2 Approaches to Enhancing Online Learning

Micki Chi

New affiliation: MLF Teachers College, ASU

Crowdsourcing Personalized Online Education, Suncadia, July 2012

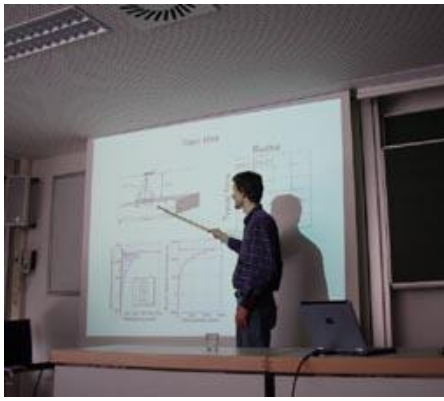
Format of Online Presentation

- Online courses typically present materials either as a

  Talking Head

  PPT presentations with narration

- This form of delivering instruction is no different from classroom lectures
- In both cases, students are attentive & listening, but we consider this to be a *passive* form of learning.



Passively receiving information

- *Passively* receiving information is not "active learning" (whatever "active learning is exactly")
- To make students, become more "active learners," online students are asked to post contributions.
- Freq of student posts (above a minimum of 1 original + 1 reply) does correlate strongly with grades (learning), $p<.001$
- Freq of instructor posts do NOT correl w student grade (Mager & Heulett, 2012)

A significant no. of students do not post (28% of students made no original post nor replies, let's call them the "lurkers"

Questions related to such online learning findings

- Freq. of posting correlated with grades, but could be that good students like to post. Is posting causally related to learning?
- Can postings be improved? Currently students make fewer replies, more original contributions.
- The correlation reported in Mager & Heulett did not include the lurkers. Do lurkers learn if they read others posts?
- Why is Teacher's or Instructor's postings not correlated with students' learning?
- Are there other ways to present information online?

A framework for "active" and "passive" learning that can answer some of these questions

- We have developed a framework that is completely centered on students' learning/*engagement activities* to define what is "active" learning (Chi, 2009; Chi & Wylie, in preparation).
- Essentially, we use students' *overt activities (& products)* to differentiate "active and passive learning" into 4 modes of activities, boundaries are fuzzy.
- These 4 modes are operationally defined as:
  - *Receiving* information and doing nothing else/*passive (P)*
  - *Selecting or* manipulating information for emphasis /*active (A)*
  - *Generating* new information beyond the instructional materials/ *constructive (C)*
  - *Collaboratively* generating information /*interacting (I)*

The 4 modes of distinguishable overt activities
Can be carried out in the contest of encoding new information from instruction or in the context of some instructional activities.

Next few slides show how we operationalize our definition.

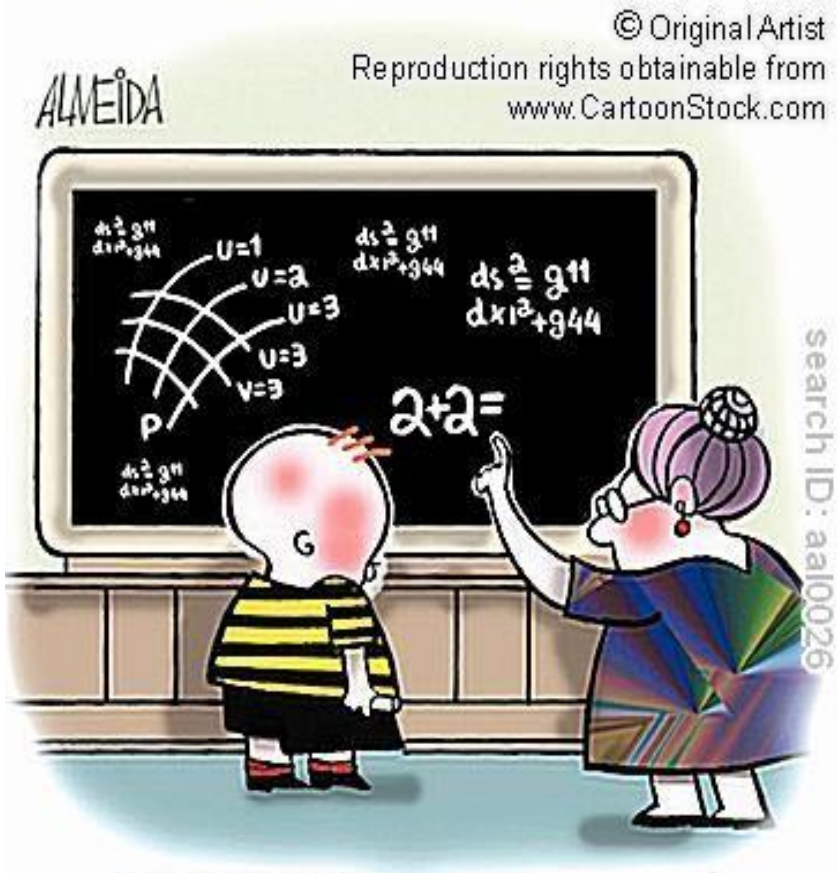
4 Modes of Overt Engagement Activities in the context of instruction

Instructional or Learning Tasks	PASSIVE *Receiving*	ACTIVE *Selecting*	CONSTRUCTIVE *Generating*	INTERACTIVE *Collaborating*
Listening to a lecture				
Reading a text				
Watching/ Studying an example being worked-out at the				

Passive: Overtly, *passive engagement* is when students are *oriented toward* and *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



"EINSTEIN!!! Stop fooling around and pay attention!"

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.

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

Active: Overtly, *active engagement* is when students are doing something that selectively manipulates the learning materials physically

Examples:

- Copying the solution from the board
- Underlining the important sentences
- 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

Examples:

- 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: refers to two or more students *collaborating* with each other through dialog

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 *interactive* does mean that both partners are *constructive,* not just *active.* Dialog encourages construction. One study looks as passin a mouse back-and-forth: this would be an *collaborative-active* vs *collaborative-constructive*

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

(Chi, 2009; Fonseca & Chi, 2012).

Overt Engagement Activities

Instructional Tasks for Learning	*(Characteristics)*	**PASSIVE** *(Receiving)*	**ACTIVE** *(Selecting)*	**CONSTRUCTIVE** *(Generating)*	**INTERACTIVE** *(Collaborating)*
	LISTENING to a lecture	Just listening without doing anything else Not taking notes.	Repeating or rehearsing Describing a presented diagram Taking verbatim notes or copy	Reflecting out-loud Drawing concept maps Asking questions Take notes in own words	Showing and discussing map reciprocally Taking a joint set of notes with a partner.
	READING a text	Just reading without doing anything else	Underlining or highlighting Reading out-loud Summarizing by copy-&-delete	Self-explaining Generating tables & diagrams Summarizing in own words.	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

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

(Characteristics)	**PASSIVE** *(Receiving)*	**ACTIVE** *(Manipulating)*	**CONSTRUCTIVE** *(Generating)*	**INTERACTIVE** *(Collaborating)*
Examples of overt engagement activities	Listening to explanations;	Taking verbatim note; Highlight sentences	Self-explaining Asking questions	Elaborating upon each other's contributions sequentially
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 selected materials are manipulated, thus activating the selected prior knowledge & schema for emphasis, & new information can be assimilated into the activated schema.	"Inferring & creating" 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 building on with inferring" processes involve both partners mutually undertaking "generating processes," e.g. elaborating each other's contributions, incorporate feedback & perspectives, challenge & requesting explanations, resolving conflicts .
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, or enriched beyond just being completion. Procedures have meaning, rationale and justifications added to them.	New knowledge and perspectives can emerge from co-construction that neither partner knew or could generate alone.
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: I>C>A>P or the ICAP Hypothesis

(Characteristics)	*(Receiving)*	*(Manipulating)*	*(Generating)*	*(Collaborating)*
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.	"Inferring & creating" 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 building on with inferring" processes involve both partners mutually undertaking "generating processes," e.g. elaborating each other's contributions, incorporate feedback & perspectives, challenge & requesting explanations, resolving conflicts .
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 or could generate alone.
Expected learning outcomes	Minimal understanding	Shallow understanding	Deeper understanding that might transfer	Understanding that might innovate novel ideas

Caveats & Clarifications

- “cognitive engagement” or “active learning” can be defined by 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 in one of the active categories.
- 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.
- Sometimes must examine the **overt products** to discriminate

More clarification: The Cognitive Processes of these 4 categories of Engagement Activities

- Cognitive processes of the engagement tasks vs cognitive processes of the learning tasks such as reading, listening.

  E.g. cognitive processes of reading includes decoding, mapping between phonemes & graphemes,
- Cognitive processes **within a mode are** relatively **comparable** for a variety of activities, but **different across modes** of activities. This allows us to generalize our prediction across tasks, age groups, topic domains, etc.

  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

The ICAP Hypothesis

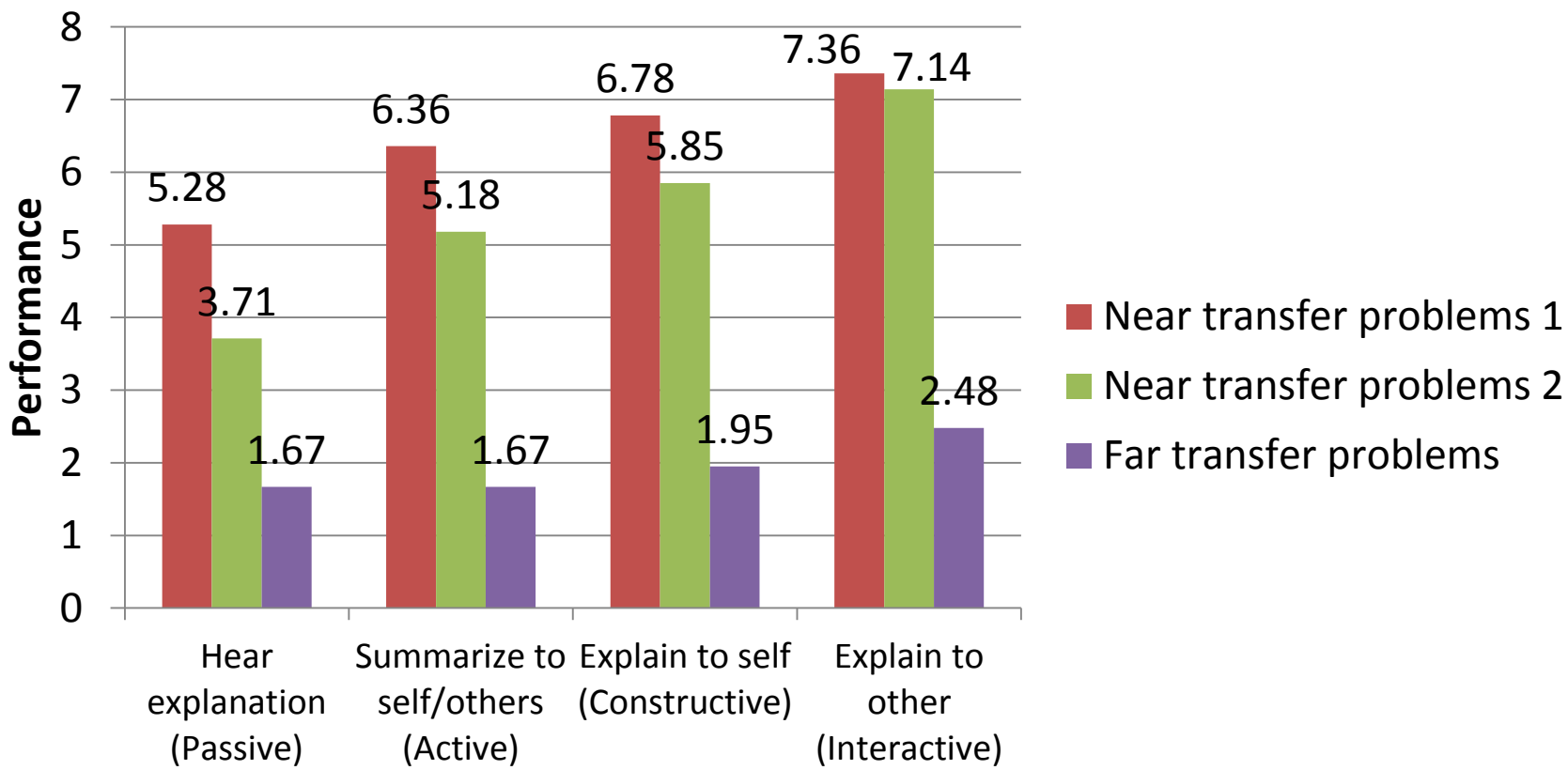
The ICAP hypothesis is centered on the students' activities only.

It says that we can predict the majority of learning outcomes on the basis of what students are asked to do.

However, other aspects of the learning experience can override the prediction of the ICAP hypothesis,
e.g. shallow assessment.

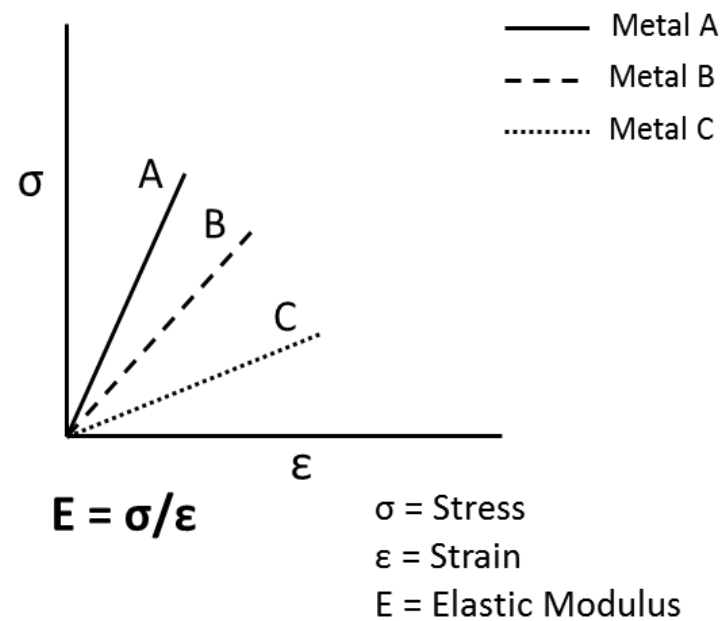
.

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

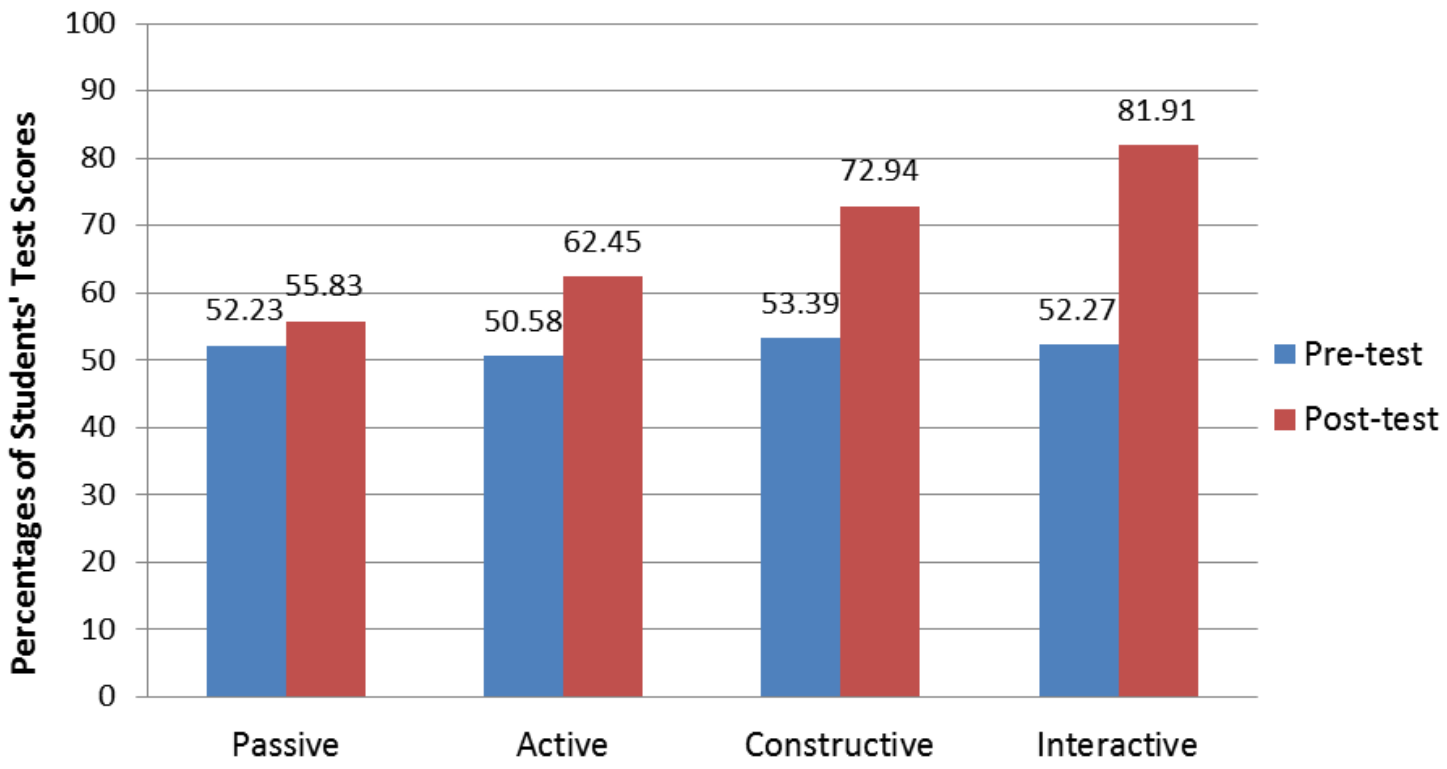


(3-person groups taking turns at hearing, summarizing, explaining: Table 3 from Coleman, Brown & Rivkin, 1997, re-ploted to conform to the 4 modes)

Our own controlled experiment, 4 conditions: Read text (P), Read + highlight text (A), Interpret graph (C), Collab. interpret graph (I)

Text for the elastic modulus concept	Graph for the elastic modulus concept
The degree to which a structure deforms or strains depends on the magnitude of an imposed stress. For most metals that are stressed in tension and at relatively low levels, stress and strain are proportional to each other through the relationship $E = \sigma/\varepsilon$ where E is the elastic modulus, σ (sigma) represents stress, and ε (epsilon) represents strain. For example, assume we have three metals: metal A, metal B and metal C. The metal A has the greatest elastic modulus among all three and the metal B has greater elastic modulus than metal C. This relationship also implies that the metal A has the greatest slope in a stress-strain curve and the metal C has the smallest slope in the same curve.	

Asking students to engage in 4 different activities across 4 modes (@ 8-10% significant improvement across each level of engagement while learning new materials)

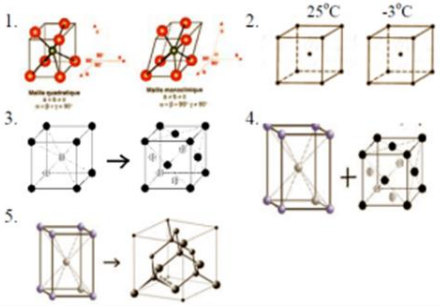


(Menekse, Stump, Krause & Chi, under review)

when we teach instructors about ICAP, they prefer to change their in-class activities: 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 II. BCC loses ductility at low temp III. ductile BCT (body center tetragonal) metal transforms to brittle powder with diamond cubic unit cell IV. cracks form in BCT ceramic when it transforms to body center monoclinic V. soft FCC phase is retained in hardened steel phase (BCT)		A. 120°C sterilization phase change B. incomplete phase transform C. loses strength above 730C D. iceberg cold environment E. temp falls below 13°C	a. sintered b. forged c. cast d. machine & heat treat e. hot rolled in steel mill

Can be changed to a 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 in the literature that present pair-wise comparisons satisfy ICAP's predictions (diagonal cells predict equivalence): Conditions in each study can be re-interpreted

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

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

Traditional (T)

[Intervention: Ask students to answer recall questions:]

What apparitions do the witches show Macbeth?

Recall of pre-stored knowledge: *Active*

Post-test: 44%

Guided Cognition (GC)

(Visualize & illustrate)

[Intervention: 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*

Post-test: 54%

Notice that 8-10% improvement is about the same as what our Engineering data found from one Engagement Level to the next. Our interpretation is that the results show an advantage for a *constructive task,* not the specifics of Visualize & Illustrate Prompts.

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 hypothesis can…

- Predict many learning outcomes based on what students are asked to do. [Can also explain discrepant findings; it also dictates what to use as a control condition …]
- It explains why freq. of posting on the discussion board improves learning. It is a constructive activity, thus more likely causal, not b/c good students posted more.
- ICAP can also implicate how we can design better instructional formats, ones that may be more suited for online delivery.
- Next set of slides show one novel instructional delivery format, the design was informed by ICAP, will have implications for lurkers.

Is it optimum to deliver online instruction via videos of Tutorial Dialog?

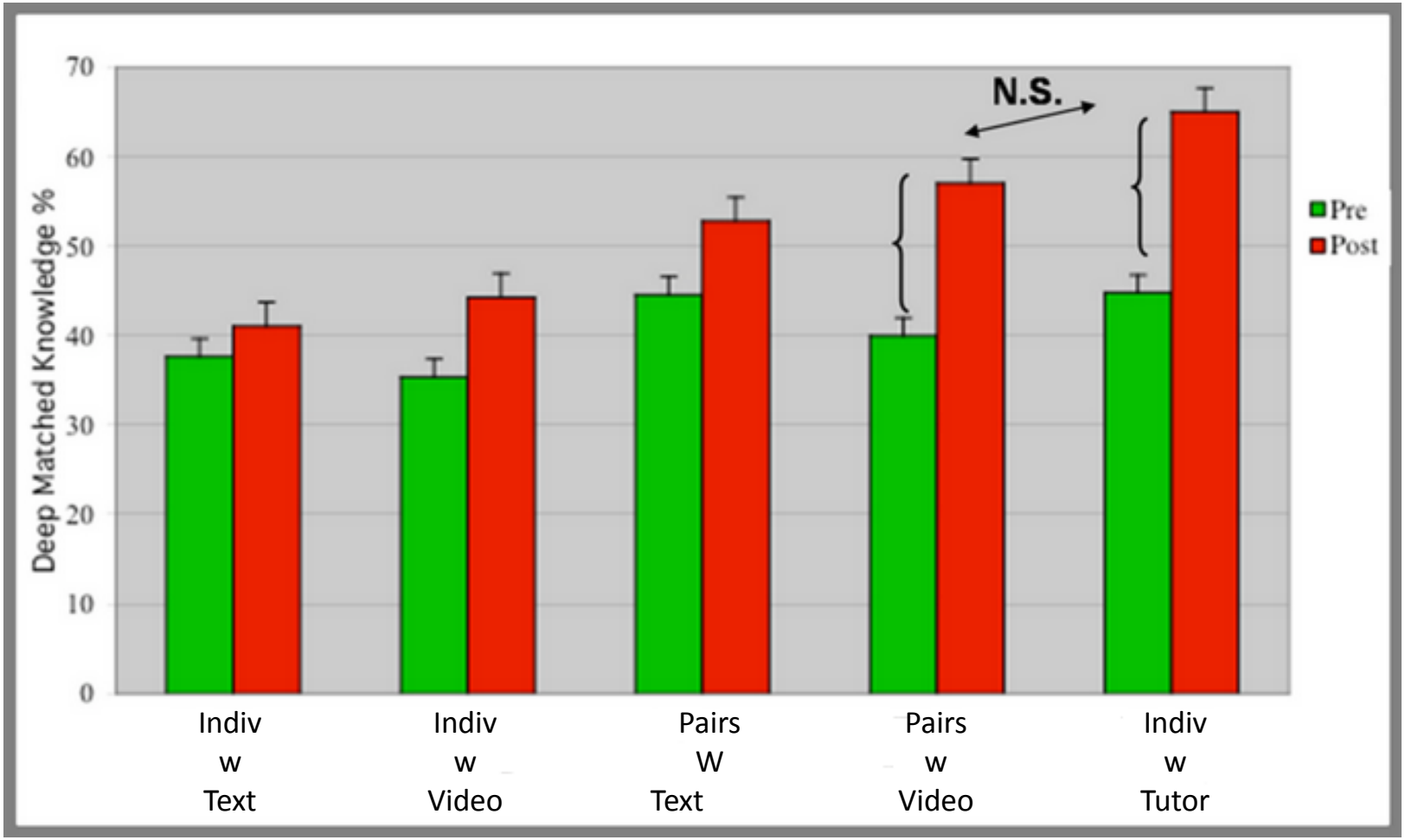
- We made the bold prediction in 2008 that a student seeing and hearing (observers of) tutorial dialog (between a tutor-and-a-tutee) can learn as well as the tutees themselves (under one condition, informed by ICAP).
- Existing evidence in (Schober & Clark) shows that in a tangram description task, solo observer cannot place the correct tangrams as well as tutee, due to lack of opportunity in the grounding process.

From the ICAP perspective, we predict that the observing student's failure to perform as well as the tutee is *NOT* because of a lack of grounding opportunities, but because the observing student is being less generative/collaborative

- Tutees typically are *generative/constructive;*
- Observers need opportunities to be *generative* (e.g., collaborate with a peer, provide the same activity sheet as tutees), then the collab observers might learn as well as the tutee.
- Our prediction was confirmed.
- Collab observers can learn as we
  Tutee, without interacting w Tut
  b/c they are constructive in coll
  (Chi et. 2008)

Tutoring = Observing Collaboratively (bold: predict null hypo & using tutees as the gold standard)

==> Because by collaborating, both observers are *constructive/generative*



Clarification of terms

- When a tutee "interacts" with a tutor, the tutee is usually given opportunities to be *constructive/generative.* The tutee is not *interactive* in the *collaborative* sense.
- Similarly, "interacting" with an ITS often makes a tutee more *constructive/generative.*
- *Interactive* in the *collaborative sense,* is more than being *constructive/generative.* It means the two partners can reciprocally build-on each other's contributions; whereas interacting with a tutor is *constructive/generative* (Chi et al, 2001)

Two Questions

- If tutorial dialog is such a powerful instructional format,
  1) How much better is tutorial dialog than instructional monolog?
  2) Can solo observers benefit from tutorial dialog over instructional monolog?

For natural dialog, dialog > monolog for college students

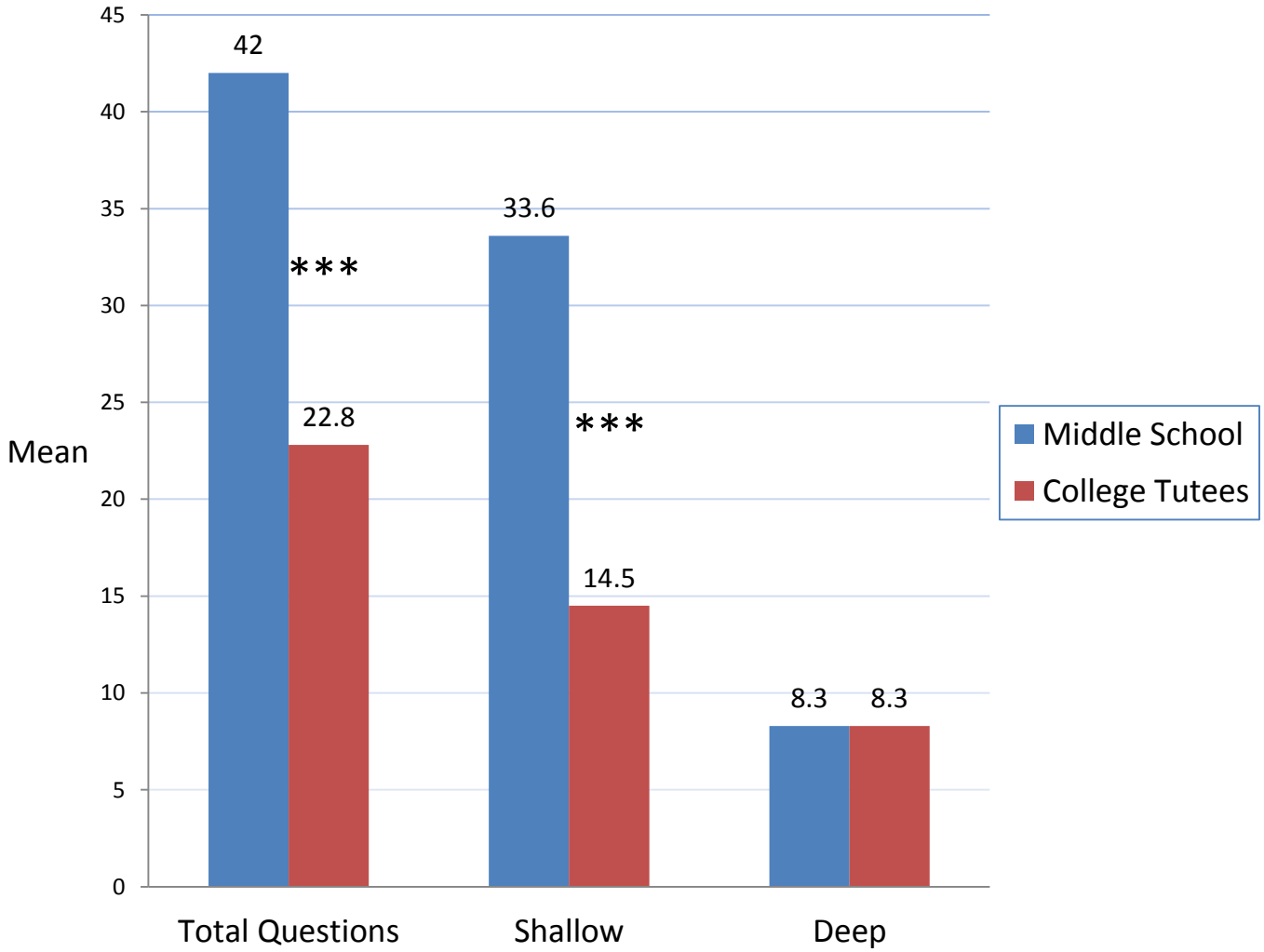
- Whether they observe individually or collaboratively.
- But dialog = monolog for young 8th-grade students, in which the tutorial videos are made with same-age 8th graders.
- Why are 8th-grade tutorial dialogs not a good source of instructional videos?
- Our tutorial dialogs were from the same 3-5 identical tutors with college and kids. We coded only the questions the tutors asked.

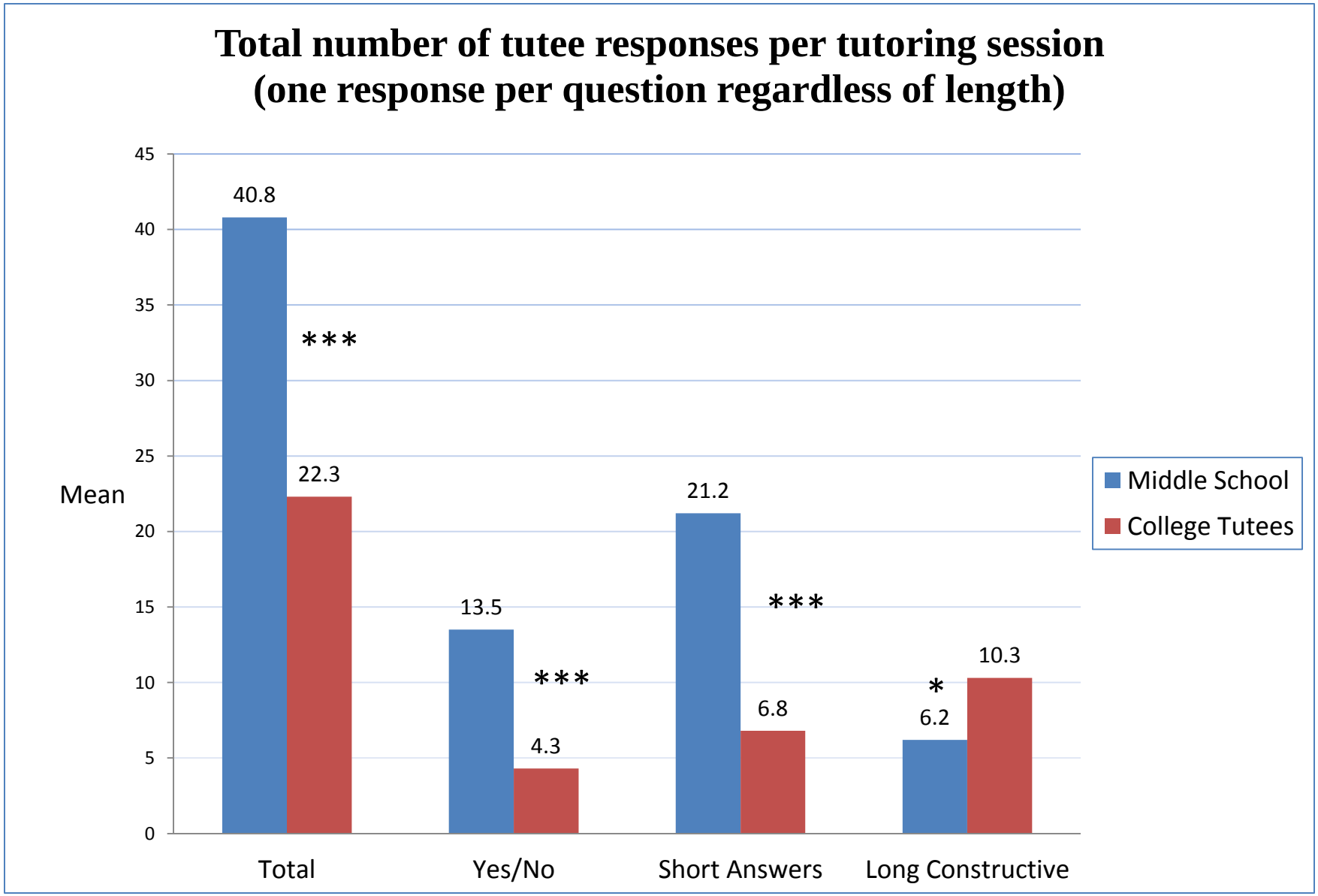
Tutors asked Kid Tutees a lot more questions
Adult and Kid Tutees's responded to tutor questions:
Consistent with other results, 1-1 corespondance.

	Adult Tutees	Kid Tutees
No. of Tutor Questions	22.8	42.0
No. of Tutee Answers	22.3	40.8

Replicate our other findings. Tutoring is really a Q-A session.
However, the quality of the Tutor Questions & Tutee responses are different.

Total number of tutor questions per tutoring session (same 4 activities, no diff in deep Q)




Total number of tutee responses per tutoring session
(one response per question regardless of length)
Mean
45
40
35
30
25
20
15
10
5
0
40.8
***
22.3
13.5
***
4.3
21.2
***
6.8
*
6.2
10.3
Total
Yes/No
Short Answers
Long Constructive
Middle School
College Tutees

Summary

- Tutorial dialogs are effective instructional vehicle for solo or collab observers if the dialog is with an adult tutee (>50-60% prior knowledge).
- This is NOT because Tutors asked deeper questions of the tutees (analogous to the finding that Instructor's postings do not correlate with student's learning online)
- Because adult Tutees respond more *constructively,* consistent with ICAP's prediction. 8th-graders gave yes/no or single-word "active" responses.
- *Constructive responses* are good learning sources for observers, as well as help tutees learn.
- Suggest that Lurkers can learn by reading the posting exchanges of other students, if they engage in some sort of activity themselves.

Conclusion

- We introduced a student-centered framework, that predicts learning outcomes as a function of what kind of overt activities students are asked to do.
- This framework not only predicts the results of hundreds of studies, but it can design new instructional format.
- It also can explain:

  a) when we get null results (e.g. when one form of note-taking is > or < than another form) or discrepant results;

  b) discrepant results depends on the control condition (compare an *active* vs *passive,* or *active* vs *constructive*)

  c) why posting is effective for learning, and why teacher's posting is not.

  d) predict that Lurkers' may be learning on online Discussion Board if the postings-and-replies are constructive comments.

- Online learning can be improved on both the delivery side and student's activities side, using ICAP as a framework.