Applying the Science of Learning to Improve the Learning of Science

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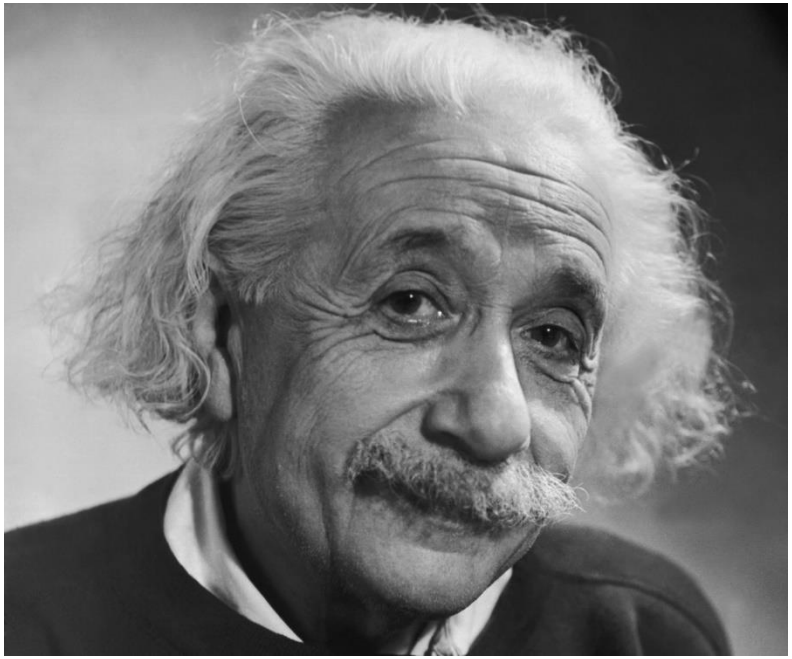
Lifetime Learning Institute

June 14, 2022

Images from images of learning science - Bing images and 56,916 Learning Science Photos and Premium High Res Pictures - Getty Images

An Opening Thought:



"The only thing that interferes with my learning is my education."

Albert Einstein

THE MONTILLATION OF TRAXOLINE

It is very important to learn about traxoline. Traxoline is a new form of zionter. It is montilled in Ceristanna. The Ceristannians gristerlate large amounts of fervon and then bracter it to quasel traxoline. Our zionter lescelidge may make traxoline one of our most lukizes snezlaus.

THE MONTILLATION AND USES OF TRAXOLINE

QUIZ:

1. **What is traxoline?**
2. **Where is it montilled?**
3. **How is traxoline quaseled?**
4. **Why is traxoline important?**

THE MONTILLATION OF TRAXOLINE

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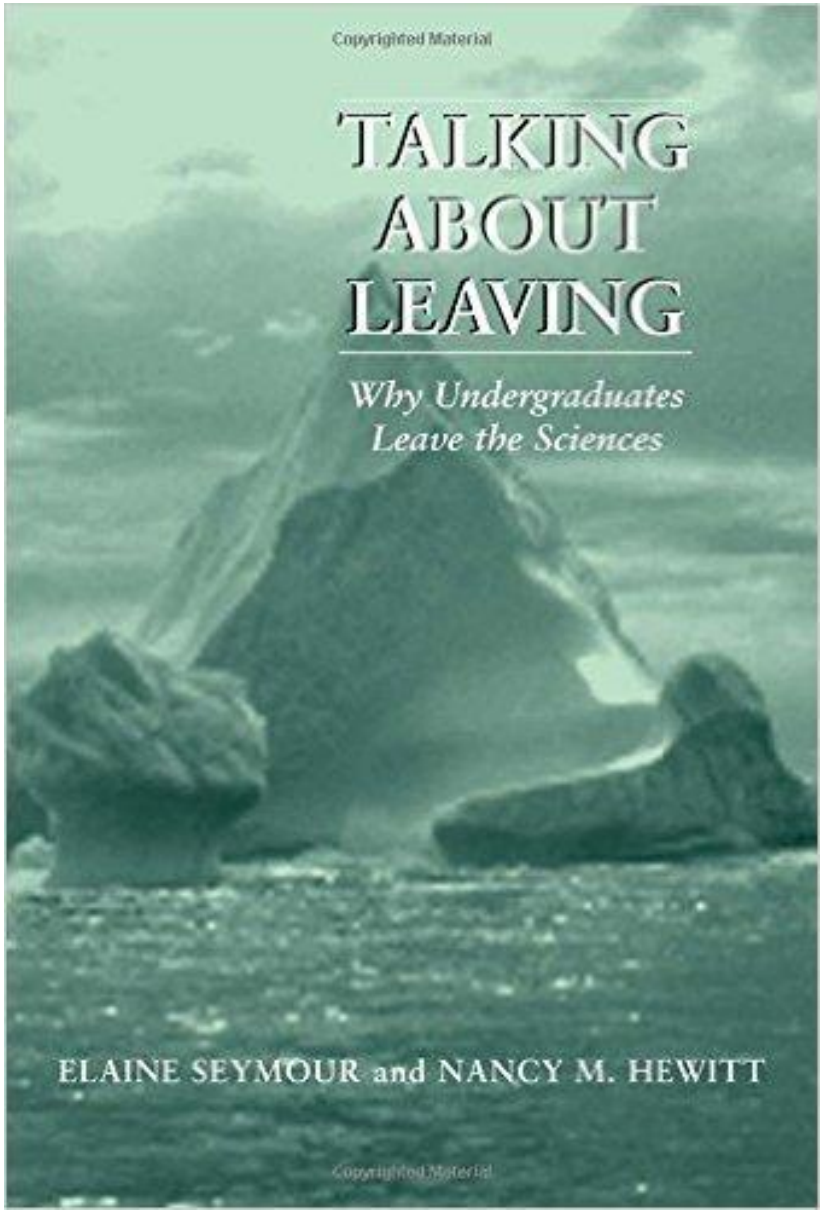
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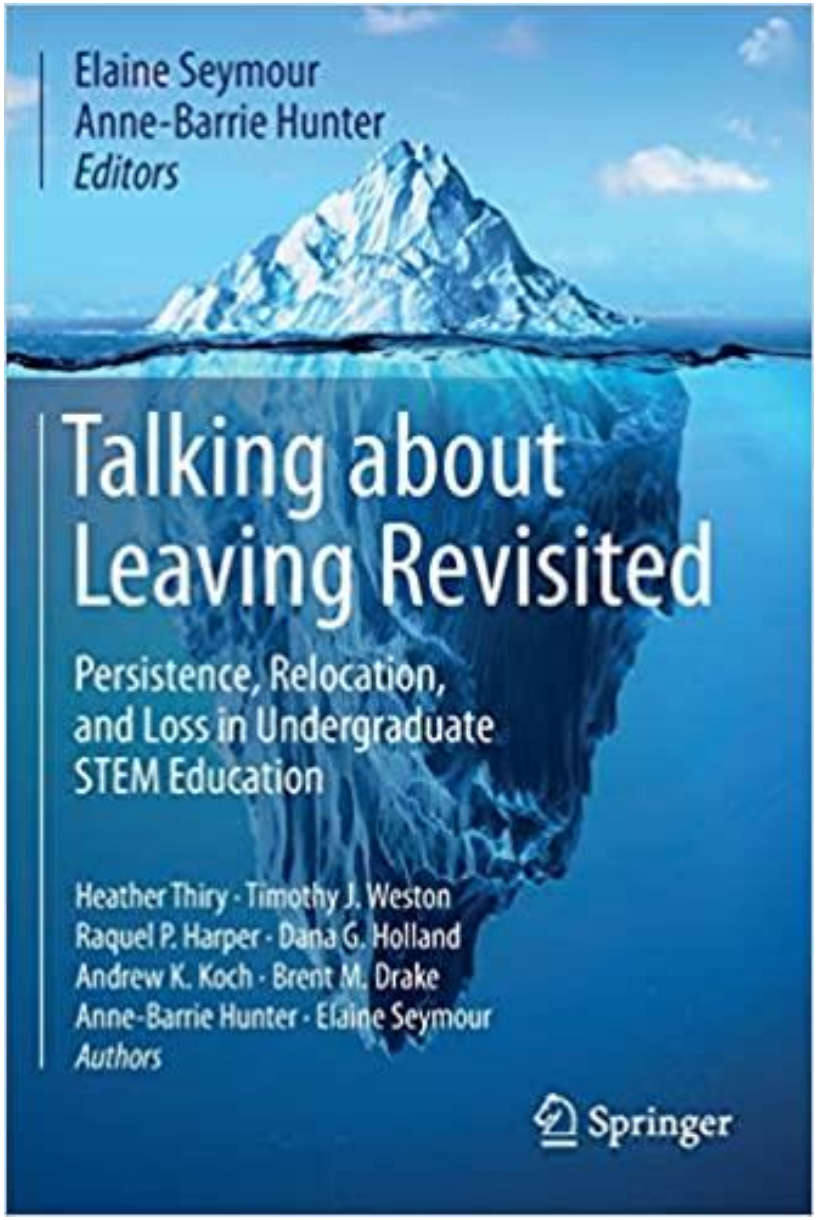

Elaine Seymour
Anne-Barrie Hunter
Editors
Talking about Leaving Revisited
Persistence, Relocation, and Loss in Undergraduate STEM Education
Heather Thiry · Timothy J. Weston
Raquel P. Harper · Dana G. Holland
Andrew K. Koch · Brent M. Drake
Anne-Barrie Hunter · Elaine Seymour
Authors
Springer

(2019)

PNAS April 2014 Scott Freeman et al.

Active learning increases student performance in science, engineering, and mathematics

Scott Freeman[a,1], Sarah L. Eddy[a], Miles McDonough[a], Michelle K. Smith[b], Nnadozie Okoroafor[a], Hannah Jordt[a], and Mary Pat Wenderoth[a]

These results indicate that average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning.

versus active learning. The effect sizes indicate that on average, student performance on examinations and concept inventories increased by 0.47 SDs under active learning ($n = 158$ studies), and that the odds ratio for failing was 1.95 under traditional lecturing ($n = 67$ studies). These results indicate that average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning. Heterogeneity analyses indicated that both results hold across the STEM disciplines, that active learning increases scores on concept inventories more than on course examinations, and that active learning appears effective across all class sizes—although the greatest effects are in small ($n \leq 50$) classes. Trim and fill analyses and fail-safe n calculations suggest that the results are not due to publication bias. The results also appear robust to variation in the methodological rigor of the included studies, based on the quality of controls over student quality and instructor identity. This is the

and studio or workshop course designs. We followed guidelines for best practice in quantitative reviews (*SI Materials and Methods*), and evaluated student performance using two outcome variables: (*i*) scores on identical or formally equivalent examinations, concept inventories, or other assessments; or (*ii*) failure rates, usually measured as the percentage of students receiving a D or F grade or withdrawing from the course in question (DFW rate).

The analysis, then, focused on two related questions. Does active learning boost examination scores? Does it lower failure rates?

Results

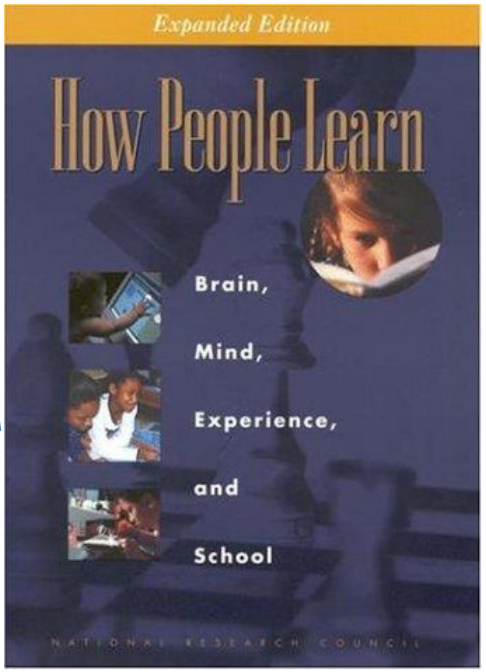
The overall mean effect size for performance on identical or equivalent examinations, concept inventories, and other assessments was a weighted standardized mean difference of 0.47 ($Z = 9.781$, $P << 0.001$)—meaning that on average, student performance increased by just under half a SD with active learning

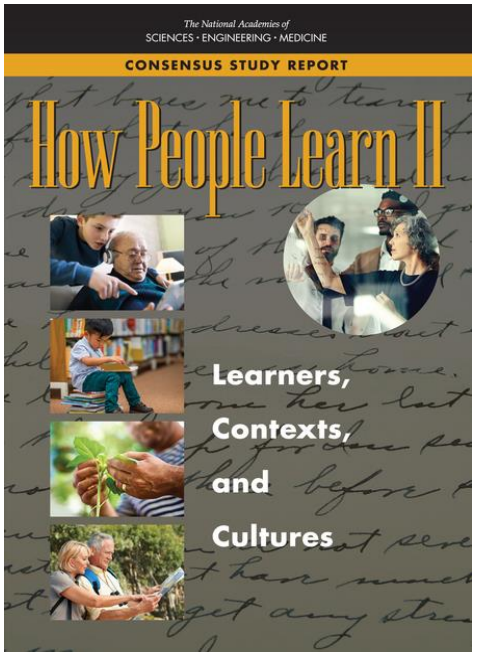
LEARNING GOALS FOR THIS SESSION:

1. Explore why it's important for learners to develop BOTH a deep foundation of factual knowledge AND strong conceptual framework.

2. Briefly explore transfer of knowledge and how difficult it is to do.

3. Consider how pedagogy, especially in science, can utilize evidence-based principles of human learning.

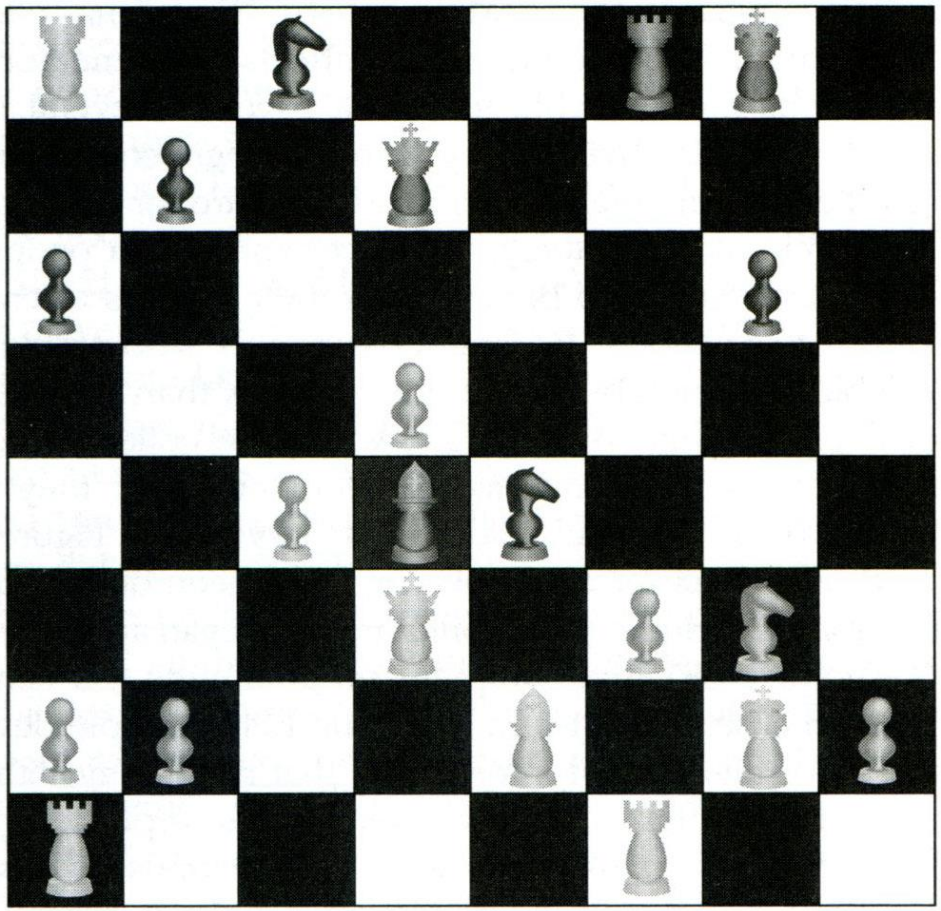




Both available for free download at http://nap.edu

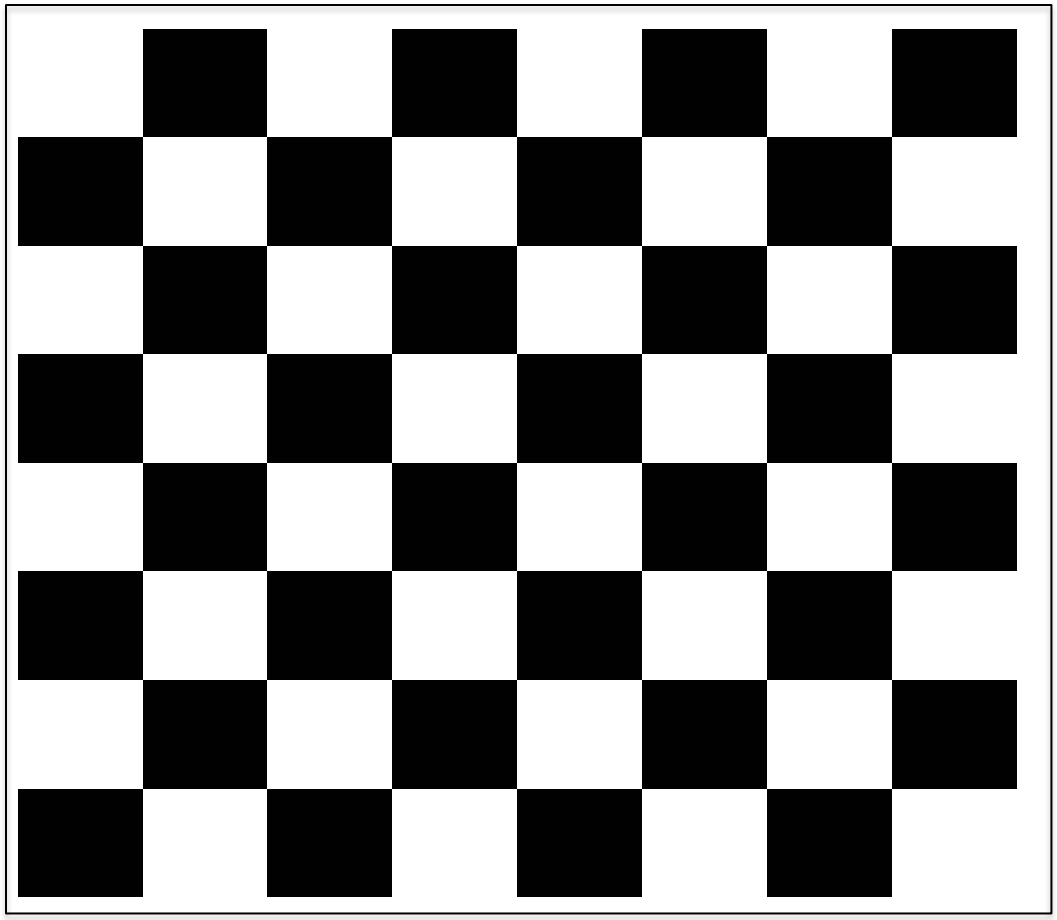
The value of conceptual frameworks vs. knowledge alone:

The chessboard challenge:



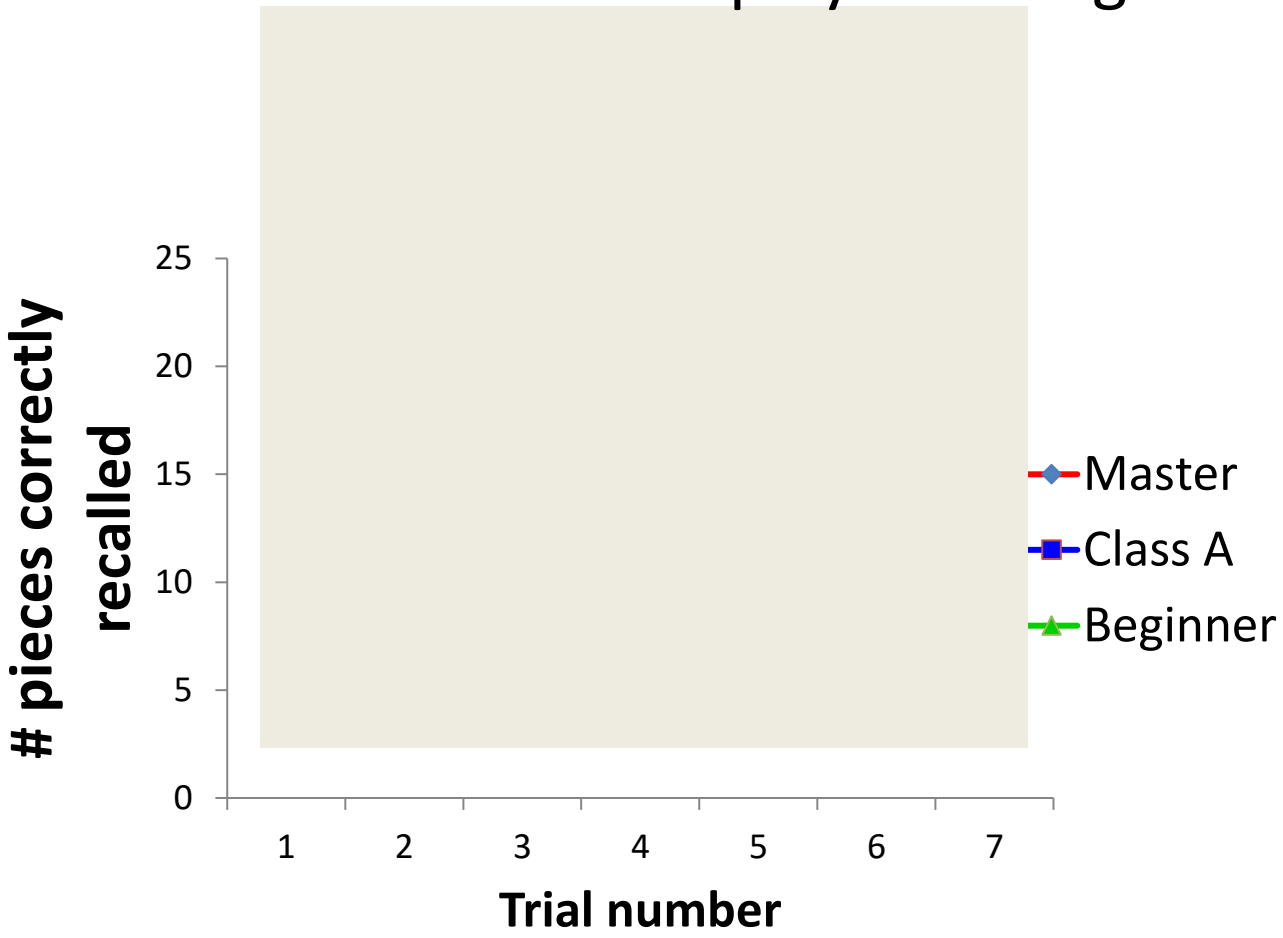
Board 1

Adopted from How People Learn, & Chase & Simon 1973

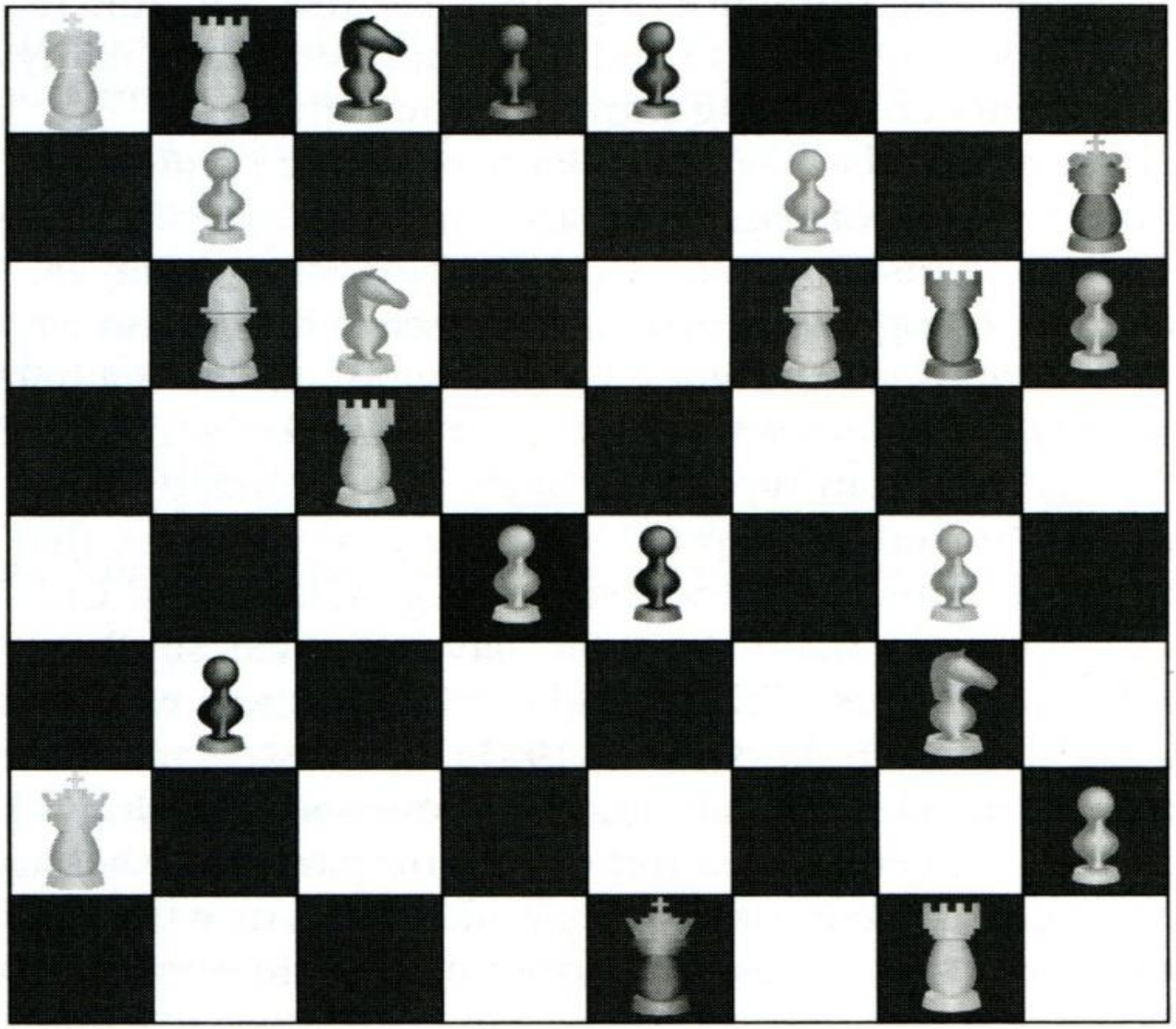


Can you correctly place the chess pieces?

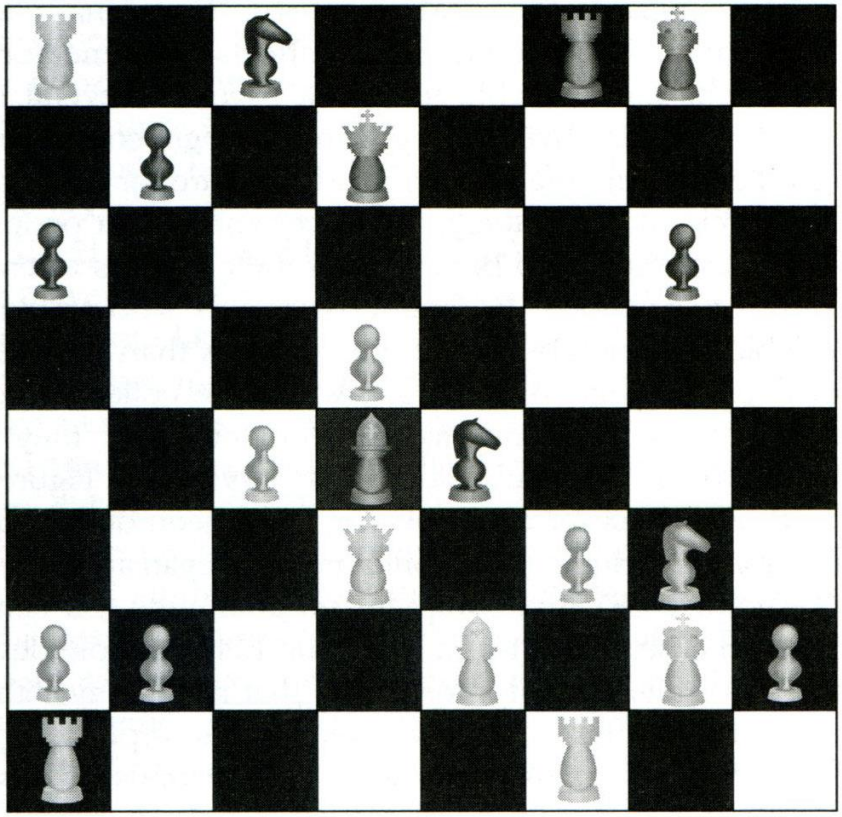
Chess masters – Class A players – Beginners



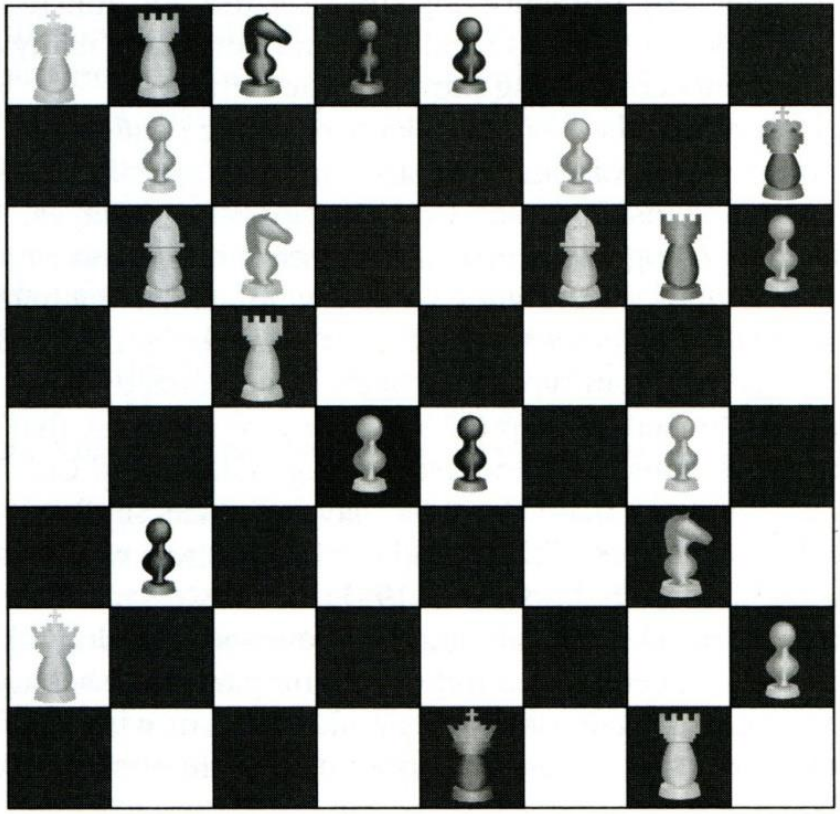
Board #2



Board #1



Board #2

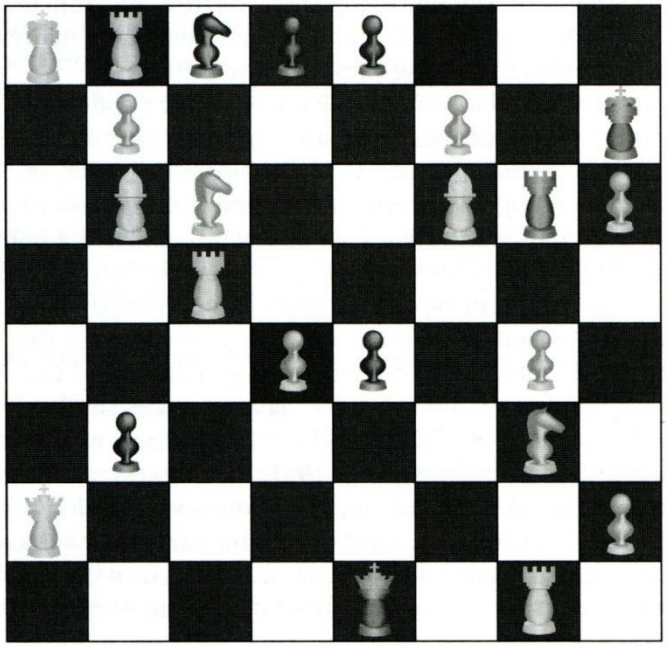


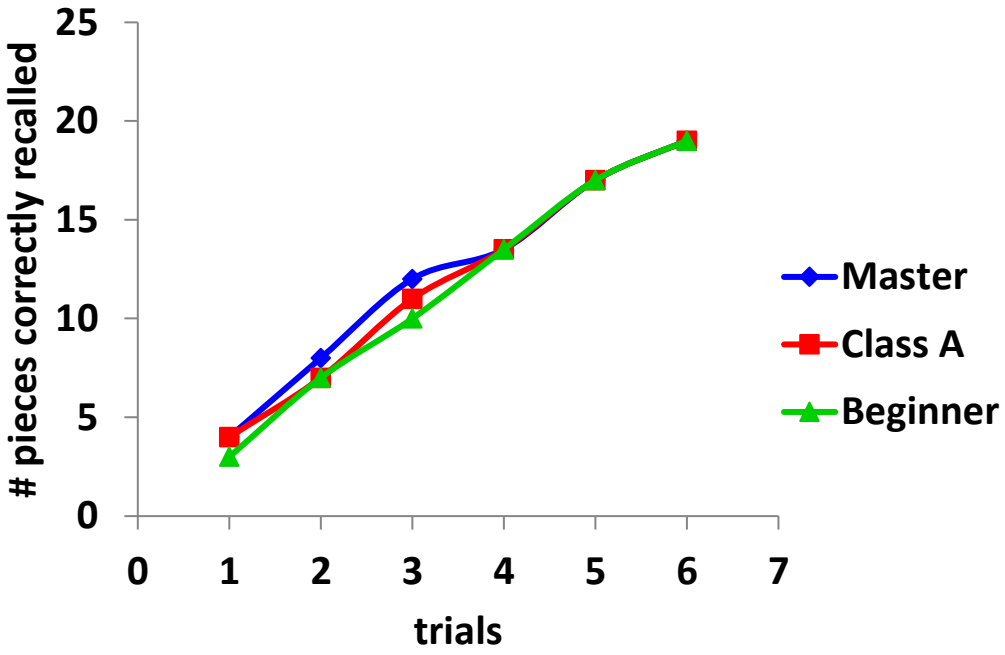
Will the results for the second board be the same as for the first board?

A Yes

B No

Board #2




pieces correctly recalled
25
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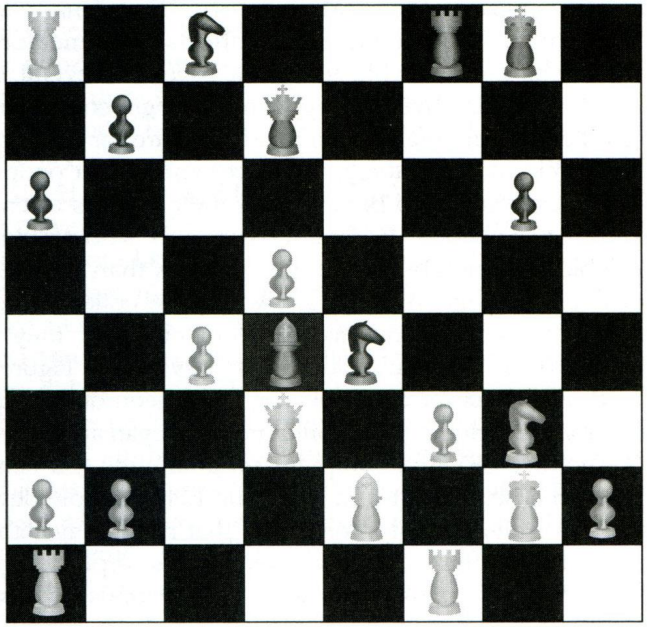
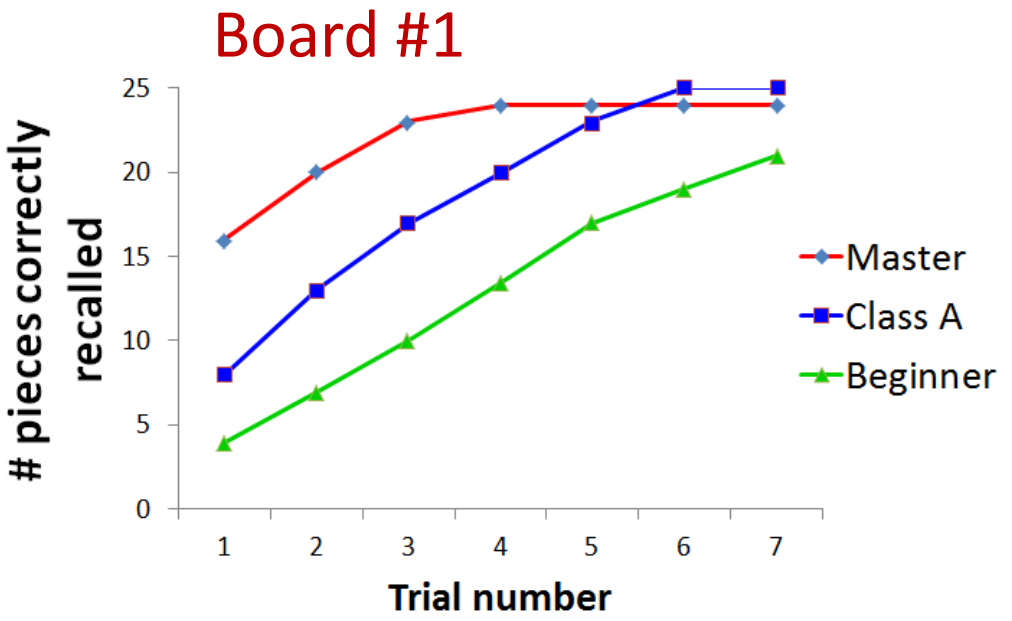
6
7
trials
Master
Class A
Beginner




Board #1
pieces correctly recalled
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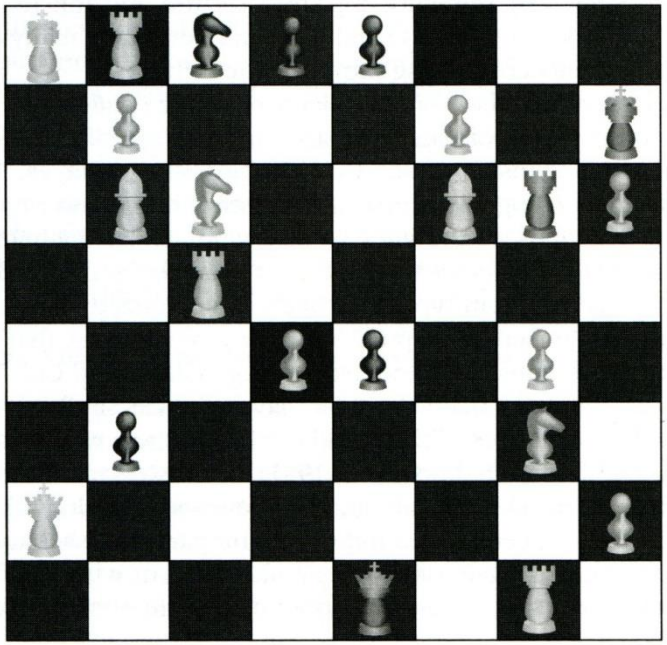
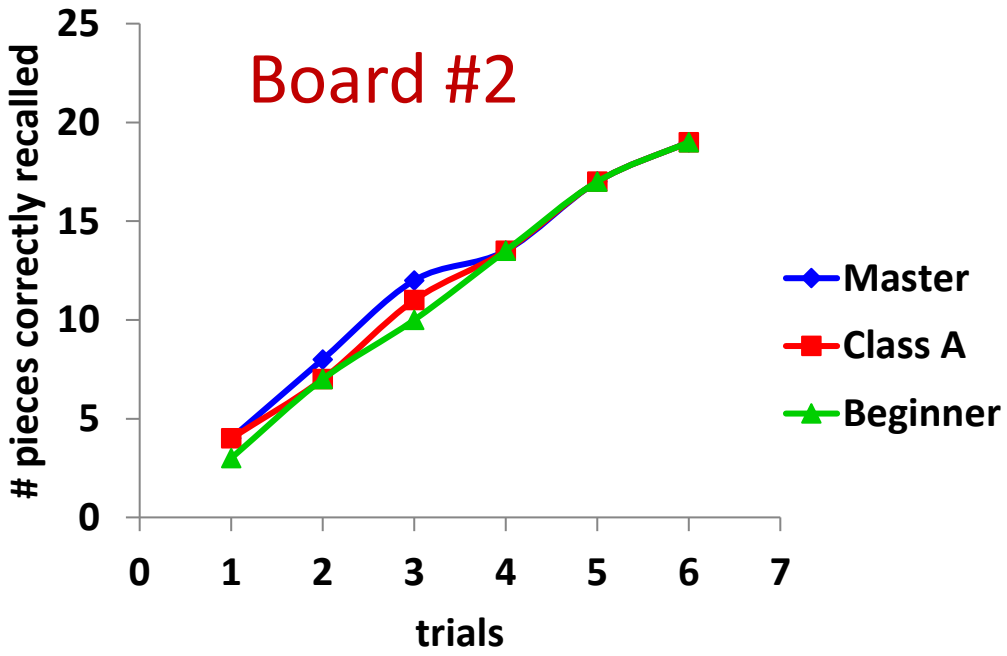
Trial number
Master
Class A
Beginner




Board #2
pieces correctly recalled
25
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6
7
trials
Master
Class A
Beginner

The Nature of Expertise:

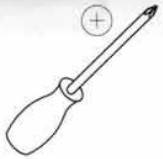
Knowledge Acquisition & Organization

Research with experts & novices reveals marked differences in the way they store, and apply knowledge:

- **Experts have a rich knowledge base that is hierarchically organized.**

- **Experts notice and remember large amounts of complex information in their domain of expertise after short exposures to a new situation.**

Outils non fournis
Tools not included
Werkzeuge nicht mitgeliefert
Herramientas no incluidas
Ferramentas nao incluidas
Accessori non forniti
Gereedschap niet bijgeleverd



- Le montage et le démontage doivent être effectués par un adulte.
- Must be assembled and disassembled by an adult.
- Der zusammenbau und das auseinandernehmen muß von einem erwachsenen durchgeführt werden.
- Het monteren en demonteren moet door een volwassene gedaan worden.
- Il montaggio e lo smontaggio vanno effettuati da un adulto.
- El montaje y el desmontaje debe realizarlo un adulto.
- A montagem e a desmontagem devem ser efectuadas por um adulto.

AAP 0780 A

A		1
B		1
C		2
D		2
E		2
F		1
G		1
H		1
J		1
K		1
L		1
M		2
N		1
P		1
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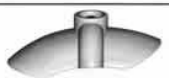
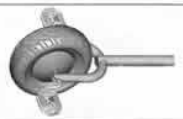
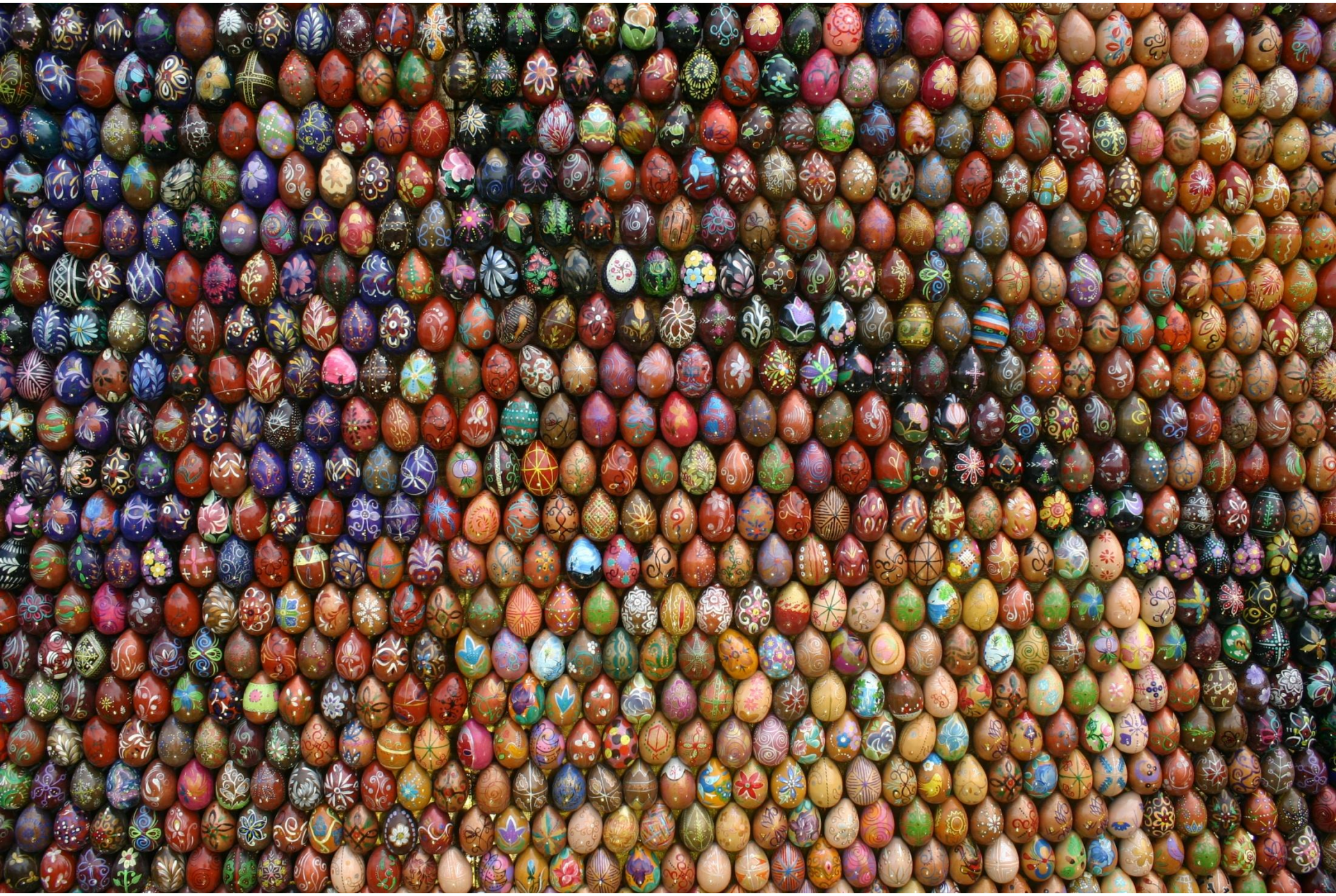
R		1

S			1
T			1
U			1
V			1
W			1
Y			1
Z		4,5 x 40	2
AA		8 x 60	1
BB		M8	1
CC		4,5 x 16	3
DD		3,5 x 15	1
EE			1
FF			1



Seeing the framework in the material can make learning easier and more effective.

Build BOTH

Factual knowledge

Conceptual framework

Implications for Teaching

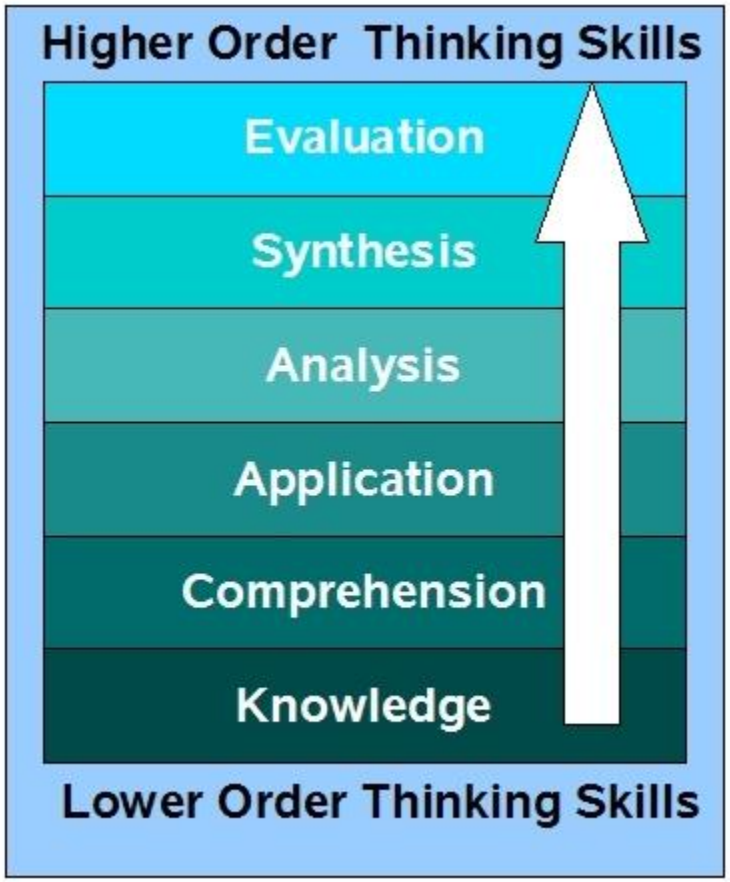
Being an expert in a topic ***does not*** imply that one will also be effective in teaching that topic. Expertise in teaching that topic is also needed (pedagogical content knowledge)

Teaching the content of a discipline without helping learners to organize that content is not optimal.

Procedures and equations used to solve problems in science & math are important but also important are the underlying principles and concepts of those equations and how and where they can be applied.

Focus on Learning vs. Teaching

Bloom's Taxonomy
A Tool for Classifying Cognition

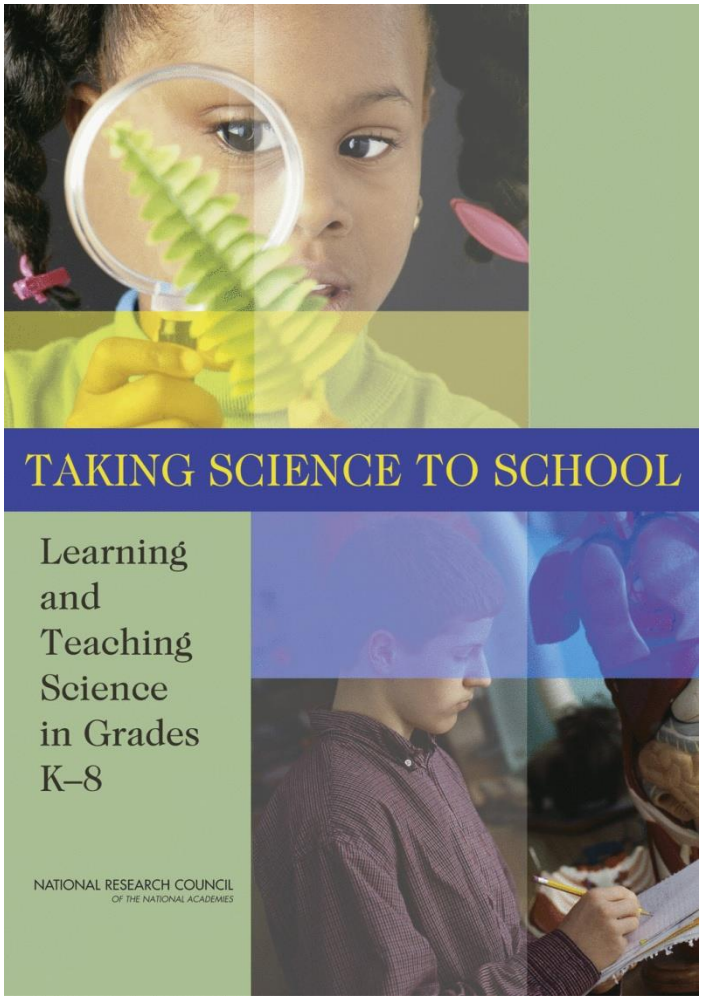


Higher order cognitive skills (HOCS)

Lower order cognitive skills (LOCS)

4 Strands of Scientific Proficiency

- Know, use and interpret scientific explanations of the natural world.
- Generate and evaluate scientific evidence and explanations.
- Understand the nature and development of scientific knowledge.
- Participate productively in scientific practices and discourse.



National Research Council (2007)

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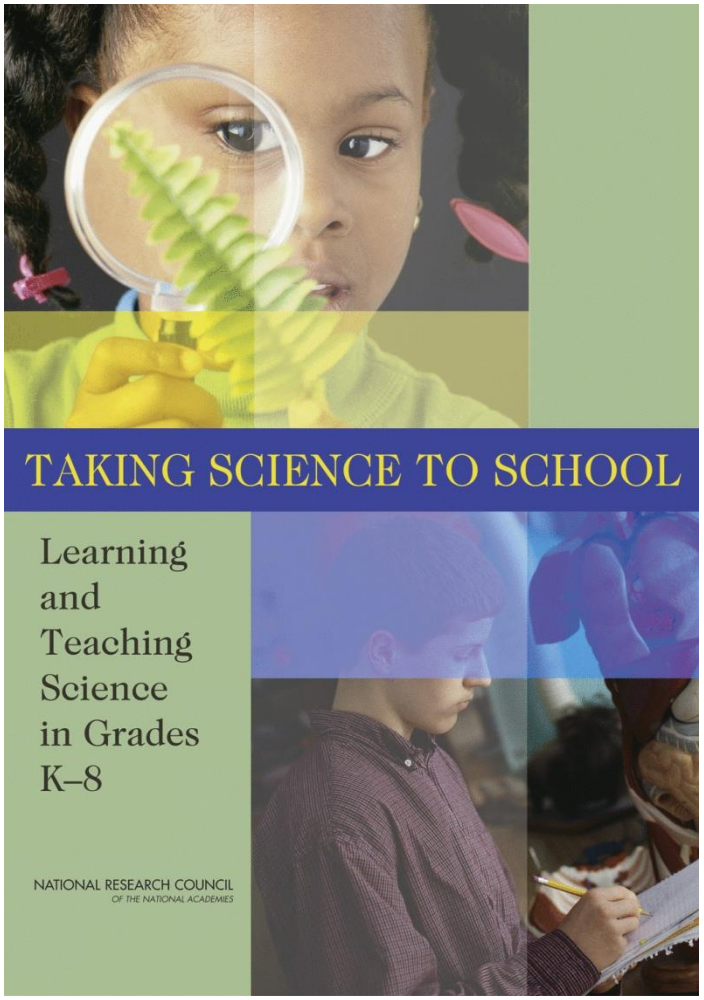


National Research Council (2007)

Transfer of Knowledge

EXAMPLE:

A general wishes to capture a fortress in the center of a country. There are many roads radiating outward from the fortress. All roads have been mined so that while small groups of soldiers can pass over the roads safely, a large force will detonate the mines. A full-scale direct attack is therefore impossible. The general's solution is to divide the army into small groups, send each to the head of a different road, and have the groups converge simultaneously on the fortress.

(Modified from How People Learn)

You are a doctor faced with a patient who has a malignant tumor in the stomach. It is impossible to operate on the patient, but unless the tumor is destroyed, the patient will die. There is a kind of ray that may be used to destroy the tumor. If the rays reach the tumor all at once and with sufficient high intensity, the tumor will be destroyed, but surrounding tissue may be damaged as well. At lower intensities, the rays are harmless to healthy tissue, but they will not affect the tumor either. **What type of procedure might be used to destroy the tumor with the rays, and at the same time avoid destroying the healthy tissue?**

Few college students could solve the second problem on their own. When told to use information from first, >90% were able to solve it.

The more that one knows about a topic, the easier it is to learn more about that topic.

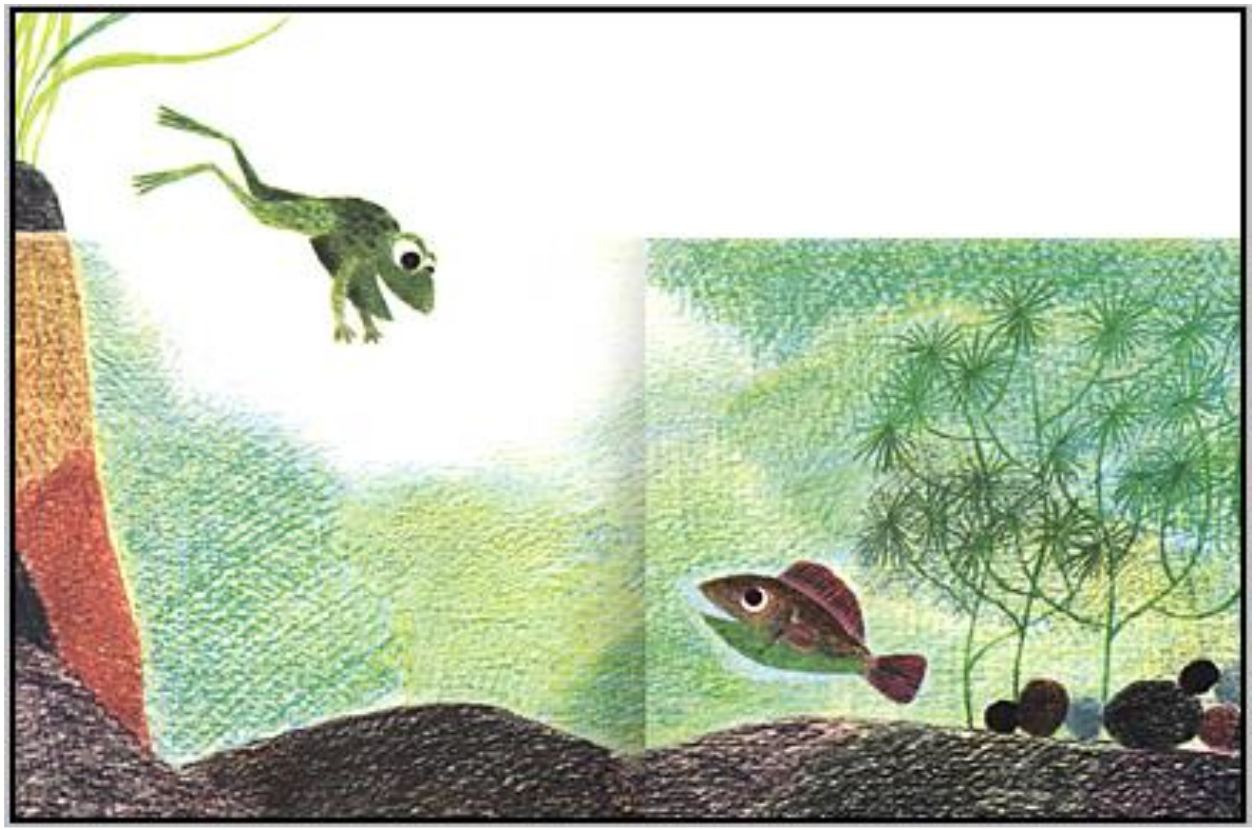
Transfer can be facilitated by knowing the multiple contexts under which an idea applies (rote learning rarely transfers.)

However, expertise in one area **does not** necessarily transfer to other areas.

Transfer of Learning and Previous Learning: Conceptions/Misconceptions/Preconceptions

New learning depends on previous learning and previous learning often interferes with what an instructor may be trying to teach (pre- or misconceptions).

Lionni’s Fish is Fish



The Fish's Image of Birds

The Fish's Image of Cows

The Fish's Image of People

Analogs to the Fish is Fish Story:

Young children who believe the earth is flat….

Physics students who assume “force of the hand” when a ball is thrown into the air

Biology students who believe that evolution occurred in the past but is not occurring now

Peoples’ beliefs about seasons -- distance from sun not tilt

METACOGNITION

"Metacognition refers to people's abilities to predict their performances on various tasks… and to monitor their current levels of mastery and understanding." (*How People Learn, Volume 1,* page 12)

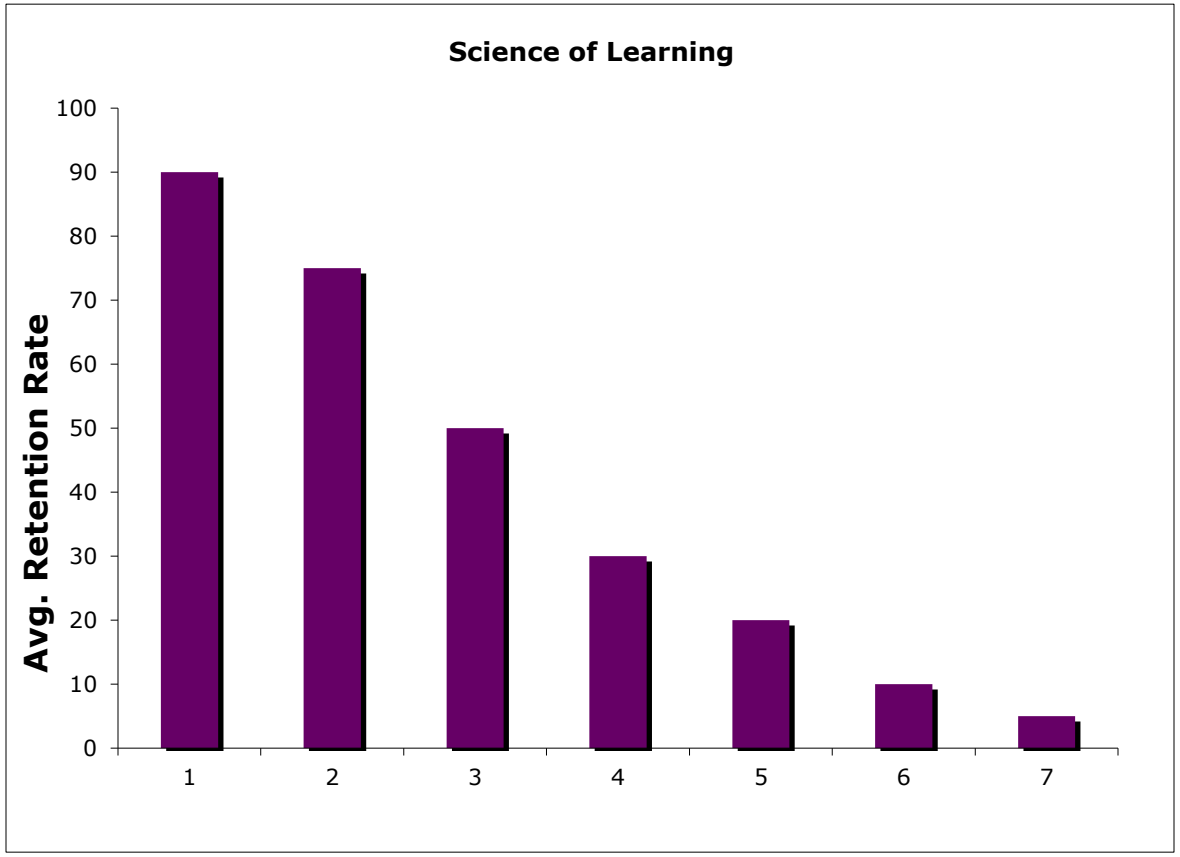
Transfer of learning can be facilitated by people become more aware of themselves as learners and who learn to monitor their own learning and performance strategies.

They need to be provided with opportunities to practice problem solving, and ongoing feedback and support to monitor progress in learning (i.e., formative assessments).

Applying the Science of Learning to the Real World

Practical Implications for Learners During and Following Formal Education

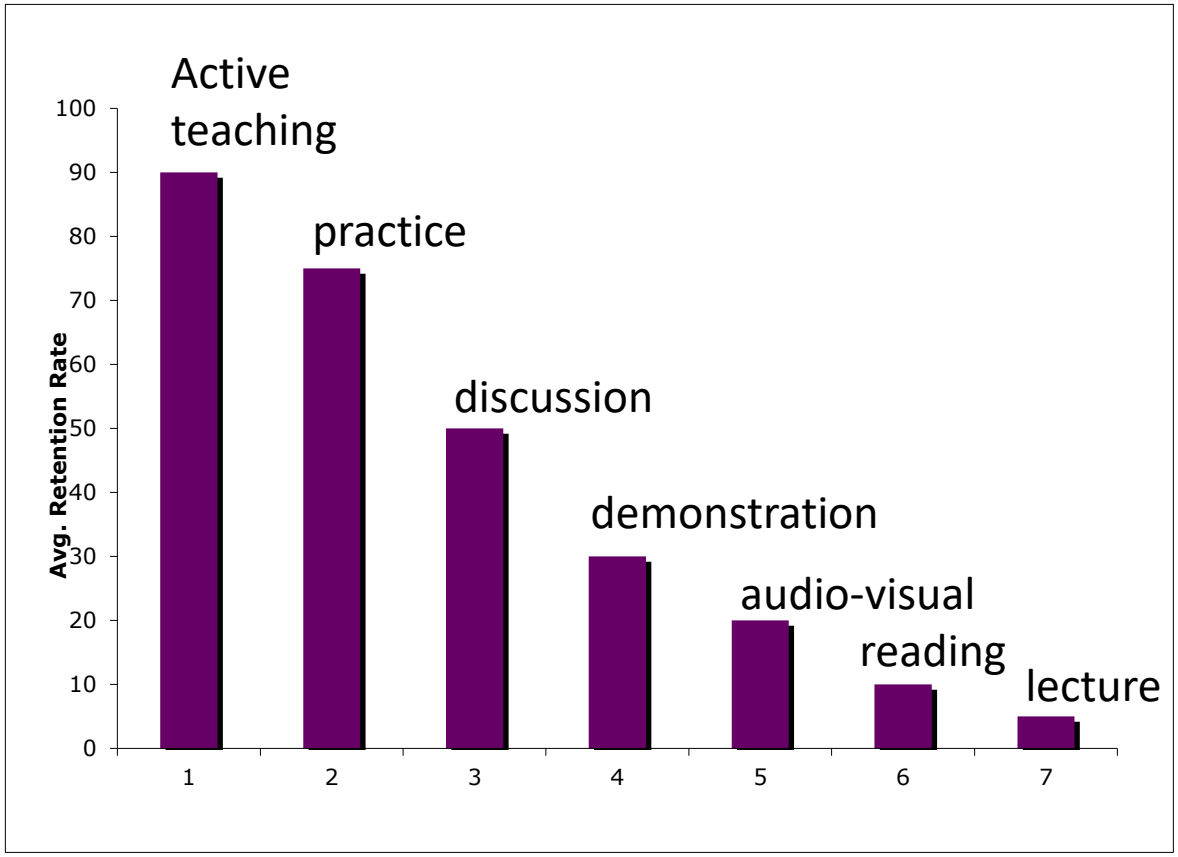
Science of Learning



- Audio-visual
- Demonstration
- Discussion
- Lecture
- Practice
- Reading
- Active Teaching

Source: Tokuhama-Espinosa, T. 2009. *The New Science of Teaching and Learning: Using the Best of Mind, Brain, and Education Science in the Classroom.* Teachers College Press

Science of Learning



- **Audio-visual**
- **Demonstration**
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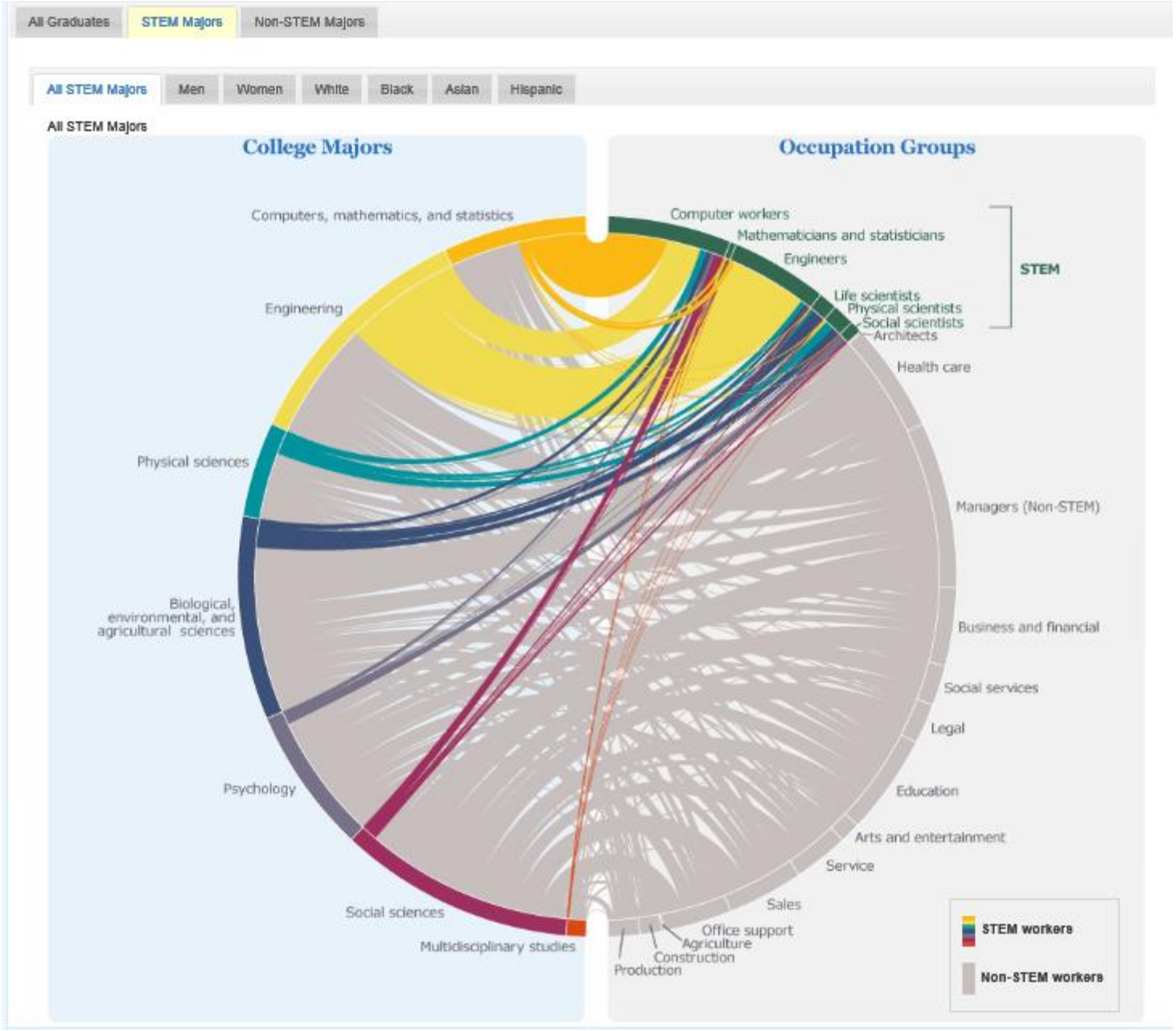
- **Practice**
- **Reading**
- **Active Teaching**

Source: Tokuhama-Espinosa, T. 2009. *The New Science of Teaching and Learning: Using the Best of Mind, Brain, and Education Science in the Classroom.* Teachers College Press

A Shifting Job Market

	20th Century	21st Century
Number of Jobs:	1 – 2 Jobs	10 – 15 Jobs
Job Requirement:	Mastery of One Field	Critical Thinking Across Disciplines
Teaching Model:	Subject Matter Mastery	Integration of 21st Century Skills into Subject Matter Mastery
Assessment Model:	Subject Matter Mastery	Integration of 21st Century Skills into Subject Matter Mastery

Courtesy of Linda Froschauer



https://www.census.gov/dataviz/visualizations/stem/stem-html/

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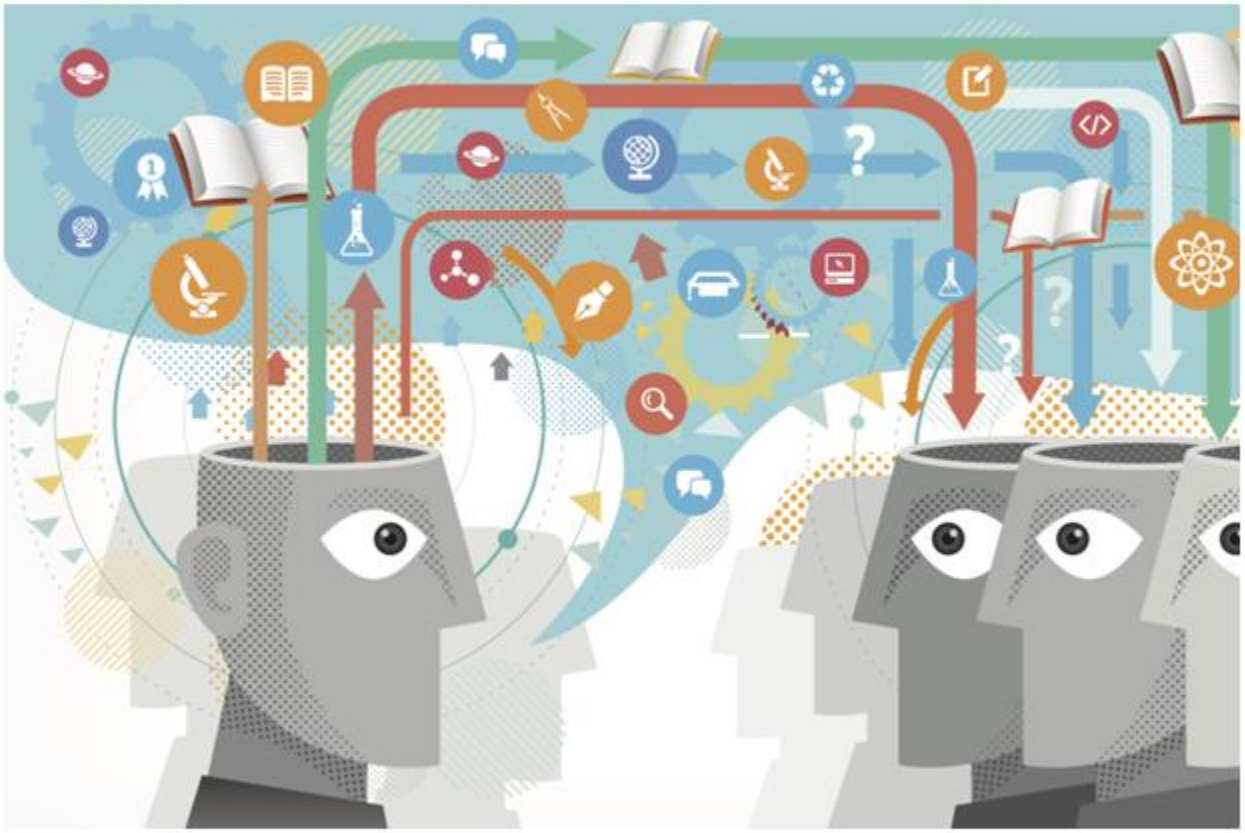
Courtesy of Linda Froschauer

VIRTUAL EVENTS: TUNE IN LIVE

CURRICULUM REFORM

Curricula for the Future



UPCOMING: June 15 | 2 p.m. ET: The skills required to succeed in the job market are constantly evolving. In this forum, experts will discuss what colleges can do to prepare their students for future employment. *With Support From USF.* **Register here.**

From the daily Table of Contents of the *Chronicle of Higher Education* June 14, 2022

Instead of beginning (and, all too often, ending) with test scores, we should begin by considering the kinds of minds that we want to cultivate in our education system.

My own reflections suggest that in the future, we need to cultivate five kinds of minds if we want to be successful as a nation and, more important, as a world. Those minds include:

Howard Gardner, "Beyond the Herd Mentality: The Minds That We Truly Need in the Future." *Ed Week, 9/14/05,* http://www.edweek.org/ew/articles/2005/09/14/03gardner.h25.html

- **A disciplined mind,**

  that can think well and appropriately in the major disciplines;

- **A synthesizing mind,**

  that can sift through a large amount of information, decide what is important, and put it together in ways that make sense for oneself and for others;

- **A creative mind,**

  that can raise new questions, come up with novel solutions, think outside the box;

- **A respectful mind,**

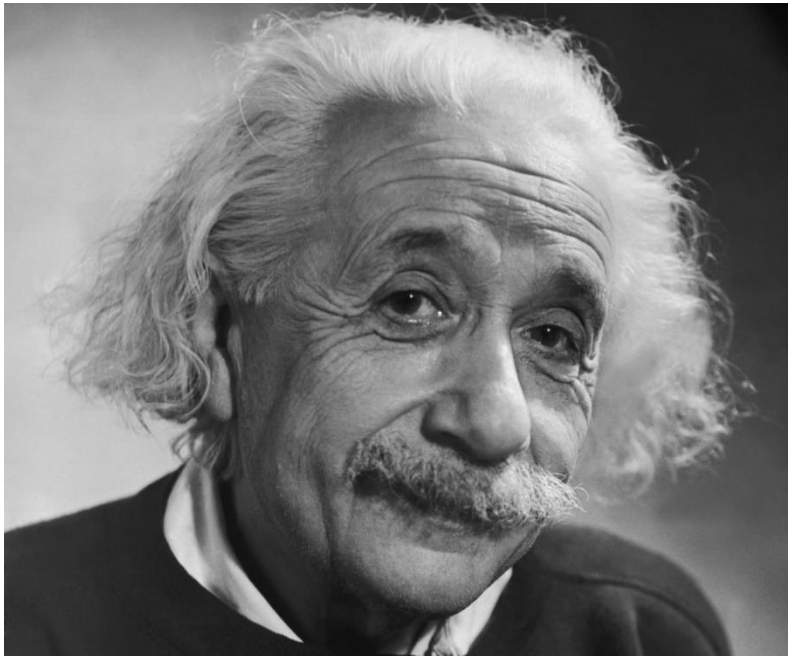
  that honors the differences among individuals and groups, and tries to understand them and work productively with them; and

- **An ethical mind,**

  that thinks, beyond selfish interests, about the kind of worker one aspires to be, and the kind of citizen that one should be.

Howard Gardner, "Beyond the Herd Mentality: The Minds That We Truly Need in the Future."
Ed Week, 9/14/05, *http://www.edweek.org/ew/articles/2005/09/14/03gardner.h25.html*

In Closing:



"The only thing that interferes with my learning is my education."

"Education is what remains after one has forgotten everything he learned in school."

Albert Einstein

Thank you!

Applying these Principles to Teaching and Learning in the Classroom: Backward Design

Standard course planning

Choose textbook

⇓

Create syllabus

⇓

Write/revise lectures, notes

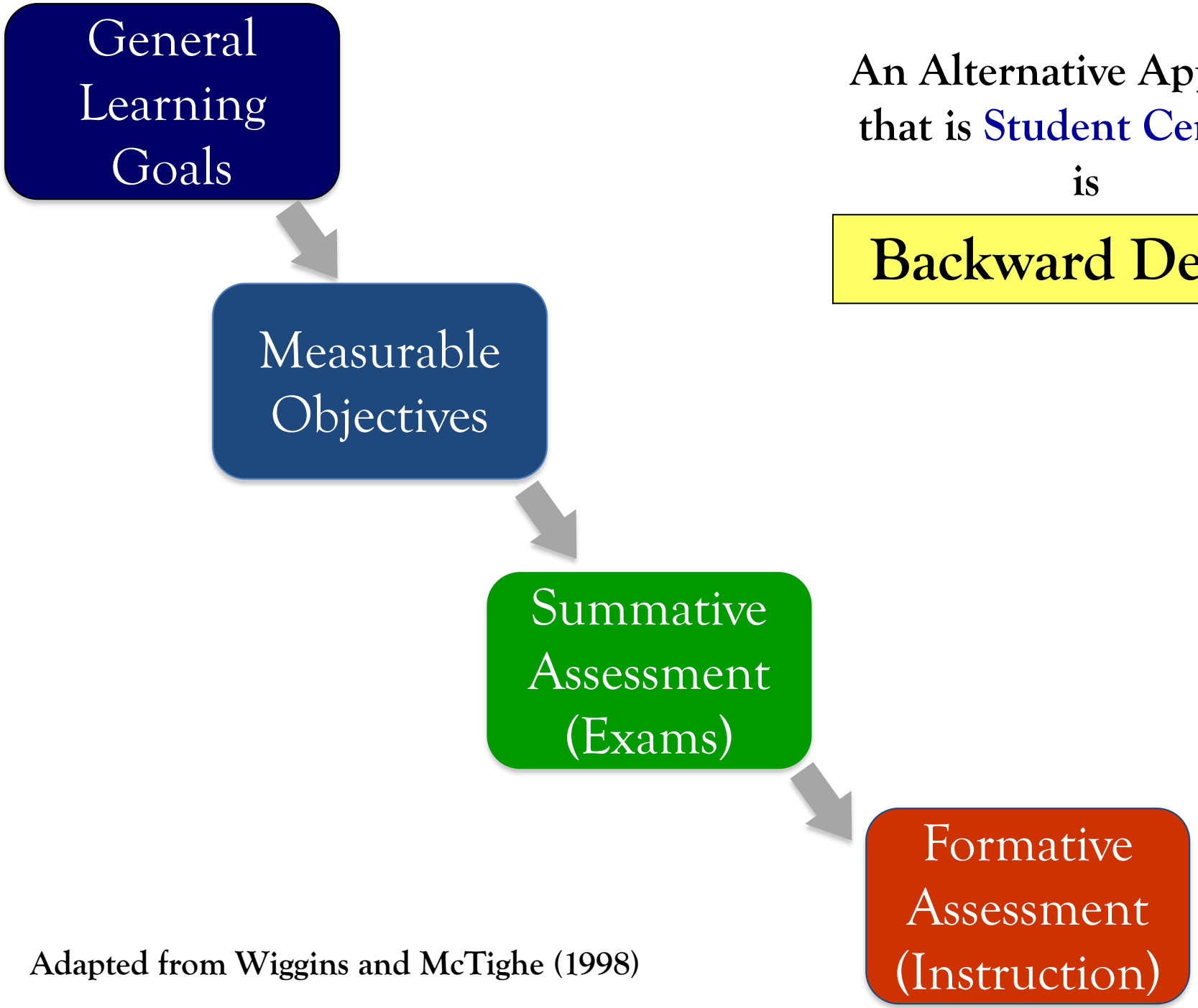
⇓

Prepare PowerPoint /lecture presentations

⇓

Write exams

Instructor-centered



An Alternative Approach that is Student Centered is

Backward Design

Adapted from Wiggins and McTighe (1998)

Goals Which Are Usually Not Measurable

“Understand”

“Appreciate”

“Think Critically”

Objectives Which Are Measurable

“Use”

“Graph”

“Design”