ICAP: A Framework for Differentiating Levels of Cognitive Engagement in “Active Learning”

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"Active Learning" is a very broad term that refers to students "constructing" their own understanding (p. 10), to students monitor their own learning (p. 12) such as setting & revising goals & plan (referred to as "active" learners, p. 68), to students working "interactively" with teachers, learning systems, and each other (p.170, Bransford, Brown,Cocking, How People Learn), in contrast to "passive learning."

- In short, "Active Learning" refers to students actively doing something about learning.
- But we (including teachers who want to encourage "active learning") cannot differentiate precisely what the terms "passive", "active", "constructive" and "interactive" mean. What activities do they entail?
- We propose a framework that defines and differentiates "active learning" strictly from the *perspective of the learners,* irrespective of the type or style of the instructional interventions.
- From this *learner's perspective,* we can interpret many results based on what the learners do.
- We refer to what "active learners" do with learning materials as *engagement.*

What is Engagement?

- The literature uses “engagement” broadly to mean attending to or having interaction with the learning materials.
- There is also a specific literature on “engagement” that defines it mostly in motivational terms: 3 types
  - Behavioral Engagement: Following rules, avoid disruptive behaviors such as skipping classes.
  - Emotional Engagement: Surveys of liking teachers, etc.
  - Cognitive Engagement: Using constructs such as investment or commitment to learning, learning goals, preference for challenge, positive coping in the face of failures [similar to constructs in the motivation literature]
- The learning literature defines cognitive engagement as being strategic and self-regulating, using metacognitive strategies to plan, monitor, evaluate own cognition (Pintrich & De Groot, 1990; Zimmerman, 1990).
- Thus, “cognitive engagement” is used synonymously with the term “Active learning.” Both terms are not well-defined.

What is a Cognitive Engagement Activity?

(Chi, 2009, *Topics in Cognitive Science*)

- We postulate that “cognitive engagement” or “active learning” can be defined in terms of the activities undertaken by learners in the service of learning.
- Moreover, we define these engagement activities in terms of the overt behaviors displayed by students.
- We assume that overt behaviors might be a good enough proxy for covert cognitive processes. However, we are NOT saying that you must display these overt activities in order to process it covertly.
- And these overt behaviors engage students to a different degree or levels.
- This definition is completely *Learner-Centered,* independent of instructional method, and domain-general.

We can discriminate 4 modes of overt engagement activities.

Students can engage in any activity with any instructional/learning task.

"Mode" to refer to the engagement activity, "level" refer to the consequence of the activity on learning.

Four Modes of Overt Engagement Activities

Instructional or Learning Tasks	**PASSIVE** *Receiving*	**ACTIVE** *Manipulating*	**CONSTRUCTIVE** *Generating*	**INTERACTIVE** *Dialoguing*
LISTENING to a lecture				
READING a text				
OBSERVING/ STUDYING an example being worked-out at the whiteboard				

Our conceptual framework of engagement activities consists of:

Operationalizing the observable *external behaviors*
(Identify with some characteristic behavior)

Postulating the underlying *cognitive processes*
for each model of engagement activity

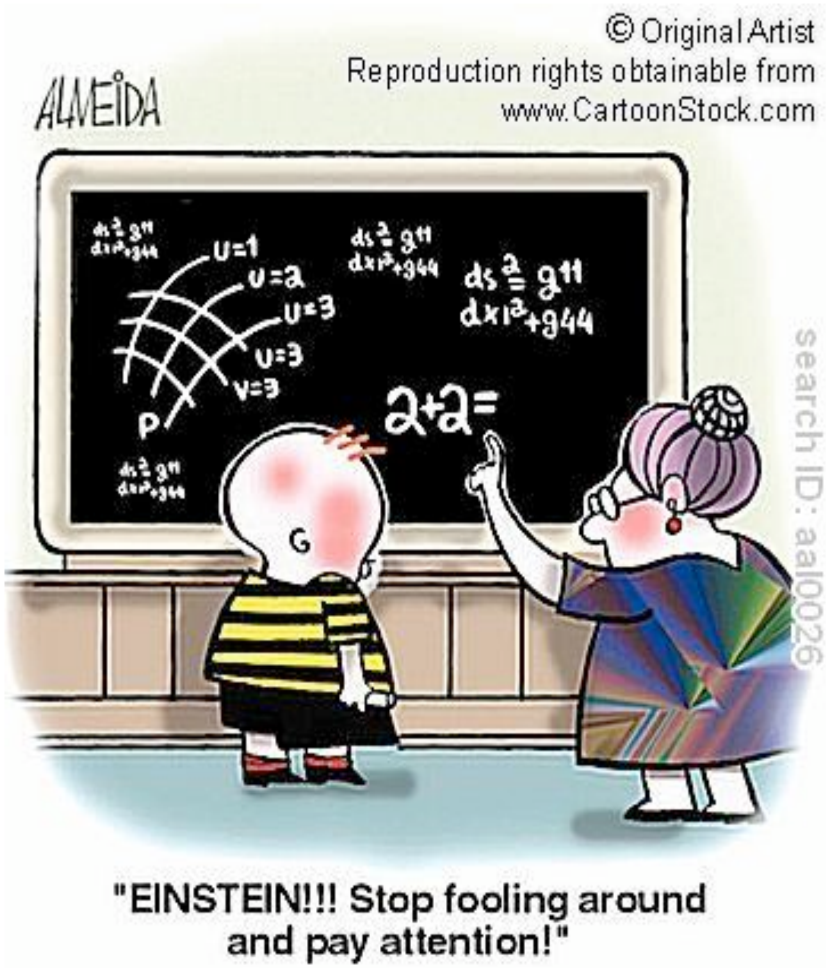
Formulating a *hypothesis*
about the level/degree of
learning for each mode

Presenting supporting evidence

Passive: We define the observable behavior of *Passive* to be when students are *oriented toward* or *receiving* instruction (this is what can be considered as “paying attention”).
But they are not doing anything else overtly.

Examples:

- Listening to a lecture without taking notes
- Watching a video or observing a demonstration
- Studying a worked example
- Reading silently



Laypersons think *paying attention* is engaging "actively".

In our framework, "paying attention" is only *passive* because the student is only oriented toward and receiving instruction.

However, it is possible that the student is doing more than *receiving*. But they are **more likely** to only passively receive information.

What is *Not Paying Attention?* Zoning out *Not Paying Attention* and is less than *Passive.*

Active: We define *active engagement* as when students are doing something with their hands (or bodies) with the materials

Examples:

- Copying the solution from the board
- Underlining the important sentences
- Manipulating or measuring test tubes
- Pointing
- Rehearsing or repeating definitions

Constructive: Students are *constructively engaged* when they *generate* some information beyond what was presented in the learning materials

<u>Examples:</u>

- Drawing a concept map or a diagram;
- Self-explaining or elaborating text sentences or solution lines in an example
- Posing questions
- Providing justifications
- Forming hypotheses
- Comparing-&-contrasting

Interactive: will be restricted for now to refer to two or more students engaging with each other through dialog [you can interact with a system]

Examples:

- Explaining jointly with a peer
- Building on each other's contributions in a WIKI way
- Arguing with a peer (requesting & providing justification)
- Reciprocally teaching a peer and responding to a peer's questions
- Discussing a joint product (concept map) with a peer

(Interaction does not have to be via dialog; but dialog is rich and more studies use dialogs as a medium of interaction. One study passes mouse back-and-forth.)

Examples of different overt engagement activities that can be undertaken for each instructional/learning task

(Chi, 2009; Fonseca & Chi, in press).

Overt Engagement Activities

Instructional Tasks for Learning

(Characteristics)	**PASSIVE** *(Receiving)*	**ACTIVE** *(Manipulating)*	**CONSTRUCTIVE** *(Generating)*	**INTERACTIVE** *(Dialoguing)*
LISTENING to a lecture	Just listening without doing anything else	Repeating or rehearsing Describing a presented diagram Taking verbatim notes	Reflecting out-loud Drawing concept maps Asking questions	Showing and discussing map reciprocally Asking-and-answering teacher's questions
READING a text	Just reading without doing anything else	Underlining or highlighting Reading out-loud Summarizing by delete	Self-explaining Questioning-the-Author Generating tables	Elaborating and building on each other's contrib Challenging each other's generated tables
STUDYING an example being worked-out at the whiteboard	Just watching the blackboard without doing anything else	Copying equations Pointing or gesturing at a diagram Predicting an outcome based on prior K or guessing	Drawing free-body diagrams Providing justifications Comparing & contrasting two examples	Arguing with a peer about the justifications Discussing similarities & differences

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(Chi, 2009; Fonseca & Chi, in press).

Overt Engagement Activities

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SE is a type of generative activity you engage in while learning . It is not "constructiv" in the sense that you can "invent" a theorem in a vacuum.

The possible cognitive processes and learning outcomes for *Passive, Active, Constructive*, and *Interactive* Engagement Activities.

(Characteristics)	PASSIVE *(Receiving)*	ACTIVE *(Manipulating)*	CONSTRUCTIVE *(Generating)*	INTERACTIVE *(Dialoguing)*
Examples of overt engagement activities	Listening to explanations;	Taking verbatim note; Highlight sentences	Self-explaining Asking questions	Asking and answering each other's questions
Possible underlying cognitive processes	"Attending" processes in which information is stored episodically in encapsulated form without embedding it in a relevant schema, b/c you are not integrating	"Gap-filling" processes in which the manipulated materials are emphasized and activate prior knowledge & schema (strengthen old knowledge), & new information can be assimilated into activated schema.	"Generating" processes include: integrating new with prior knowledge, elaborating, connecting, comparing & contrasting, analogizing, generalizing, inducing, reflecting on conditions of a procedure, explaining why something works.	"Mutually generative" processes involve both partners mutually undertaking "generating processes." This mutuality further benefits from opportunities & processes to incorporate feedback, to entertain new ideas, to re-direct search, etc.
Expected cognitive outcomes	Inert knowledge, cannot recall without proper context. Can recall information in a verbatim way	Schema is more complete and strengthened; Can retrieve more easily & recall meaningfully; Can solve similar problems	New inferences are generated, or existing mental models are repaired, analogies can be formed. Procedures have meaning, rationale and justifications.	New knowledge and perspectives can emerge from co-construction that neither partner knew.
Expected learning outcomes	Minimal understanding	Shallow understanding	Deeper understanding that might transfer	Understanding that might innovate novel ideas

The expected cognitive outcomes for each mode of engagement activities translate to different expected learning outcomes

(Characteristics)	**PASSIVE** *(Oriented, Receiving)*	**ACTIVE** *(Manipulating, Emphasizing)*	**CONSTRUCTIVE** *(Generating)*	**INTERACTIVE** *(Dialoguing)*
Examples of overt engagement activities	Listening to explanations;	Taking verbatim note; Highlight sentences	Self-explaining Asking questions	Asking and answering each other's questions
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Expected learning outcomes	Minimal understanding	Shallow understanding	Deeper understanding that might transfer	Understanding that might innovate novel ideas

Caveats

- We propose that "cognitive engagement" or "active learning" can be defined in terms of the **overt activities** displayed by students while learning.
- We assume that overt behaviors might be a good enough proxy for covert cognitive processes, and easy for teachers to assess how engaged students are.
- However, we are NOT saying that you must display these overt activities in order to process materials actively.
- We are only saying that you are **more likely** to reflect a certain level of engagement as a function of the overt activities you display.

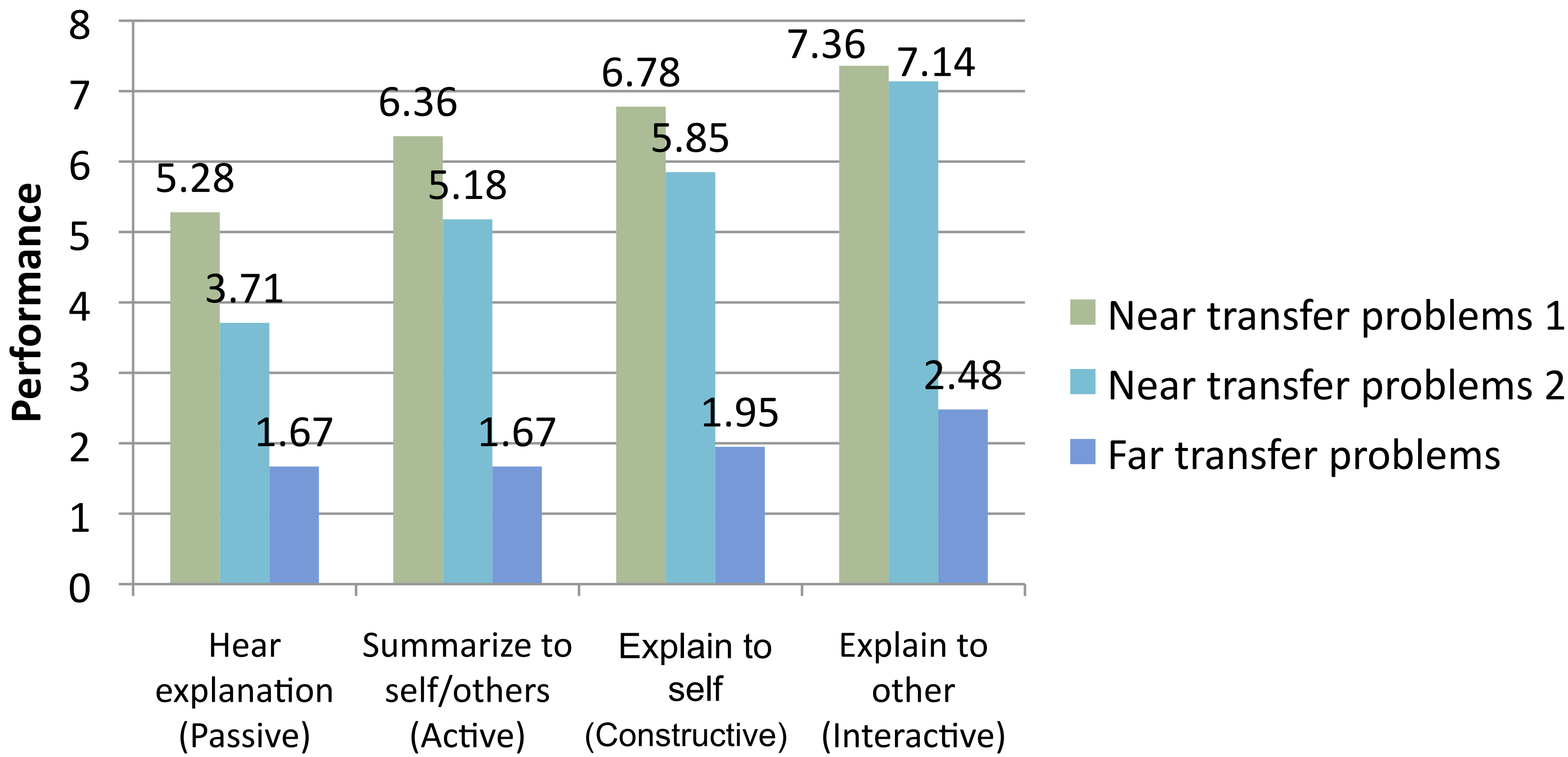
The Cognitive Processes of Different Engagement Activities

- The cognitive processes of engagement activities are not exactly the same as the cognitive processes of the learning tasks such as reading, listening.
- E.g. cognitive processes of reading includes decoding, mapping between phonemes & graphemes,
- While the cogn processes of the engagement activities are relatively comparable or the same for a variety of activities within each mode, but different across modes of activities.
- E.g. whether you are underlying a sentence or repeating a sentence (for the *active* mode), you are essentially *activating and strengthening prior knowledge and assimilating new knowledge with activated knowledge.*
- but cognitive process of the *active* mode is different from the cognitive processes of the *constructive* mode (e.g. generating new inferences).
- Cogn processes of each higher level subsume the lower level: That is, the processes of generating new information (*constructive* mode) subsumes the processes of activating the relevant information (*active* mode).

The expected learning outcomes, as a function of the postulated cognitive processes, predict that learning is best most of the time for INTERACTIVE, followed by CONSTRUCTIVE, followed by ACTIVE, followed by PASSIVE: ICAP Hypothesis

ICAP HYPOTHESIS	**PASSIVE** *(Receiving)*	<	**ACTIVE** *(Manipulating, Emphasizing)*	<	**CONSTRUCTIVE** *(Generating)*	≤	**INTERACTING Constructively** *(Dialoguing)*
Expected cognitive learning outcomes	Inert knowledge, cannot recall without proper context. Can recall information in a verbatim way		Schema is more complete and strengthened; Can retrieve more easily & recall meaningfully; Can solve similar problems		New inference are generated, or existing mental models are repaired, analogies can be formed, allowing deeper understanding. Procedures generalized, allowing for transfer		New knowledge and perspectives can emerge from co-creating that neither partner knew. "Guided-creating" can enhance learning from corrective & guided feedback
Expected learning outcomes	Minimal or Shallow understanding		Shallow understanding		Deeper understanding that might transfer		Understanding that might innovate novel ideas

Is there any evidence that the ICAP hypothesis is supported across 4 modes?

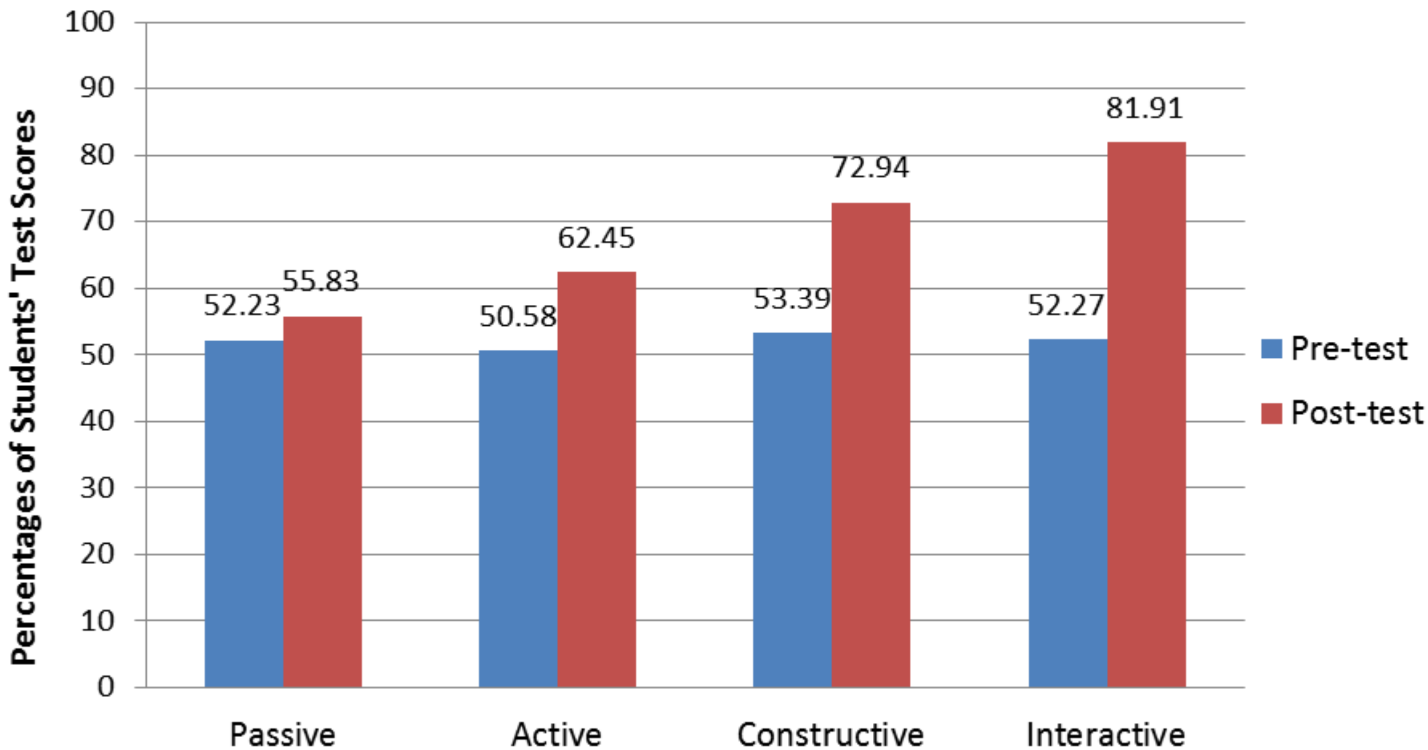


(3-person groups taking turns at hearing, summarizing, explaining: Table 3 from Coleman, Brown & Rivkin, 1997, re-ploted to conform to the 4 modes)

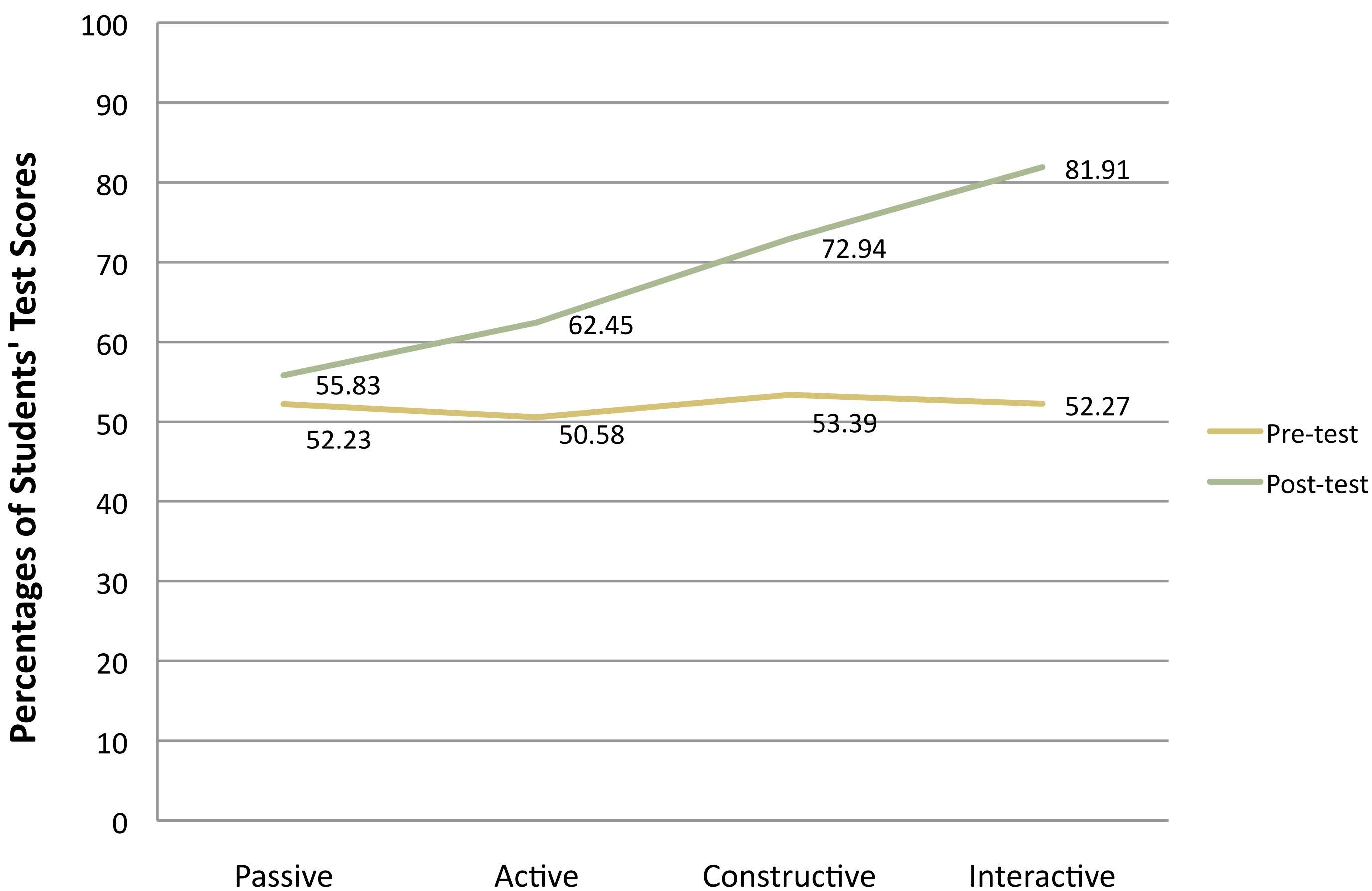
Our own evidence that the ICAP hypothesis is supported across 4 modes:

- In the domain of engineering
- 4 types of activities were designed
- Everyone read the the text, took pre-test
- Passive: Read out-loud
- Active: Read + Highlight sentences
- Constructive: Given 4 figures & construct explanations for the figures, relations between Metal A, Metal B, Metal C. Explain your selections
- Interactive: Do it together in dyads

A variation of the Materials Engineering tasks run across 4 activities modes



Re-plot of Muhsin's results: about 7-10% improvement from level to level



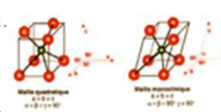
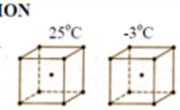
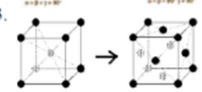
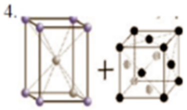
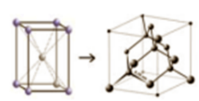
It is also easy to "upgrade" a homework task from one mode to another

- We have done similar studies in an engineering classroom where we helped the instructor upgrade his homework and seatwork assignments.
- See next 2 slides for examples.

Selection *(Active)* task in Atomic Bonding

Concept Learning in Context: Materials Science of Unit Cell Disasters

Occurrence (Object)	Property & Change	Unit Cell Transformation	Condition for Change	Original Processing Method
Napoleon's failed winter invasion of Russia 1812 (tin button)	______	______	______	______
The World Trade Center 9/11 (steel girders)	______	______	______	______
The Titanic sank (steel rivets)	______	______	______	______
Helicopter Crash (steel gear)	______	______	______	______
Grandma's hip joint failed (ceramic ball cracked)	______	______	______	______

PROPERTIES & CHANGE	UNIT CELL TRANSFORMATION	CONDITION FOR CHANGE	PROCESSING
I. steel BCC to FCC higher temp	1. 	A. 120°C sterilization phase change	a. sintered
II. BCC loses ductility at low temp	2. 	B. incomplete phase transform	b. forged
III. ductile BCT (body center tetragonal) metal transforms to brittle powder with diamond cubic unit cell	3. 	C. loses strength above 730C	c. cast
IV. cracks form in BCT ceramic when it transforms to body center monoclinic	4. 	D. iceberg cold environment	d. machine & heat treat
V. soft FCC phase is retained in hardened steel phase (BCT)	5. 	E. temp falls below 13°C	e. hot rolled in steel mill

Constructive Version






	Occurrence (Object)	Condition for Change
A	Napoleon's failed winter invasion of Russia 1812 (tin button)	temp falls below 13°C
B	The World Trade Center 9/11 (steel girders)	loses strength above 730C
C	The Titanic sank (steel rivets)	iceberg cold environment
D	Helicopter Crash (steel gear)	incomplete phase transform
E	Grandma's hip joint failed (ceramic ball cracked)	120°C sterilization phase change

Based on the given information above: (1) State and explain properties and change of crystal structures; (2) Draw unit cell transformation; (3) State and explain original processing method for each object.

OBJECT	PROPERTIES & CHANGE	UNIT CELL TRANSFORMATION	ORIGINAL PROCESSING METHOD
A			
B			
C			
D			
E			

Many more studies that present pair-wise comparisons and ICAP's predictions (diagonal cells predict equivalence)

	Passive	Active	Cnstrctive	Interactive
Passive	=			
Active	>	=		
Cnstructv	>	>	=	
Interactive	>	>	≥	=

Evidence will be presented for laboratory studies (with learning and other outcome measures) as well as classroom studies

	Passive	Active	Cnstrctive	Interactive
Passive	=			
Active	>	=		
Cnstructv	>	>	=	
Interactive	>	>	≥	=

How I analyzed and re-interpreted a study (example 1): A study comparing Traditional vs. Guided Cognition Homework for *Macbeth,* Act IV

Traditional (T)

[Ask students to answer recall questions:]

What apparitions do the witches show Macbeth?

Recall of pre-stored knowledge: *Active*

Guided Cognition (GC)
(Visualize & illustrate)

[Ask students to visualize and illustrate:]

Close your eyes and imagine the scene between Macbeth and the witches. Draw a simple diagram of their positions, and devise a way to list the apparitions as part of the diagram.

Draw diagram & Devise a list: *Constructive*

Example of Guided Cognition In-Class Homework

(Basically asking students to Relate it to prior experience)

Part A

- Bernie has $22\frac{3}{4}$ pounds of dog food.
- If his dog eats $1\frac{3}{4}$ pounds of dog food each day, how many days will this supply of dog food last?
- Solve this problem.
- Remember to show all of your work.

Part B

- Tell about a situation like Bernie's that you have experienced, read about, or can imagine, where knowing how to divide mixed numbers could help you determine how long some supplies will last.
- Circle the mixed numbers in your example, (but do not work the problem).

Results for both Math and Stories: they claim transfer (Rabinowitz)

- Analysis of In-Class Homework condition (T *vs.* GC) by Review Activity problem type (Numerical *vs.* Story) revealed:
  - main effect of condition, GC>T
  - main effect of problem type, Numerical>Story
  - no interaction

	Passive <	Constructive	
	T	GC	GC>T
Numerical Problems	81.12%	88.41%	7.29%
Story Problems	44.48%	53.59%	9.11%

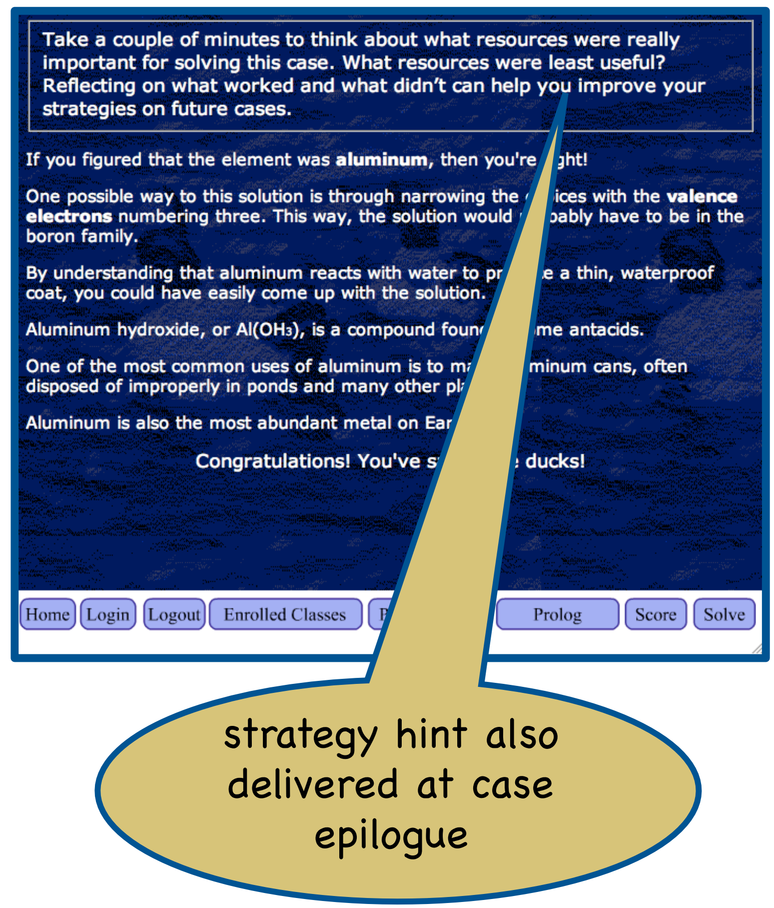
Notice that 8-10% improvement is about the same as what Muhsin found from Engagement Level to Engagement Level.

They would conclude that a specific intervention such as Guided Cognition is effective, in fact effective across 2 domains, so presumably generalizable, whereas our framework would interprete the results merely as showing that *constructive* is better than *active,* and that there is nothing speical about Guided Cognition as they defined it.

How I analyzed and re-interpreted a study (example 2):

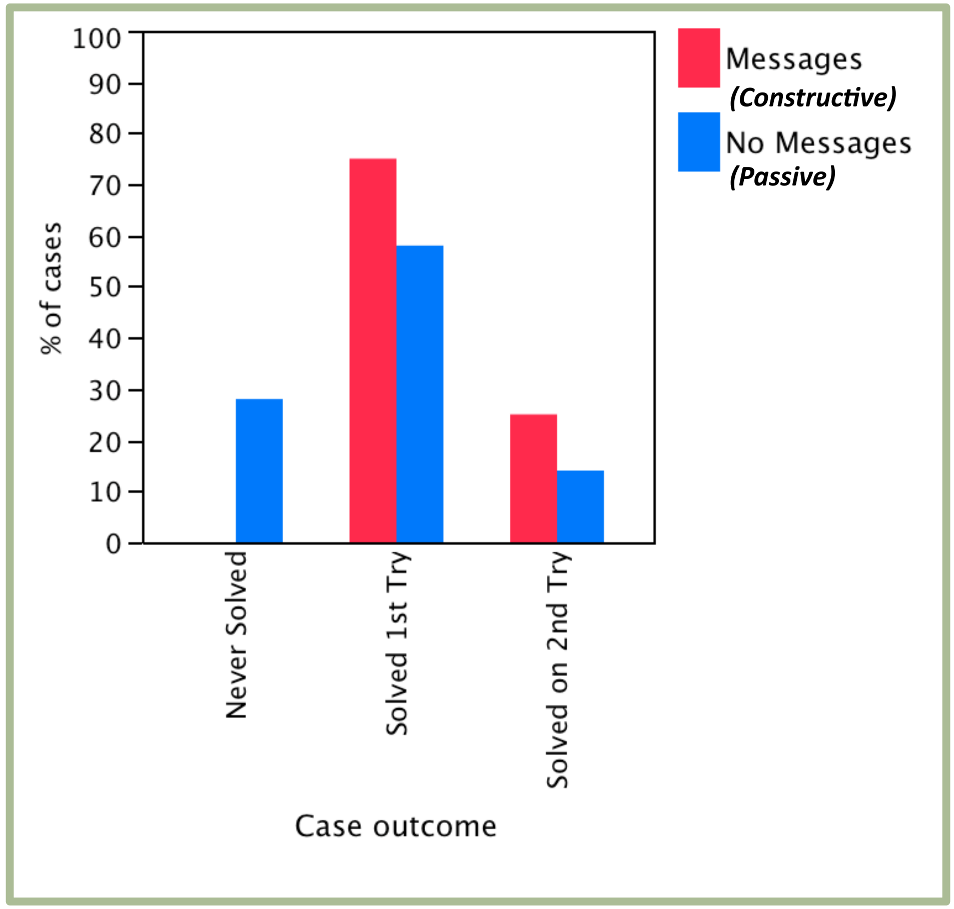
Strategy intervention (Carole Beal & Ronald Stevens)

- Epilogues encourage self-reflection & strategy review:
  - e.g., "Look at your notes for this case. Are they organized? Can you see the path you took to get to your answer? If not, can you think of [GENERATE] one or two ways of making them more organized? (If you didn't take notes, take them – it will help!)"
- Epilogues also target motivational issues in problem solving:
  - e.g., "Sometimes students get discouraged by this case. If you solved it, that's great! If you didn't, don't be too hard on yourself. You can learn even when you don't get the right answer. Make failure work for you by figuring out what to do differently next time."



Results: Impact of message intervention

- More cases were correctly solved by students who viewed messages in Duck Run



They further showed the benefit of metacognitive guidance as compared to academic advice

- Earlier work indicated that message content is critical:
- *No* benefits for messages that provide generic academic advice
- [But these messages do not require any constructive outputs from the students, that's why no benefit]

"Successful students use a planner to keep track of notes and assignments"

"It's a good idea to keep up with your class reading. Don't let yourself get too far behind!"

Thus, Beal & Stevens would conclude that Metacogn Guidance is useful for enhancing Learning (above & beyond giving academic advice), but our framework interprets it merely as a contrast between *passive* (for academic advice) and *constructive* (for Metacogn Guide)

Using same method of reinterpreting results from the learner's perspective: Lots of evidence for Pair-wise comparisons of *laboratory studies* in support of ICAP

	Passive	Active	Constructive
Active	•Observing video with practice **>** Watch only (tying knots, Schwan & Riempp, 2004) •Rotating objects **>** Observing objects (James, et al., 2002) • Copying a concept map **>** Reading a concept map (Willerman & Mac Harg, 1991) •Retrieving information > Re-studying the same information [long-term retention; "testing effect" Karpicke & Roediger, 2008)	• Knowledge telling **=** summarizing (Voss & Wiley, 1996) • Studying physics text alone + solving **=** observing tutorial alone + solving (Chi, Roy, Hausmann, 2008)	
Constructive	•Building concept maps **>** Reading a text (Amer, 1994; Chang, Sung, & Chen, 2002) •Filling incomplete worked examples **>** Studying completed examples (Stark, 1999) •Fading example steps **>** Not fading (Atkinson, Renkl & Merrill, 2003)	•Placing objects with explanation **>** Placing objects only without explaining (Kastens & Liben, 2008) •Summarizing who-what **>** Reading out-loud (Mastroperi, et al., 2001) •Create links in concept maps > Select links (Yin, et al., 2005)	• Free form **=** semi-structured form (Trafton & Trickett, 2001) • Generating questions **=** generating concept maps (berry & Chew, 2008) • Summarizing in own words **=** generating questions (King, 1992)
Interactive	•Assemble a plant with an animated agent **>** No assemble (Moreno, et al., 2001) •Reciprocal tutoring **>** Studying alone (Chan & Chou, 1997)	• Peer tutoring **>** Filling out guided notes (Mastropieri, *et al.*, 2003) • Jigsaw group **>** Individuals gathering information (Doymus, 2008)	•Solve math problem with a peer **>** alone (Shirouzu, Miyake, Masukawa, 2002) •Taking notes collaboratively **>** Taking notes individually (Kam, et al., 2005) •Collaboratively creating maps **>** Individually creating maps (Okebukola & Jegede, 1988; Czerniak & Haney, 1998)

Evidence for Pair-wise comparisons of *classroom studies*

	Passive	**Active**	**Constructive**
Active			
Constructive	•Building concept maps **>** Whole class discussions (Chularut & DeBacker, 2004; Guastello, Beasley, & Sinatra, 2000)	• Questioning the author **>** Regular reading lessons (Beck, et al., 1996) •Meta-cognititve prompts + Search > Search (Beal & Stevens, 2010) •Compare + Contrast + Write + Solve > Solve (Ross, et al., 2010)	• Summarizing in own words **=** Generating questions (King, 1992)
Interactive	•Cooperative groups **>** Traditional lecture (Ebert-May, et al., 1997) •Discuss cause-effect relations **>** Observe teacher finding cause-effect relation (Hendricks, 2001) •Predict, Reason, Solve, Critique, S-S Discussion **>** Listen to lecture (Deslauriers, Schelew & Wineman, 2011) •	• Peer tutoring **>** Filling out guided notes (Mastropieri, *et al*., 2003) • Jigsaw group **>** Individuals gathering information (Doymus, 2008)	•Self-explaining **+** receiving feedback **>** Self-explaining without receiving feedback (Kramarski & Dudai, 2009)

ICAP: I ≥ C > A > P

- When is it true that: I > C, I = C, or can I < C, ?
  - Interaction involves 2 people: Sam and John.
  - Sam and John cannot both be *passive*, otherwise no interactions.
  - But Sam can be *passive* while John is *active* or *constructive* (P-A, P-C)
  - Likewise, Sam can be *active,* while John is *active* or *constructive* (A-A, A-C)
  - Of course, both Sam and John can be *constructive* (C-C)
- I = C when only one partner is *constructive* or dialog is dominated by one speaker (P-C, or A-C). Evidence shows that the constructive partner learns more than the receiving partner.
- I < C when neither partner is *constructive* (P-A, A-A)
- I > C when both partners are *constructive* (C-C)
- But is mutually constructive partners' learning merely twice as much as a single partner's constructive learning?
- No, it can be more because in interactions, there are many other advantages above and beyond a single person constructing: feedback, complementary knowledge, accountability, motivation, etc.
- See my other talk.

Within a diagonal cell

- For the diagonal cells, we predicted equivalent learning outcomes when we compare the same mode of engagement activities: I vs I, or C vs C, or A vs A, P vs P.
- Although they should be equivalent, but sometimes the task demands are quite different for 2 activities within the same mode, so it is possible they are not equivalent. But even if not equivalent, they will still be better than a mode at a lower level.
- Let's take a look at an example.

2 studies show basically that:
Explaining-to-self (self-explaining) while reading a text **>** Explaining or Teaching-a-peer partner after reading a text.

- Moreno,(2009, jigsaw condition); Roscoe & Chi, 2008
  - ***Constructive* > *Interactive* (should be C < I)**

- In SE a text, goal was to serve oneself in learning (generated more inferences and new knowledge), resulting in knowledge-building statements
- whereas explaining-to-other, students tended to generate more episodes of knowledge-telling (74% knowledge-telling, from protocol analyses) than episodes of knowledge-building (37%).
- Telling what explainers already knew became more of an *active* activity since telling is retrieving pre-stored knowledge. Thus, Teaching-a-peer in a knowledge-telling way was really *Active, not Interactive.*
- Thus it made sense that Self-explaining (*Constructive* activity) > Teaching-a-peer when the teaching was mostly knowledge-telling, which is *Active.*

ICAP framework can also explain discrepant results of the same engagement activity: e.g. Summarizing

- Summarizing is a learning strategy (or engagement activity) that is often used in lab studies and classroom studies. Sometimes it is effective and other times less effective.
- We can explain such discrepant results by scrutinizing on how it is implemented and what other activities it is compared with.
  (1) Summarizing in a copy-and-delete> Listening to a partner's summary (Coleman, Brown & Rivkin, 1997).
  (2) Summarizing in own words = generating questions (King, 1992)
  (3) Reading Summaries < Contrasting cases (Schwartz & Bransford, 1998)
- (1) Active > Passive; (2) Constructive = Constructive
  (3) Passive < Constructive.
- How summarizing is implemented (copy-delete vs in own words) makes it either an *active* or *constructive* activity.

Conclusion

- Our conceptual framework, can explain or predict in a parsimonious way the results of numerous studies, without appealing to all the specific reasons postulated in a variety of those studies.
- ICAP framework can predict whether one treatment condition is better or worse than another treatment or control condition, on the basis of whether they involve the same or different mode of engagement activities undertaken by the learners.
- ICAP can explain when null results are obtained (diagonal cells), and why they are not obtained when they should be obtained.
- Our framework prescribes that a relevant control condition should be one from the same mode of engagement activity.
- ICAP framework also explains why discrepant results are obtained for the same engagement activity (depends on how it is implemented and what other mode of activity it is compared with).
- Framework is relevant to the design of learning environments in terms of what responses to request from the students. Thus, although interacting with an ITS or a computer-supported collaborative system can be classified as interactive, it is still important to know whether the learner is being *active* or *constructive,* in order to interpret the results appropriately.