turn toward helping students cope with information overload by teaching critical thinking skills needed to find reliable information, interpret that information, and apply knowledge to solve problems. These are the complex skills essential to the development of disciplinary expertise.

During the past century, educational research has advanced significantly, providing scientific evidence to clarify how people best learn and develop expertise. Some popular educational practices have proven to enhance learning and others such as “learning-styles” assessments, though interesting, have ultimately demonstrated disappointing outcomes.³ The following are evidence-based practices proven to promote learning and help develop expertise in multiple settings.

Deliberate Practice

It has been said in many venues, both popular and scientific, that it takes 10 years of practice to become an expert.^{4,5} Interestingly, this timeframe roughly corresponds to a

student's journey from first entering veterinary school to emerging with board certification and a PhD. However, not all individuals who practice a discipline this long or even longer become experts but rather, many become experienced non-experts. To what can we attribute this great disparity of performance even among students trained in similar environments?

In his own research and while reviewing other studies of expertise spanning 100 years, Ericsson concluded that expertise is optimized when training employs the four tenants of "deliberate practice." That is, when tasks are:

1. clearly defined
2. ramped to a level that continually challenges but does not overwhelm the learner
3. coupled with helpful and timely feedback
4. repeated multiple times, with correction of mistakes⁴

Research from Ericsson and others shows that these expertise-enhancing factors generalize across many seemingly disparate domains such as medical diagnostics, surgery, sports, chess, ballet, music, and typing. There is a surprising lack of evidence to show that talent is innate, but rather is strongly associated with time devoted to deliberate practice.⁶ Why don't all of us who spend time practicing golf, piano, or chess turn into experts after 10 years? To acquire expertise, one needs to practice while maintaining full concentration on the activity, its goals and outcomes, and also seek informative feedback from experts, constantly correcting errors and adjusting performance. Elite athletes often work under the direction of a coach who constantly ramps up the difficulty, and gives feedback, while pushing them to greater and greater expertise. For most of the rest of us, it is not the custom to stop in the middle of a tennis game, asking our opponent for a "do over" and tips on how we might improve. If we spent an equal amount of time practicing with a coach who started us at our current level and then steadily ramped the session up with tougher and tougher volleys, while providing informative feedback, we would progress faster. While the feedback of missing a serve is inherently immediate and obvious, feedback for a pathologist who misses a surgical biopsy diagnosis is often more complex. Here, obtaining follow up and feedback often requires extra effort and is seldom immediate, (for instance waiting for a necropsy) and accordingly does not occur while the memory of the original decision-making is still fresh and at the optimal interval to promote expertise.

Not all forms of feedback are created equal. In a meta-analysis of types of feedback Hattie and Timperley found that:

- Feedback is effective when students are first allowed to respond to instruction and resulting feedback is directed toward how to improve a specific part of the student's performance.
- Feedback is most beneficial when it addresses misconceptions rather than a complete lack of comprehension. Unless the student understands concepts enough to relate feedback to what they already know, it often has a negative effect on learning.
- Feedback has a positive effect when it is directed toward a specific goal. However, this positive effect depends on goals that are clear to both instructor and student.

This sort of feedback is especially beneficial if the goal is challenging but the assignment is uncomplicated.

- Feedback that is personal but not directed to the learning goal (e.g. good job!) does not have much of an effect. However, feedback that jeopardizes self-esteem causes negative effects.
- Using extrinsic rewards unrelated to the learning goal, especially when conducted in a controlling way yields especially negative effects.
- Feedback that ultimately leads to self regulation (self correction and more deliberate practice) is the most beneficial.⁷

How might we design training in veterinary pathology that leverages deliberate practice and effective feedback with error correction?⁸⁻¹⁰

Gradually ramping up the difficulty of practice leverages what is known about cognitive load theory. Proponents of cognitive load theory¹¹ propose to tailor instruction to the level of the learner, focus it on goals that are essential and inherent to learning (intrinsic), reduce tasks that do not relate to the goal (extraneous), and employ helpful strategies for learning (germane). Proponents suggest instruction should be designed to ramp up from simple to complex, with exercises that ultimately emulate authentic practice in a discipline, moving through multiple gradual stages of greater and greater fidelity to that practice.

A series of experiments by Miller led him to conclude that the mind can only hold 5-9 pieces of new data in memory at a time without processing it (what he called “chunking”).¹² With experience, more and more bits of information are incorporated into these chunks ultimately forming highly organized mental knowledge structures called schema. Schemata are thought to be constantly remodeled through experience, aggregate with other schemata, and help bring new knowledge into long-term memory. This process is thought to facilitate thinking and problem solving and occurs gradually as expertise builds. Schema theory is used to explain why it is easier to remember new facts when they are associated with previously internalized knowledge compared to rote memorizing facts out of context.¹³

Continuing with the athletics example, we all know that elite athletes do not just read a book about their sport and then “cram” their practices. In a large number of disciplines, research shows that expert performers spread about four hours per day of deliberate practice fairly evenly and in a consistent manner with breaks and interspersed naps. Greater than four hours of practice per day tends to backfire and reduces performance.¹⁴ How might we learn from this research on cognitive load for teaching pathology to veterinary students, residents and for our own recertification and lifelong learning?¹⁵⁻¹⁷

The Evolution of Reasoning as Novices Become Experts

A growing body of research shows that experts think through problems differently than novices. Accordingly, it can be difficult and confusing for an expert to teach novices in effective ways without understanding how novices think and how instruction is best designed to build expertise. In a review of both her own extensive research on medical expertise and that of others, Patel et al. explain that experts generally use the process of

forward reasoning when thinking through common problems while novices use *backward reasoning*.¹⁸ Forward reasoning uses data to make rapid sequential inferences while progressively fine-tuning hypotheses to reach a diagnosis. Forward reasoning depends on highly structured knowledge schemata as a result of a wealth of experience and sophisticated pattern recognition strategies. Expert diagnosticians are able to quickly connect with mental schemata that contain pertinent data while simultaneously excluding extraneous data. Forward reasoning strategies used by true experts have proven to be highly accurate.

Though it is tempting for novices to emulate expert mentors by using forward reasoning, this sort of rapid thinking without appropriate experience is highly prone to mistakes because the process does not have inherent checks for accuracy of reasoning. Though less efficient, novices tend to use a form of thinking called backward reasoning. Novices think through diagnostic problems by proposing multiple hypotheses and test them using a hypothetico-deductive method. Patel's research found that beginning medical students propose many hypotheses but their analysis of the possibilities was often disorganized while senior medical students became progressively more organized in their hypothesis testing.

Forward reasoning only seems to work for experts when the problem is straightforward or routine, and is part of their well polished schemata. When symptoms don't fit the norm or the presentation is otherwise unusual, experts tend to incorporate a mix of backward reasoning and forward reasoning to solve the problem. How might we learn from this research on cognitive load for teaching pathology to veterinary students, residents and for our own recertification and lifelong learning?¹⁵⁻¹⁷

The author wishes to acknowledge Dr. Jared Danielson, who has patiently and deliberately coached me on the scientific basis of what I knew previously only by intuition, apprenticeship, and experience. I hope that in the future, more veterinary pathologists and social scientists continue to have such supportive and fruitful partnerships.

References

1. Drucker, P. *Landmarks of Tomorrow: A Report on the New 'Post-Modern' World*. (Transaction Publishers, 2011).
2. Freq - SR by Carn.pdf. at http://nsse.iub.edu/2014_institutional_report/pdf/Frequencies/Freq%20-%20SR%20by%20Carn.pdf
3. Pashler, H., McDaniel, M., Rohrer, D. & Bjork, R. Learning Styles Concepts and Evidence. *Psychol. Sci. Public Interest* **9**, 105-119 (2008).
4. Ericsson, K. A. in *The Road To Excellence: the Acquisition of Expert Performance in the Arts and Sciences, Sports, and Games* (ed. Ericsson, K. A.) 1-50 (Psychology Press, 2014).
5. Gladwell, M. *Outliers: The Story of Success*. (Back Bay Books, 2011).
6. Anders, K. & Charness, N. Expert performance: Its structure and acquisition. *Am. Psychol.* **49**, 725-747 (1994).
7. Hattie, J. & Timperley, H. The Power of Feedback. *Rev. Educ. Res.* **77**, 81-112 (2007).

8. Bender, H. S. & Danielson, J. A. A Novel Educational Tool for Teaching Diagnostic Reasoning and Laboratory Data Interpretation to Veterinary (and Medical) Students. *Clin. Lab. Med.* **31**, 201–215 (2011).
9. Michaelsen, L. K., Knight, A. B. & Fink, L. D. *Team-Based Learning: A Transformative Use of Small Groups in College Teaching*. (Stylus Publishing, 2004).
10. Michaelsen, L. K., Parmelee, D. X., McMahon, K. K., Levine, R. E. & Billings, D. M. *Team-Based Learning for Health Professions Education: A Guide to Using Small Groups for Improving Learning*. (Stylus Publishing, 2007).
11. Van Merriënboer, J. J. G. & Sweller, J. Cognitive load theory in health professional education: design principles and strategies. *Med. Educ.* **44**, 85–93 (2010).
12. Miller, G. A. The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychol. Rev.* **101**, 343–352 (1994).
13. Jonassen, D. *et al. Handbook of Research for Educational Communications and Technology: A Project of the Association for Educational Communications and Technology*. (Routledge, 2008).
14. Anders, K., Krampe, R. T. & Tesch-Römer, C. The role of deliberate practice in the acquisition of expert performance. *Psychol. Rev.* **100**, 363–406 (1993).
15. Danielson, J. *et al.* Characteristics of a cognitive tool that helps students learn diagnostic problem solving. *Educ. Technol. Res. Dev.* **55**, 499–520 (2007).
16. Danielson, J. A., Bender, H. S., Mills, E. M., Vermeer, P. J. & Lockee, B. B. A Tool for Helping Veterinary Students Learn Diagnostic Problem Solving. *Educ. Technol. Res. Dev.* **52**, 63–81 (2003).
17. Bender, H. S. *et al.* Mechanism-based diagnostic reasoning: thoughts on teaching introductory clinical pathology. *Vet. Clin. Pathol. Am. Soc. Vet. Clin. Pathol.* **29**, 77–83 (2000).
18. Patel, Vimla L., (first), Kaufman, David R. & Magder, Sheldon A. in *The Road To Excellence: the Acquisition of Expert Performance in the Arts and Sciences, Sports, and Games* (ed. Ericsson, K. A.) 127–166 (Psychology Press, 2014).