What all instructors should know about learning

Carl Wieman

Research relevant to optimizing learning in nearly every context

Major advances past 1-2 decades
Consistent picture ⇒ Achieving learning

classroom studies

brain research

cognitive psychology

Outline

1. Background context-- most effective learning

2. Motivation
   what motivates & demotivates

3. A. Retention
   B. Limits on working memory

4. Learning as brain development--
   A. What changes brain, including role of feedback

   B. Impact of prior thinking & expert-novice differences

   C. Expert mental frameworks, learning concepts and transfer to novel contexts

Bunch of different ideas on learning relevant to most students and classes.

Challenge to present!

"like abbreviated Cliffs Notes for driver's manual"
Skip many subtleties and details.
NOT covering implementation in teaching

Assume you are all "expert" learners- have context, framework, background knowledge, and motivation.

Slides on CWSEI website, www.cwsei.ubc.ca
Many more references there & others appearing.
Research on learning & implementing in teaching.
Experts you can consult…

Science Teaching and Learning Fellows

Computer Science

Beth Simon

Earth and Ocean Sciences

Brett Gilley

Francis Jones

Ben Kennedy

Physics and Astronomy

Jim Carolan

Life Sciences

Tamara Kelly

Jared Taylor

Harald Yurk

Skylight Affiliates

Gulnur Birol
Life Sciences

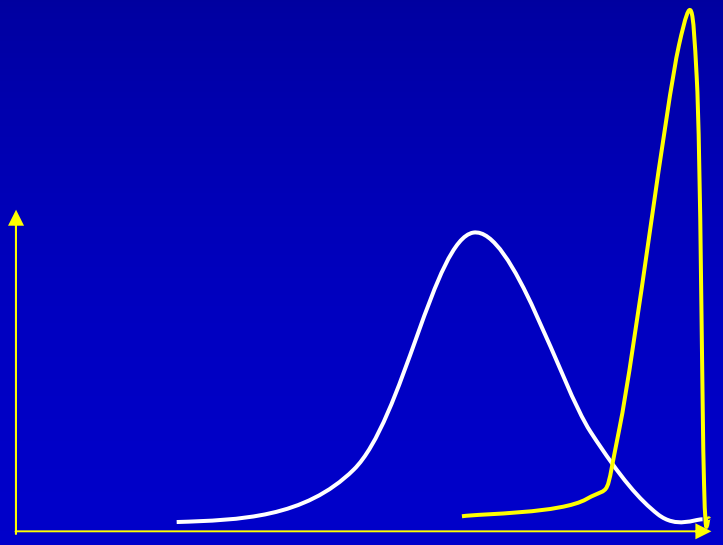
Jackie Stewart
Chemistry

Context-- What does research say achieves the most learning of any educational approach?*

⇒ **expert** individual tutor

Large impact on all students

Average for class with expert individual tutors >98% of students in class with standard instruction



* Bloom et al *Educational Researcher*, Vol. 13, pg. 4

Characteristics of **expert** tutors*

- **Motivation major focus** (context, pique curiosity,...) limited praise, never for person, all for process
- Understands what students do and do not know. ⇒ timely, specific, interactive feedback
- Almost never tell students anything-- pose questions.
- Mostly students answering questions and explaining.
- Asking right questions so students challenged but can figure out. Systematic progression.
- Let students make mistakes, then discover and fix.
- Require reflection: how solved, explain, generalize,...

Reflect broadly applicable principles

*Lepper and Woolverton pg 135 in Improving Academic Achievement

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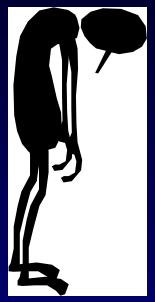
2. Motivation-- essential for student learning

(& relevant to teacher enjoyment)



Don't want to learn, see no reason to learn.
⇒ Won't learn!

Learning requires effort!
Survival trait-- don't expend energy without reason.

Study of successful experts-- **primary characteristic, strong motivation to succeed.** Put in necessary hours of intense effort. (A. Ericsson)

Origins of motivation for learning
Motivation to learn given subject not innate, shaped by background & perspective, highly malleable.

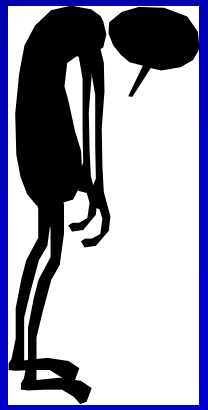
clicker question on motivation

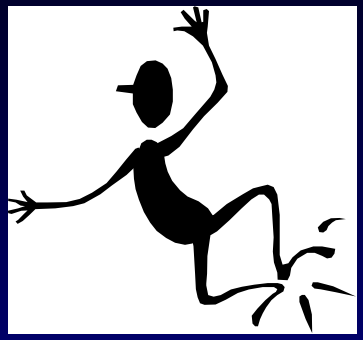
“This class is very hard and many of you will fail so you need to study really hard.”

How does this impact university student motivation to learn the material?

a. increases b. decreases

Focus groups and interviews indicate is demotivating for university students. Psychology studies support.





What motivates to learn (*some* tested examples)?

a. Subject relevant to lives, future plans, explains world they know, solves problems or answers questions they care about ("meaningful context")

b. Instructor attitude

"Subject hard for everyone, but all can master with effort, and my goal for course is for all of you to succeed."

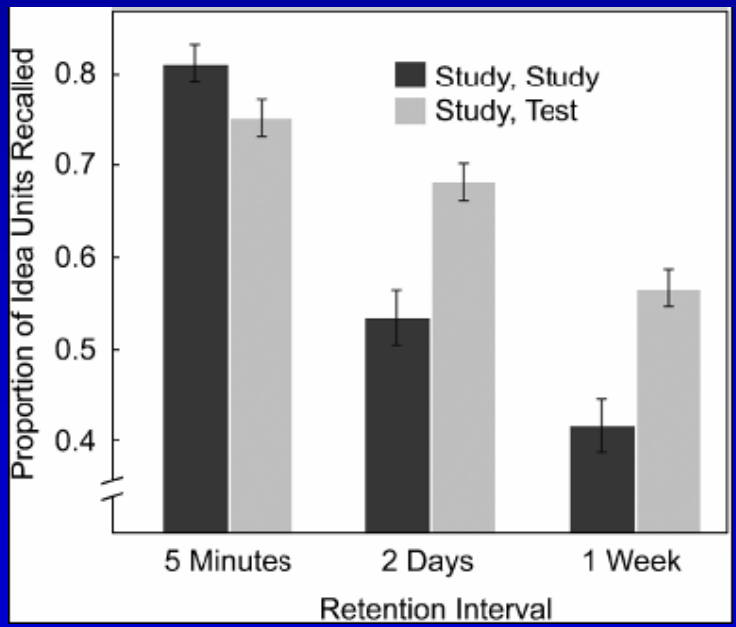
3. Two basics- Retention and Working Memory

3A. Retention--

Retention enhanced by repeated spaced retrieval, number of mental "hooks", depth of processing (?)

- 5 hours studying one day vs. 1 hour/day for 5 days
  performance on exam? about the same
  performance 3 months later? 1hr/day higher

- Retention from review vs. retrieve & apply
i.e. hearing again or rereading vs. being tested (by self or other), <u>even if score unknown</u>



H. Roediger, J. Karpicke
Psych. Sci. Vol.17 pg 249

Learn by explaining

(retrieval +)

Hooks for retention-- mental connections
(many varieties)

e.g. lesson on fasteners-- here are all the types and how they are used.
vs.
Here is an interesting job problem, here are possible types of fasteners for solving problem, and here is how a certain type of fastener solved it. *same initial,* **better retention**

Fastener example "*attached hook*" for retention through relevant context

dumb joke about fasteners-- hook to improve your retention of idea of hooks to improve retention

3.B. Capacity of working memory

Working memory capacity
VERY LIMITED!
every added demand hurts learning
("cognitive load")

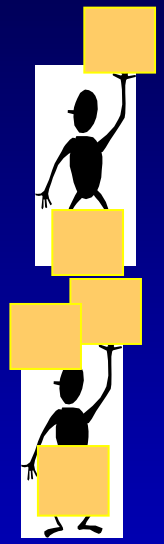
(remember/process max 4-7 unrelated items)

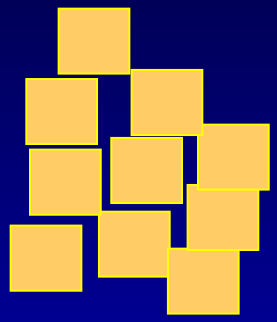
Without great care, exceeded in almost every lecture.

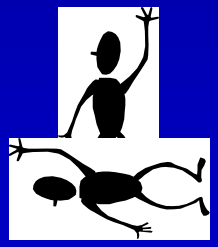
Mr. Anderson, May I be excused?
My brain is full.

Implication for learning--Reducing any unnecessary demand on working memory improves learning.

~~jargon~~ use figures, connect topics, …







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Expertise and its development*

Cognitive psychology

What makes up expertise?
How is it acquired?
What happens in the brain?

*Cambridge Handbook on Expertise and Expert Performance

Expert competence research

Expert competence =

- factual knowledge
- **Organizational structure** ⇒ effective retrieval and use of facts

or ?

- **Ability to monitor own thinking**

("Do I understand this? How can I check?")

- How develop expertise?

Changing the brain

Expert-like ways of thinking--
not just more informed-- new way to think.
Built into long term memory-- new "wiring"

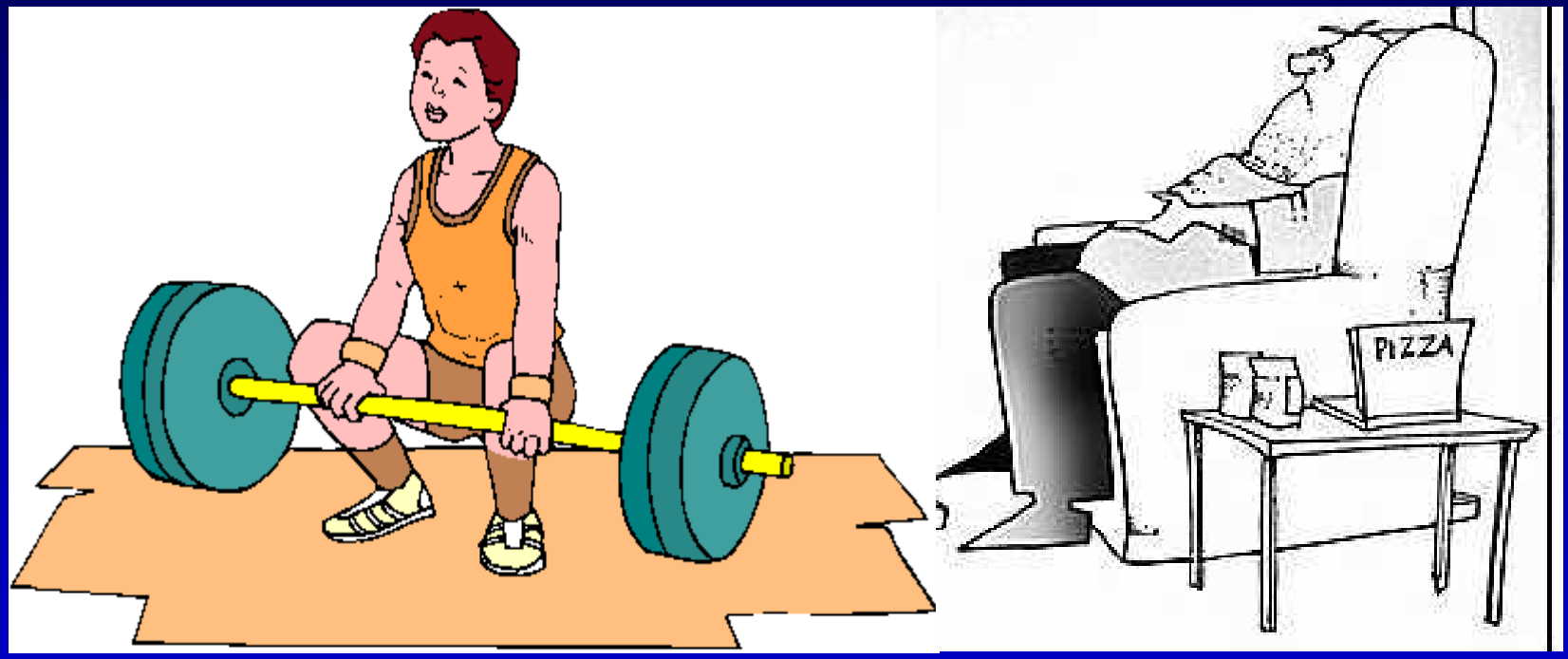
Learning requires active construction of understanding.

Brain **is** changing--

- See in brain activation and imaging studies
- Understand in terms of chemical and biological basis of long-term memory
- See in development of expertise

recent research--Brain development much like muscle

Requires strenuous extended use to develop
(classroom, cog. psych., & brain imaging)



stronger?

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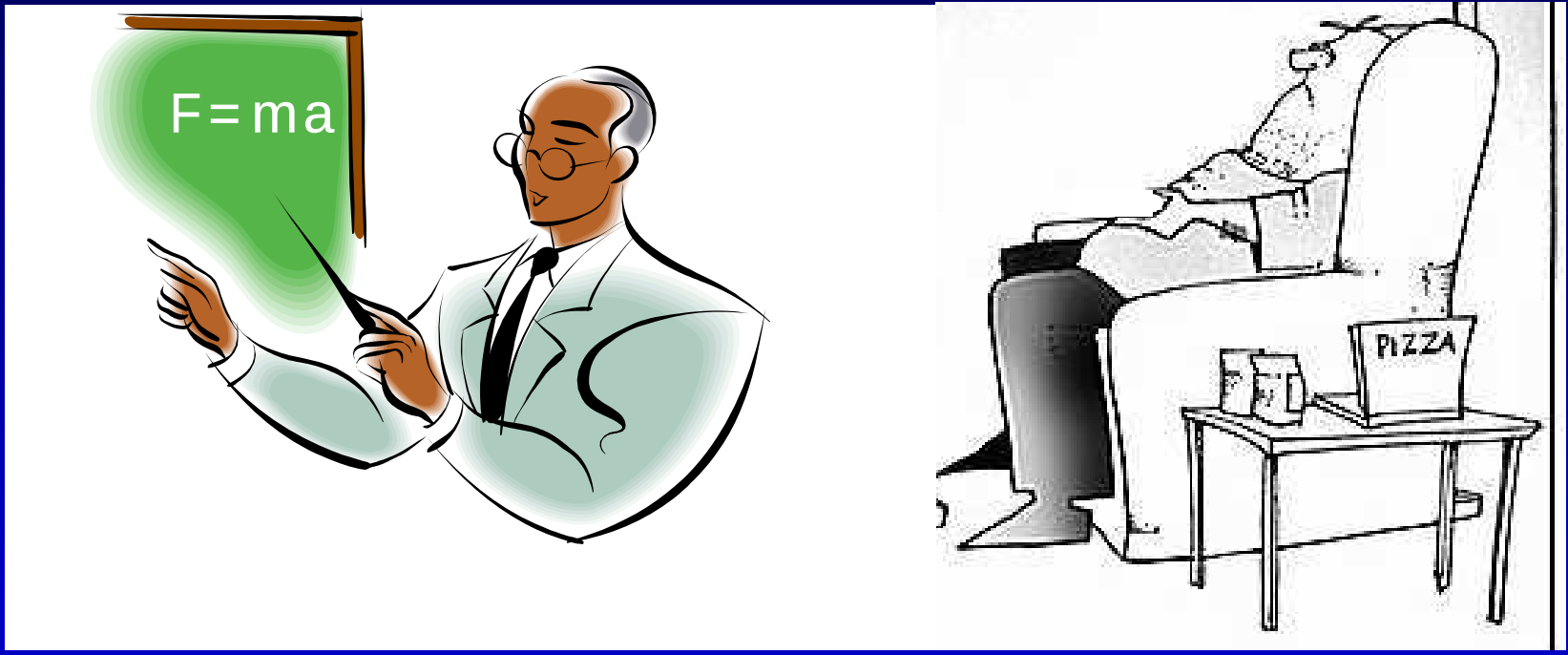


Smarter?

Learning expertise--how best to develop brain?

Student GPA correlates with time spent studying?

a. yes
b. no

amount of time studying not correlated, or slightly anticorrelated with GPA!

GPA is correlated with amount of **certain type** of studying.

Effortful practice / study

Cog. Psych. research on development of expertise--
Expertise requires many hours of "effortful practice"--
endless low level study/practice⇒ no improvement

Characteristics of effortful practice/study

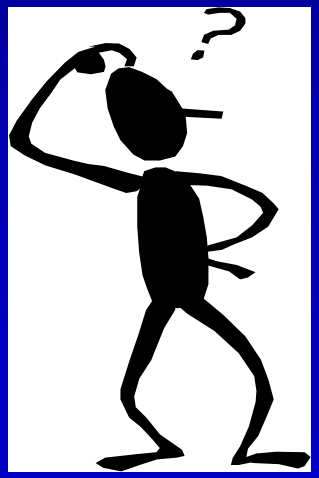
- Always focused on next higher level; attainable, but only with full concentration/effort *(limited hrs/day)*
- Feedback on progress
- Reflection upon success-- *how improved/learned, lessons for next step*

(experts learn to monitor own thinking and learning)

Feedback-- what helps & what doesn't help learning (all contexts)*

1. Helps learning *(likely essential!)*
Timely & specific.
⇒ feedback that guides subsequent thinking

2. Not helpful--
Delayed significantly in time
Nonspecific⇒ zero or negative effect



last months exam scores
G.A. 27
H.D. 65
R.M. 62

*Knowing What Student Know, Pelligrino et al eds. NAS Press (2001)

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Fish is Fish
L. Lionni
Dragonfly Books

3.B. Impact of prior thinking
Expert-novice differences*

*Long term memory **always** built on prior thinking.*
*People **always** interpret in terms of past knowledge.*

Manifested in <u>many</u> ways:

1) Nonexperts perceive images, demonstrations, labs in unintended ways.

2) Prior thinking shapes interest, motivation, how to learn, …

* How People Learn, Bransford et. al eds, NAS Press (2000)

Expert-novice differences (cont.)

2. Prior thinking can be helpful or harmful depending on what it is, if recognized, how guided.

Misapplied prior knowledge ("misconceptions") very robust! *(lots of research in physics & chem)*

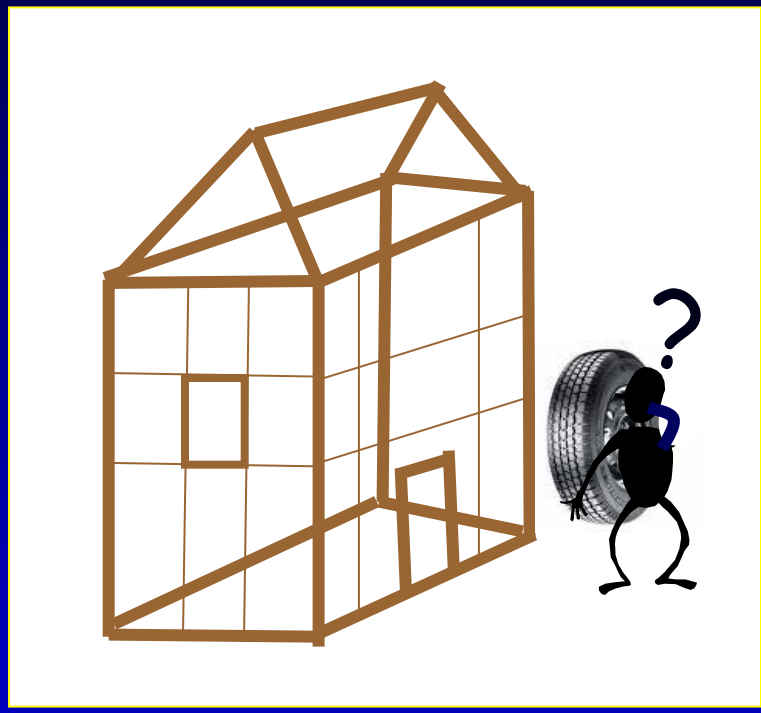
Will override repeated explanations, solving hundreds of problems.

Changed only by convincing person of necessity to examine and reconsider their thinking.

3.C. **Expert Mental Frameworks, Learning Concepts, Transfer to Novel Contexts.**

Nonexperts have poor framework for organizing knowledge.
Often not recognized by teacher.

Most common difficulty students express-- cannot understand structure, what is important and what not, how fits together? …



When proper framework established, cog. load reduced, learning and retention much better.

Learning Conceptual Understanding -- concepts are expert framework--way of organizing and applying knowledge.
physics--"conservation of energy"

Related to "transfer"-- ability to apply understanding to novel context. "Concept" is what transfers.

How learn conceptual understanding and transfer?

- What does not work

Hearing (or reading, etc.) abstract generalization.
Solving algorithmic problems. *(lots of physics ed. data!)*

- What does work *(with effort)*

1. Multiple specific examples & applications.
2. Compare & contrast examples.
3. Think explicitly how to generalize. Reflect & apply.

final test-- retrieve and apply

Controlled study.* Two comparable groups of students. Predict which group scored higher on the test & why?

Group 1 went to lecture, took notes and reviewed them, then took test on the material.

Group 2 did not go to class, got the lecturer's notes and reviewed them, then took the same test on the material.

ans. group 2.
Studies of student note taking show why. Only the students who already know the material pretty well are able to take notes that follow the organizational framework and are accurate.

For the others, do not have the framework, cog. load too high, their notes (and lecture) are not of much use.

*K. Kiewra, Ed. Psych. 1985, V. 20, pg. 33-39

What research says about enhancing learning

- Motivation
- Retention
- Limits on working memory
- Learning as brain development-
  A. What changes brain
  B. Impact of prior thinking & expert-novice differences--
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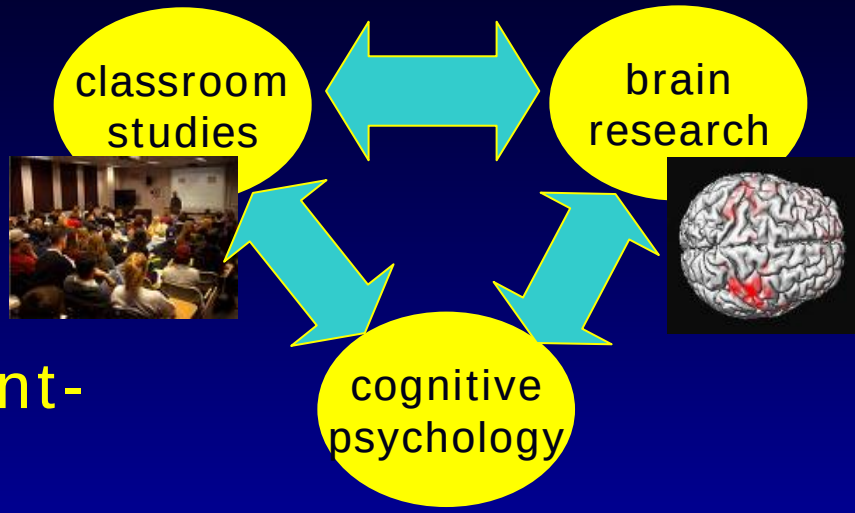

characteristics of expert tutors-- close match
⇒ guidance for applying in classes

www.cwsei.ubc.ca slides & more refs at "resources"

Extra bonus slides

Expert-novice differences: **Beliefs about subject & learning**

Novice	Expert
Content: isolated pieces of information to be memorized.	**Content: coherent structure of concepts.**
Handed down by an authority. Unrelated to world.	**Describes nature, established by experiment.**
Problem solving: pattern matching to memorized recipes.	**Prob. Solving: Systematic concept-based strategies. Widely applicable.**

Beliefs set by past experience. Shape interest and motivation and how to learn.
Need to convince in order to change.
Into. chem & physics reinforces novice beliefs.

see refs at www.CLASS.Colorado.edu

References

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- Cambridge Handbook of Expertise and Expert Performance, edited by K. Ericsson, N. Charness, R. Hoffman, and P. Feltovich (Cambridge University Press, 2006).
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other references at www.cwsei.ubc.ca

Recorded webcast on IK Barber Learning Centre website: www.ikebarberlearningcentre.ubc.ca