Engineering Expertise and the Neuroscience of Teaching and Learning

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Nature and Implications of Expertise

- + What is Expertise? What does it take to be good at my job?
- Implications for all fields -- computer programming, medical diagnosis, engineering, instrument repair, sports of all kinds
- Virtually every skill that feeds society's rampant needs for high performance
- The capacity to acquire expertise is one of the great and peculiar strengths of the human species
- The challenge for us (particularly engineers) is how best to use this capacity to the benefit of all
- To meet that challenge, we need to understand better what it means to acquire expertise, what fosters and what stunts its development, and how it functions in people's lives and work

What is Expertise?

- The main thing research shows is that expertise requires enormous amounts of knowledge-far more than anyone, even the experts, had supposed
- This radically changes the whole scale of problems related to expert knowledge and skill
- The practical upshot is the need for years of training and experience
- + We already knew this
- + But Expertise in itself may not be enough...

Experts at Work!



Novice-Expert Framework Issues

- It's not just about mistakes that experts sometimes make
- There is a fundamental lack of deep thinking about expertise... especially by experts themselves
- We typically compare experts (many years' experience) to novices (very little experience)
- + But as an organization, we are not just concerned with novices
- + Eventually they will quit being novices, without our having to do much about it (time & experience)
- + The important question is what they will become

Making Adaptive Experts

- + We assume with time and experience they will become expert but what kind of expert?
- + Many so-called experts swell the ranks of incompetent / mediocre functionaries
- + As scientists, engineers, or managers, how will they compare with their counterparts in other industries/countries? Competitive edge?
- + As the builders of tomorrow, will they have creativity and breadth of vision?
- Will they be able to grasp, and make headway against, the large problems that face us?
- We need to know what separates expertise from mediocrity... and what is needed -- besides training and experience-- to foster continuing growth in competence
- + From Expert to Adaptive Expert

Conventional Wisdom of Expertise

- It becomes all too apparent that skills, processes, and practices violate conventional wisdom about expertise on a number of counts
- Conventional wisdom has it that Practice makes Perfect and that expertise is the natural outcome of years of practice
- Take writing... few people become good writers, no matter how much they write
- For many, the effect of years of practice is simply to produce increasingly fluent bad writing
- Conventional wisdom, backed by scores of experiments comparing novices and experts in various fields, sees experts doing quickly and easily what novices do laboriously, if they can do it at all
- Novices have to reason things out, whereas experts know what to do without thinking

Two kinds of Expertise

- Hatano and Inagaki (1986) differentiate Adaptive Expertise (AE) from "routine" expertise
- Some work environments tend to foster routine expertise where people can be highly efficient without a need to deeply understand what they are doing and why it is relevant
- Routine experts develop a very high, but rather narrow, procedural proficiency with a particular set of cultural tools
- Other workplaces demand change and variability which requires routine experts to develop more of a learning stance (i.e., adaptive expertise)

Adaptive Expert=Expertise + Edge

- + It turns out that everyone can grow an edge to their expertise -- every expert, in whatever field, has potential for a growing edge
- Doctors often remark that the great majority of cases they see are unchallenging
- Routine diagnostic and treatment procedures suffice
- Five or ten percent of cases might be challenging
- + Those cases test the growing edge of the doctor's expertise
- The doctor who treats them in a routine way stops growing (15 percent of doctors designated "major deficiencies" by Ontario College of Physicians and Surgeons)

What does Expert Edge mean?

- There is potential for anyone to grow an edge to knowledge
- Some workers approach their tasks in ways that minimize opportunities for growth, whereas Adaptive Experts maximize growth opportunities
- The result is a multiplier effect, where the more expert keep gaining in expertise while the less expert tend to stagnate
- When working at the edge of their competence, the more expert go about things in ways that result in their learning still more
- This suggests something about how they got to be experts in the first place
- + Why do so many people with time, experience and opportunity fail to gain expertise?

Evidence of Adaptive Expertise

- + Teaching and Learning with innovative methodology
- + Challenge Cycle vs. Transmission model has immediate and verifiable impact
- + Agency connects with adaptive expertise
- Safe learning environment (as well as safe working environment) aligns with AE
- + Discussion about "comfort zones" helps explore AE

Simple Solution thru Methodology



Plasticity

- + Early 1960s Marian Diamond's lab -- first to ask might the brain be able to change in response to the environment?
- + This became known as plasticity.
- + At that time nobody thought the brain could change
- + Once you got to adulthood that was it No changes
- She raised mice/rats in an enriched environment? Lots of toys, lots of other play mates, treadmill wheel

We use this much of our Brains

+ 1. Humans use about 10% of their brains

+ 2. Women use about 35%, Men use about 15%

+ 3. Humans use 100% of their brains

+ 4. Brain use follows the Pareto (80/20) rule

Diamond's Enriched Environment





Impoverished environment



Diamond's Enriched Environment



Implications of Plasticity

- What she found was revolutionary clear structural changes in the brain
- + Thicker outer cortex
- Neurotransmitter level changed (especially the neurotransmitter for memory - acetocholine)
- + More synapses the connections between the neurons
- Raising mice/rats in enriched environments caused the birth of new neurons in a key structure in the brain important for memory - hippocampal neurogenesis

Neuroscience in Workplace Learning

- Focus on Potential instead of content
- What to do with content? Co-Construct with Backward Design
- + Highlight Plasticity so that effort is meaningful
- + Level the playing field Mindset (growth vs. Fixed)
- Knowledge about Hippocampal Neurogenesis and new memories (learning)

Mindset for Critical Mental Model



Fixed

Mindset

Growth

Desire to Look Smart		Desire to Learn
Avoid Challenges	Challenges	Embrace Challenges
Give up easily	Obstacles	Persist in the face of setbacks
See effort as fruitless	Effort	Effort as path to mastery
Ignore useful negative feedback	Criticism	Learn from criticism
Feel threatened	Success of Others	Find lessons and inspiration
	End Result	
Plateau early achieve less than full potential		Reach ever higher levels of achievement
Confirms a deterministic view of the world		Greater sense of free will

Connecting Neuroscience to Expert

+ Adaptive Expertise = Expert + Edge

- + Edge derives from Mindsets
 - Aware of the possibility of Fixed vs. Growth
 - Know how to manage mindset
- + Edge derives from Mental Models about Learning
 - Plasticity
 - Potential
 - Metacognition
 - Backward Design