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ICAP: How to Promote Deeper Learning by Engaging Students Cognitively: Translating the ICAP Theory on Student Engagement into Practice

Micki Chi
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Mary Lou Fulton Teachers College
Michelene.Chi@asu.edu

Define terms & abbreviation (Ss=students, Ts=teachers, K=knowledge)

"**School Engagement**" has been referred to from 3 perspectives:

- Motiv & Emotional perspective: Interested in subject, their classes, their instructors
- Behavioral perspective: Attend classes and do homework
- Cognitive perspective: vaguely defined as "Invested in learning" (e.g. do S put in metacognitive effort, such as preferring to solve harder problems). This definition is sometimes entwined with motivation constructs (e.g. adopting learning rather than performance goal)

So, **cognitive perspective is vague and not well-defined.**

We define "**cognitive engagement**" as:

- What students do (or how Ss participate, or interact) with instruction or the instructional materials
- in the context of classroom instruction.

Outline

Part 1) Describe our ICAP Theory of Cognitive Engagement, consisting of:

- **A taxonomy** of 4 behavioral modes: Defining the 4 modes in concrete & operational way, without compounding it with motivation, emotion, etc., without relying on students' self-reports, or reflections in afterwards, based on assessing what students *do (and produce)* when they are naturally engaged in learning.
- **Cognitive knowledge-change processes** associated with each mode
- **A hypothesis I > C > A > P**, that predicts levels of achievement (learning)
- **Supportive evidence** from the literature

Part 2) Translate theory into practice:

- Can we teach teachers about ICAP so that they can **promote/elicit greater cognitive engagement** from their students?
  - Assess teachers' success at implementing ICAP
  - Measure students' learning outcomes
- Using ICAP to train teachers how to ask questions that elicit *C* & *I* student resp

Disengaged (OFF-task) and **Engaged** (ON-task) behaviors are easy to identify & often conceived of as binary. A student is either on-task or off-task.

Disengaged: Off-task:

Engaged: On-task:

Off-task or On-task are also the major discrimination researchers try to make to detect cognitive engagement in online learning (Gobert, Baker, Wixon, 2015)

However, we propose that students can be **on-task** in a variety of ways

Paying at

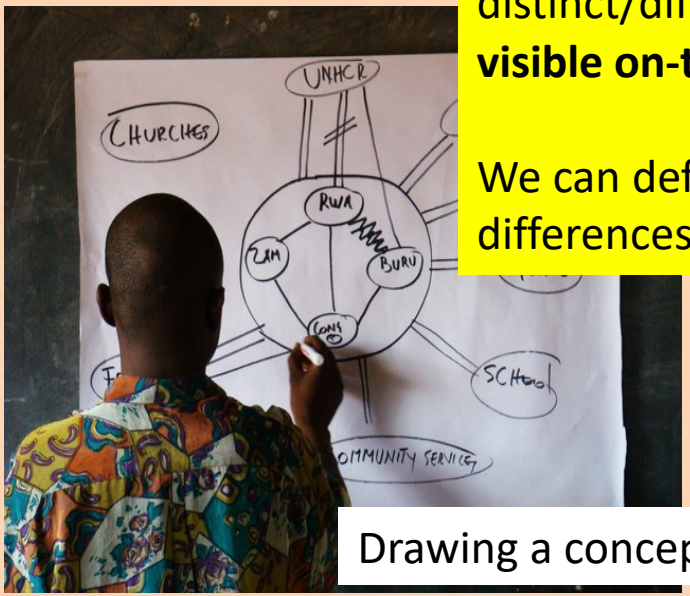
A

B

easuring

We claim that:
These 4 groups of activities represent distinct/differentiable "***modes/types***" of **visible on-task behaviors & products.**

We can define each mode and show their differences.



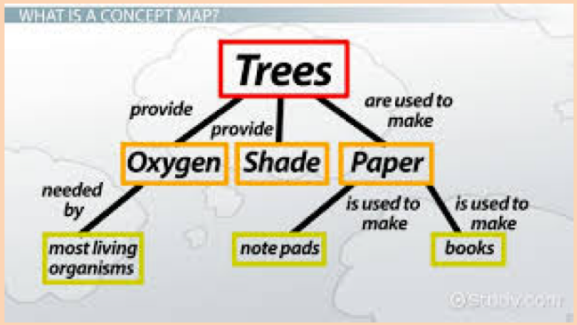
Drawing a concept map

Comparing ideas, justifying, arguing

That is, we propose that cognitive engagement can be determined and discriminated:

- *approximately* by the overt (visible) behaviors of how students interact with instruction (or instructional material).
- The overt behavior suggesting an engagement mode can be confirmed by analyzing the content of the products they produce.

==> **Overt Behavior** **+** **content of the Product**



- jointly, determine pretty accurately the cognitive mode that students are engaging.
- Thus, we are using behaviors + products to indicate ***cognitive*** engagement (we are not talking about behavior engagement, which measures persistence, effort, resiliency, purposefully seeking out information (Sinatra, 2015; Buhs & Ladd, 2001).

The next few slides show the Taxonomy:

1. Show the 4 modes of behaviors
2. The products each mode produced
3. How each mode can be defined to *differ* from another;

Attending or *paying attention* behavior: (***Passive mode***)

Ss are ***paying attention,*** oriented toward & receiving instruction.
But they are ***not doing anything else overtly or producing anything***

Examples	Products
• *Listening* to a lecture without taking notes • *Watching* a video • *Observing* a demonstration • *Reading* a worked-out example	• *None*

Manipulating behavior: (***Active mode***)

Ss are paying attention and ***physically manipulating*** the instructional materials, either alone or with a peer, but *not adding any new information*.

Examples	Products contain components identifiable in the instructional content
• *Copying* the solution from the board	• Solution steps provided
• *Underlining* the important sentences	• Underlined sentences is a subset of all sntences
• *Selecting* an option/icon	• Choosing 1 of the available options
• *Describing* a scene	
• *Moving* a slider to location	• Locations on slide provided
• *Pouring* quantities in the lab,	
• *Recording* amount measured	Amount shown on the instrument
• *Pointing* & gesturing	
• *Repeating* definitions	

Generating behavior: ***(Constructive mode)***

-Ss are ***producing*** some additional information that may contain (incidentally or intentionally) small pieces of knowledge that is new to oneself & new to the instructional materials. i.e., Ss are adding minute pieces of knowledge ***beyond what was presented in the instructional materials,*** literally.

-[*Not discovering knowledge/principles novel to the domain!]*

Examples	Products reflect information not in instructional content
• *Drawing* • *Explaining* • *Posting* • *Taking* • *Providing* • *Comparing & contrasting* • *Evaluating* • *Predicting* • *Reflecting* • *Monitoring*	• Concept map/diagrm • Explanations • Questions • Notes • Justifications • Similarities & differences • Reviews • Outcomes • Insights of one's own understanding

Collaborating behavior: ***(Interactive mode)***

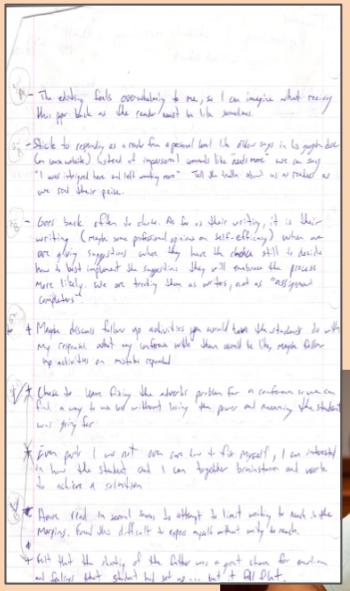
Working with a peer (exchanges mostly in dialog): that each person is *generating* and building on the other person's contributions in a mutually *co-generative* or *co-constructive* way.
Sometimes this has been referred to as transactive dialogues.

Examples	Products (conversation) extend beyond content & extend beyond each partner's contributions
• *Explaining to each other* • *Debating* • *Discussing* • *Solving jointly*	• Richer explanations • Better formulated arguments • Consensus • Innovative new ideas

Some behaviors are ambiguous, so need to examine the external products in order to accurately determine the student's mode of engaging. But jointly, they are quite adequate to reflect engagement mode.

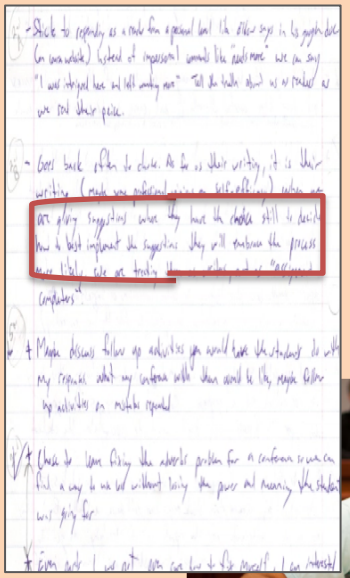
Manipulative (active)

No new ideas added in notes



Generative (constructive)

Notes contain new ideas

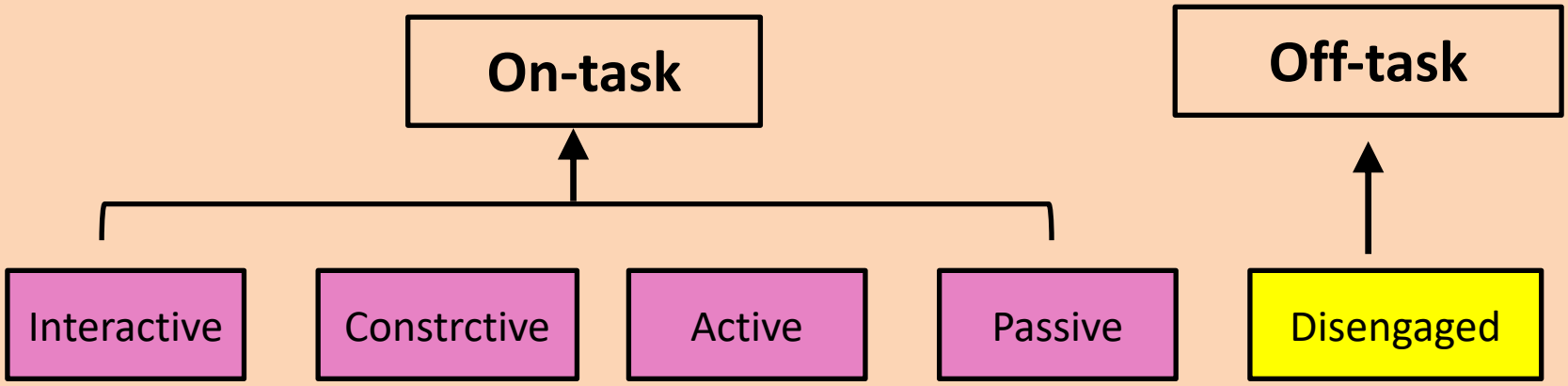


Summary of the 4 differentiated behavioral modes of on-task cognitive engagement & products

	Attending *Passive*	**Manipulating** *Active*	**Generating** *Constructive*	**Collaborating** *Interactive*
Student Behaviors				
Descriptions	**Paying attention only, not doing anything with instructional materials**	**Physically manipulating instructional materials, without adding any new knowledge**	**Generating new K, evident in outputs**	**Generating new K w peer + responsive to peer's contributions, evident in outputs**
Products	None	Components in the products are identifiable in the content of instruction	Components add K beyond content of instruction, the added K need not be novel to domain	Extend beyond content & beyond self & partner's contributions,

Summary of the Taxonomy: Our claim essentially is that

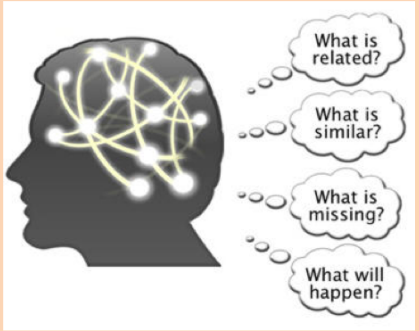
- What students **do** (i.e. their **overt behaviors)** and what they **produce** (i.e., content of their **products),** while interacting with instruction/instructional materials,
- **differentiates** how students are cognitively engaged.
- We have imposed 4 modes (or types) of behaviors & products for **On-Task** behaviors:



Learning can be defined as changes in one's knowledge base.

- What knowledge-change processes might correspond to these 4 behavioral modes? Hypothetical

- If we agree that people can perform at least these 4 simple "knowledge-change" processes while learning:
  - **Store** New information
  - **Activate** Prior K
  - **Link** New information with prior K
  - **Infer** What new knowledge from prior K or from new information



We can then speculate on which of the 5 knowledge-change processes are associated with each mode

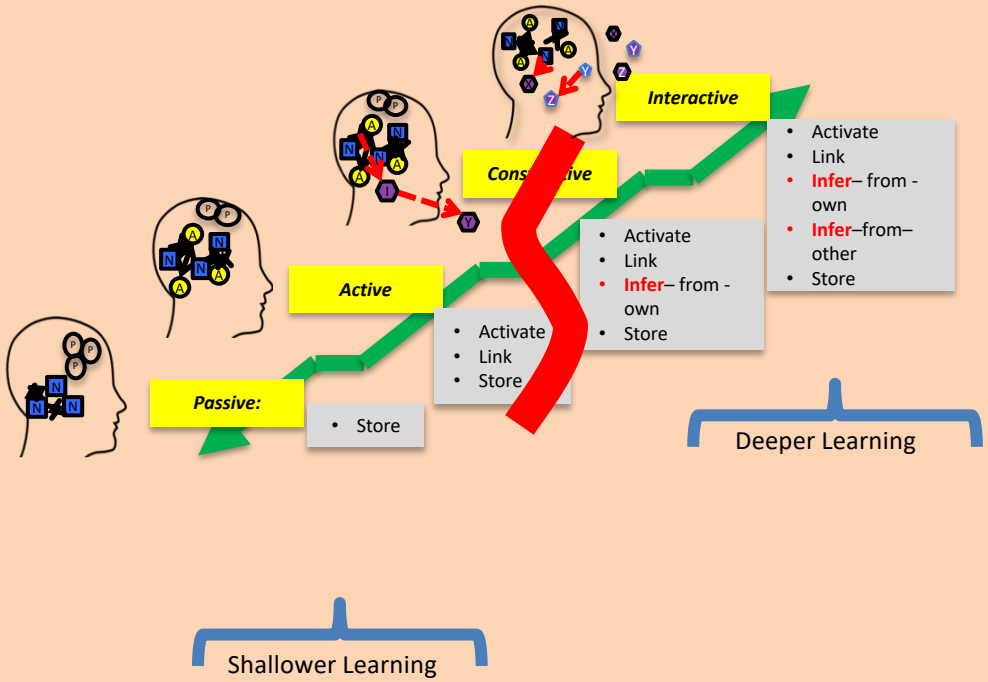
- ***Passive:*** **Store** (i.e. just listen)
- ***Active:*** **Activating** prior K (Manipulated parts of instruction cause more attention to focus on it, thereby activating relevant prior K)

  Storing by **Linking** activated parts with new information.
- ***Constructive:*** generative activity **Activates** & builds on stored knowledge by ***Inferring*** new knowledge, then **Storing** newly generated K & **Linking** it with prior K.
- ***Interactive:*** Same as *Constructive* except one can ***Infer*** from partner's K, **Store** and **Link** partner's knowledge with one's own.
- In sum, more knowledge-change processes are undertaken from the *Passive* mode to the *Active* mode, and only the *Constructive* and *Interactive* mode have the process of *infer.*

The knowledge-change processes that might underlie each mode resulting in richer and richer representation) suggests that the level of learning might decrease in this direction:

1) **Hypothesis:** ***I > C > A > P*** across 4 modes.

2) **Corollary:** ***I ≥ C >> A ≥ P*** because only the *C* & *I* modes have INFER (in order to generate new information)



To confirm that our hypothesis's predictions are correct in this I>C>A>P direction: We summarize 3 sets of evidence

1) We show the advantage of being *Constructive* and define "deeper learning" from our old study

2) We illustrate one study with a very young age group.

3) Hundreds of laboratory & classroom studies from literature, reinterpreted the intervention in terms of ICAP mode, to predict relative differences:

-pairwise comparison (***C > A, C > P, I > C)***

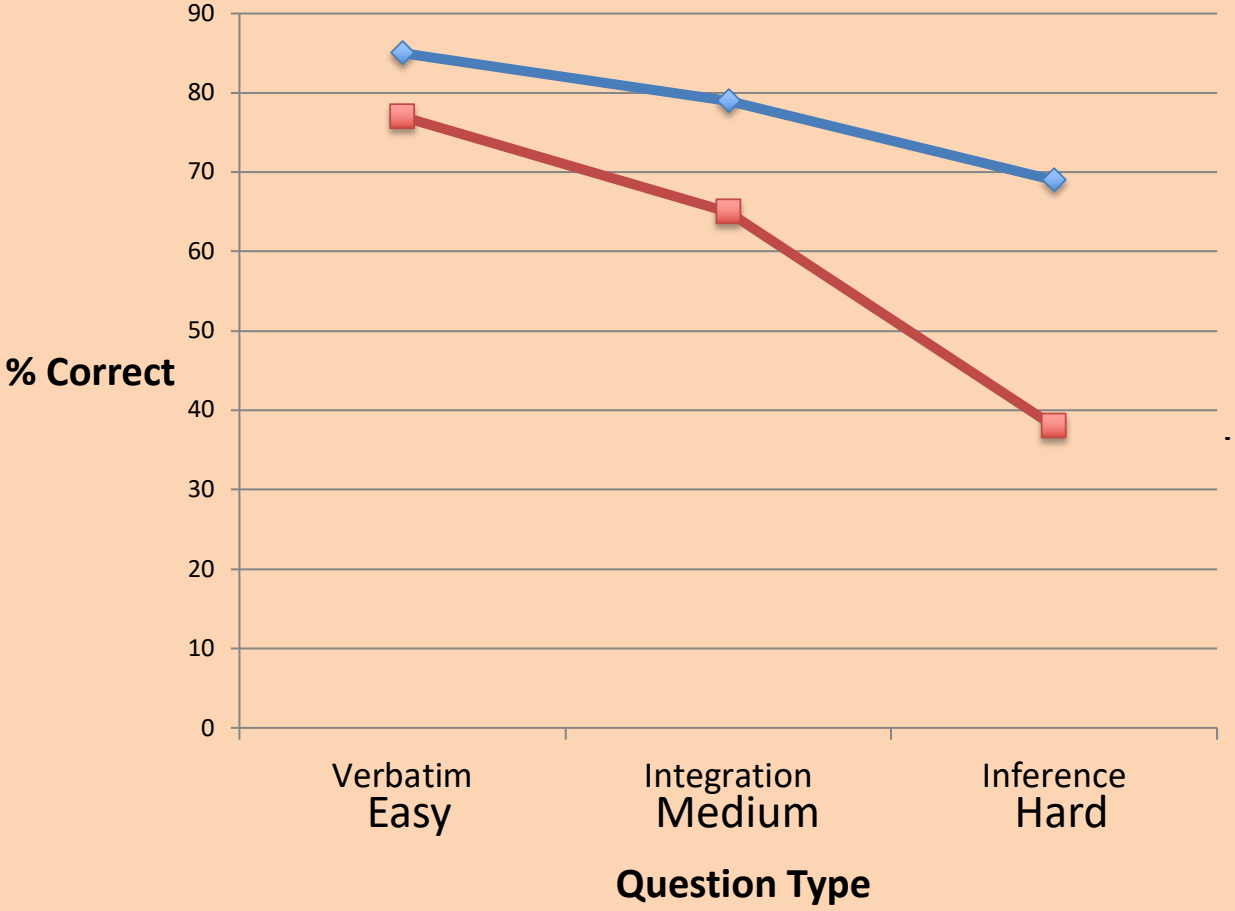
4) Our own lab study comparing all 4 modes, college students;

(1) Self-explanation study
(Chi, de Leeuw, Chiu, & LaVancher, 1994)

- Students read a long passage (about 87 sentences) @ human circulatory system.
- As they read each single or multiple sentences, they were encouraged say what these sentences mean to them. Saying what sentences mean is *adding information beyond what was provided.* We call this learning activity self-explaining.
- So this self-explaining is a *Constructive* activity.

Text sentence	Self-explain the structure
The septum divides the heart into two sides.	"I wonder whether the septum is solid or porous."

We compared students who explained more ”Hi explainers” with students who explained less “Low explainers.”



We define “**deeper learning**” simply as the ability to answer harder questions.
Notice: The difference is greater for the Harder questions.
➔ The more generative students learned more deeply.

(2) An example of a study in the literature showing how we map the conditions of a study onto ICAP modes. An example with a young age group

(Legare, Lombrozo, 2014; *J. of Experimental Child Psychology*)

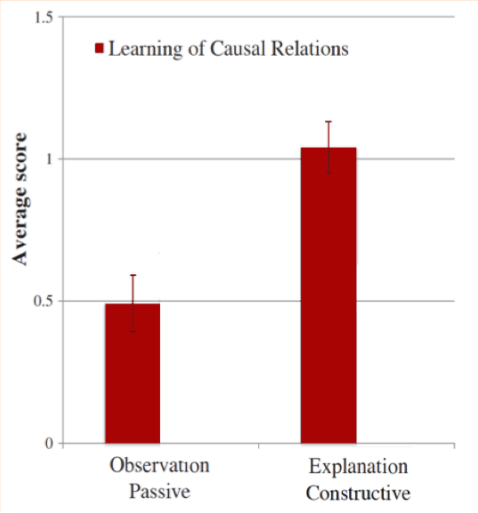
- Preschoolers were shown 5 interlocking gears,
- a crank that turns a fan. Asked to:

  Watch "Let's look at this" turn the crank-fan, 40 sec

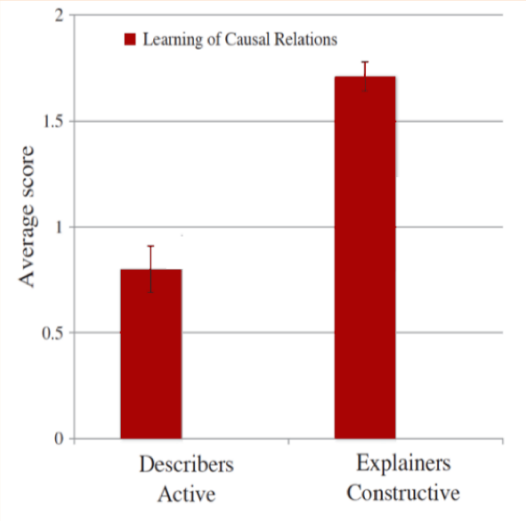
  Explain "Tell me how this works" while turning for 40 sec.
- Learning measure: Children as asked to explain the causal-functional relationship between the crank and the gears to allow the machine to work.

Study 1: Freq of correct explanations for Observe (*Passive*) **<** Explain groups (*Constructive*)

Study 2: Freq of correct explanations for the Describers *(Active)* **<** the Explainers *(Constructive)*



Study 1: Freq of correct causal expl greater for Explainers than Observers. ➔ ***C > P***



Study 2. For the Explain condition, some Explain and some Describe. Freq of correct causal expl (red) greater for Explainers than the Describers. ➔ ***C > A***

(3) Hundreds of laboratory studies in literature can be *re-interpreted* to show *relative* pairwise comparison for 2 ICAP modes (i.e. in each cell below), including comparing studies with null results. Not a meta-analysis. "Re-interpret" these studies means that we align the conditions of the studies with ICAP modes and look at the direction of outcomes.

	Passive	**Active**	**Constructive**	**Interactive**
Passive	=			
Active	>	=		
Constructive	>	>	=	
Interactive	>	>	>	=

Pairwise comparisons of numerous lab studies in support of ICAP's predictions (incl. diagonal cells of null results). (Also for classroom studies.)

	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) • Speaking a word outloud > Silent reading (MacLeod et al, 2012) (the *production effect)*	
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)

(4) Evidence from our own lab across conditions corresponding to 4 modes (College Ss, Engineering concepts)

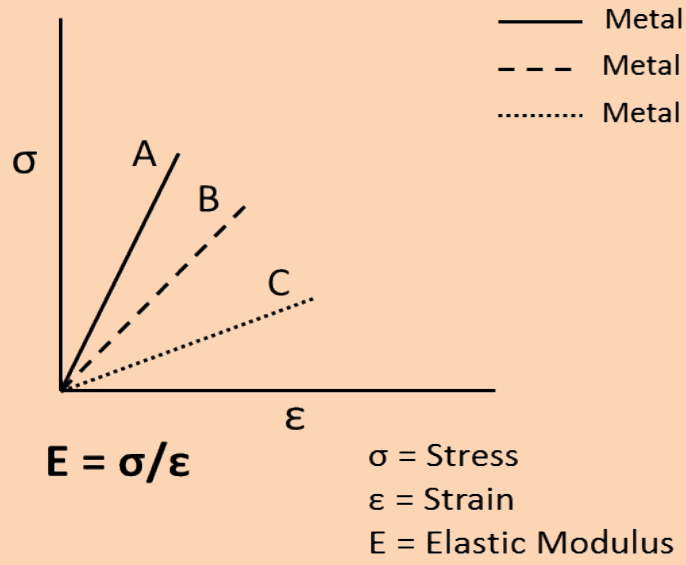
Text Only **or** **Diagram Only**

Read (*passive*)	Read & underline (*active*)	Explain (*constructive*)	Explain Jointly(inter*active*)

Text for the elastic modulus concept

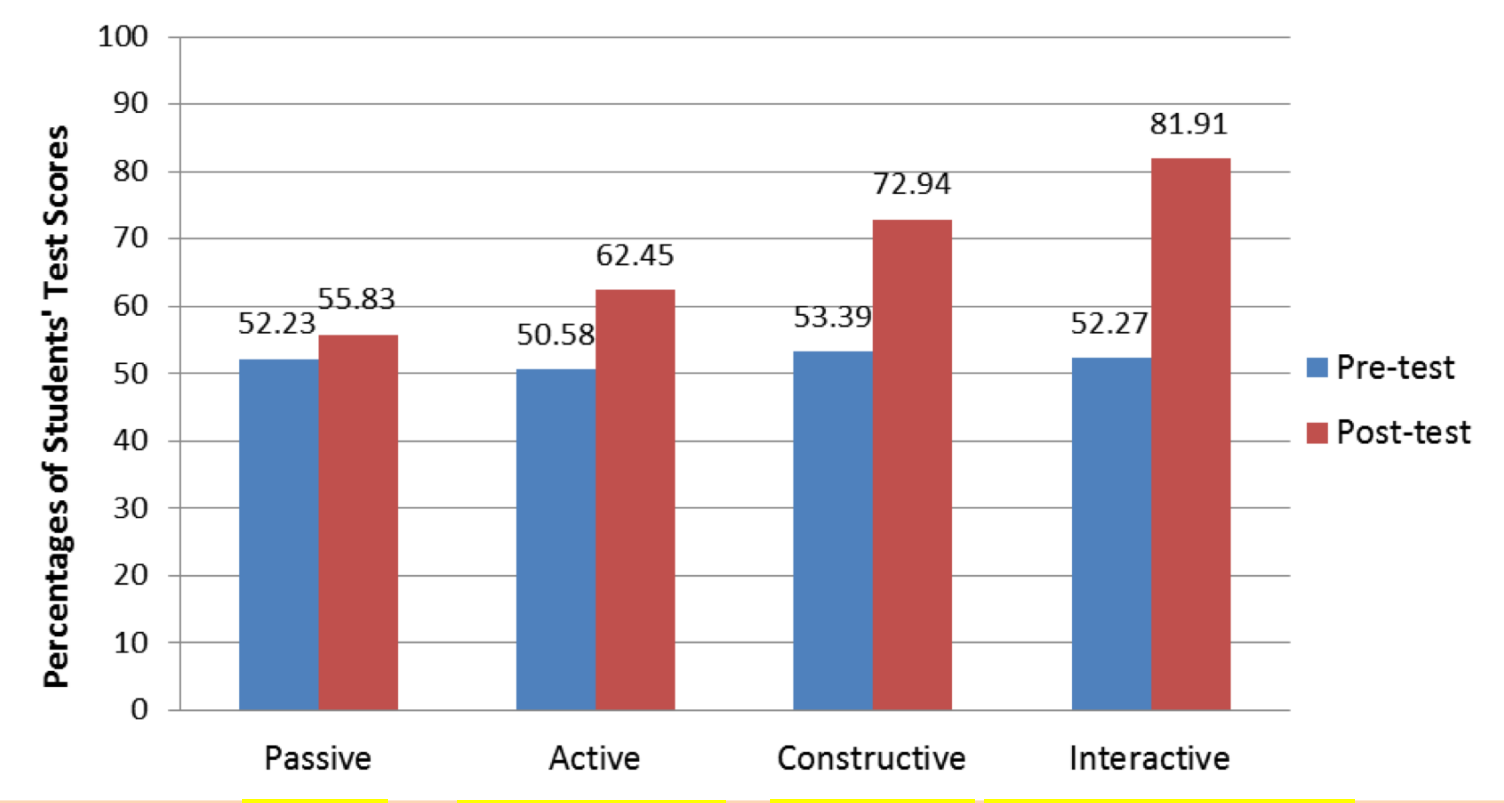
The degree to which a structure deforms or strains depends on the magnitude of an imposed stress. For most metals that are stressed in tension and at relatively low levels, stress and strain are proportional to each other through the relationship $E = \sigma/\varepsilon$ where E is the elastic modulus, 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.

Graph for the elastic modulus concept



Explain the relations between Metal A, Metal B, Metal C. Justify your selections

Learning a materials engineering content using tasks that vary across 4 activity modes supports ICAP: From pre-test to post-test, the amount of improvement per mode is significant across modes



READ | UNDERLINE | EXPLAIN | EXPLAIN JOINTLY

Menekse, Stump, Krause & Chi (2013). Differentiated overt learning activities for effective instruction in engineering classrooms. *J. of Engineering Education,* 102, 346-374.

Summary of Theory Part (A)

1. **Taxonomy:** Can operationally define 4 modes of cognitive engagement based on students' overt behaviors & products (when necessary);
2. **Universal**: these modes of behavior can be exhibited in learning all domains, ages, context or activities
3. **Hypothesis:** Hypothetical cognitive processes associated with these behaviors can generate a hypothesis that predicts the *relative* levels of learning in this decreasing order, ***I>C>A>P,***

   & corollary that: greater similarities between I-C and A-P,

   but greater gap between 2 higher modes (I-C) & 2 lower modes (A-P) because of the process INFER.
4. **Evidence:** Abundant studies in literature supporting various pair-wise comparison: I > C, I > C, C > A, C > P, I > A, etc.
5. **Critical point:** The key to determining the mode of engagement is whether ***students produced any knowledge*** beyond the instructional information given. Main jump in learning is between *Constructive* (new knowledge is produced) and *Active* (no new K).

Part (B). Applications: Translating the ICAP theory into practice

ICAP implies that teachers should be eliciting higher modes of Ss engagement in order to promote deeper learning.

Q1: Do primary and secondary school teachers elicit higher modes of student engagement?

Q2: If not, can we teach teachers to elicit higher modes of student engagement? That is, can we train primary and secondary teachers to apply ICAP to their lesson plans and instruction?

1) Describe our training module: Evidence of teachers' understanding of the module.
2) Evidence of teachers' design & implementation;
3) How students responded;
4) How students learned.

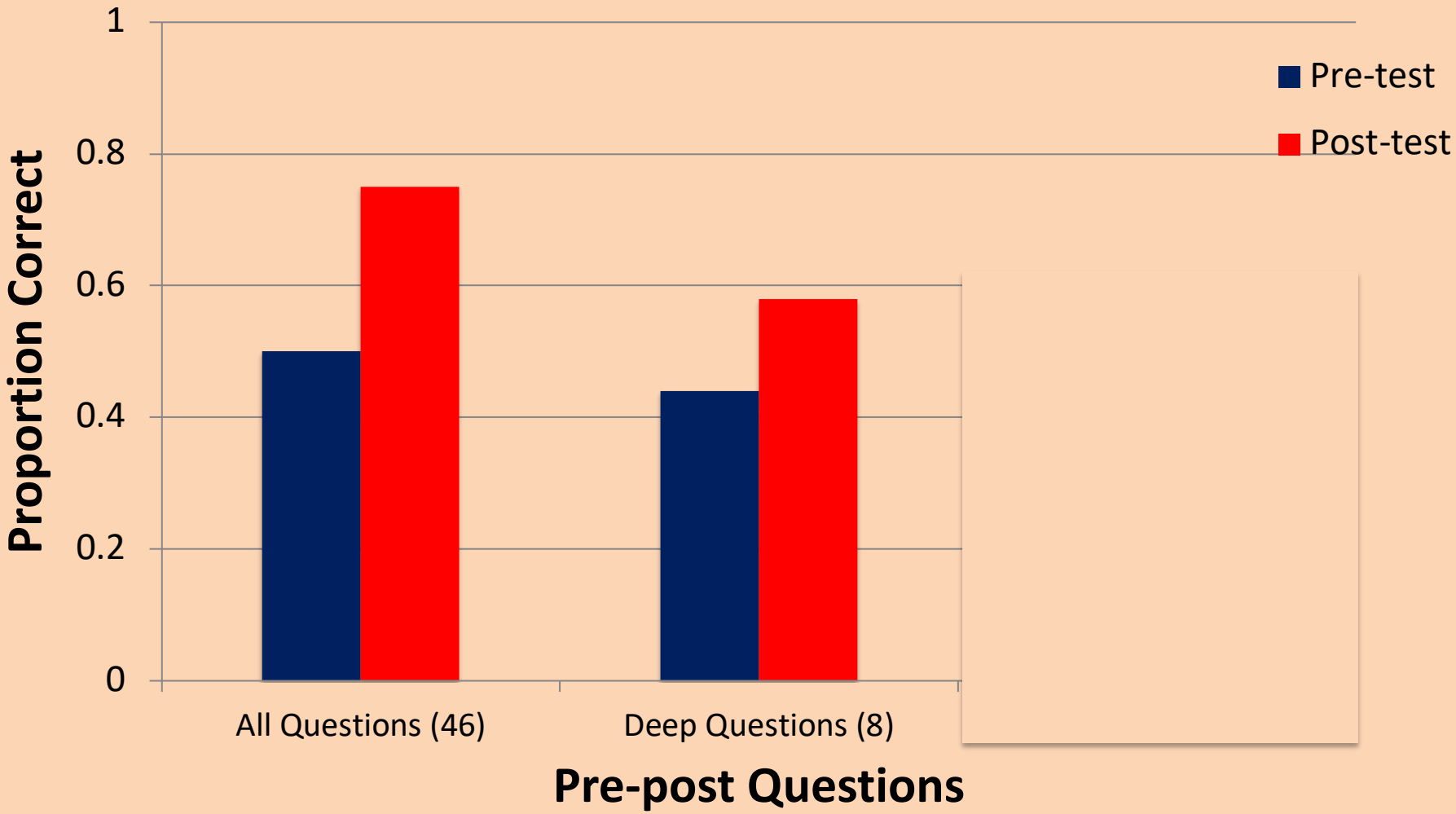
(1) Our teacher training Study to teach teachers about ICAP

- We developed an **Online ICAP Module**
  - Lesson 1: explained what ICAP is, with lots of embedded questions.
  - Lesson 2: contain exercises to *upgrade or bump-up* activities within a lesson from one mode to the next (e.g. from *Active* mode to *Constructive*)
  - Lesson 3: explained how to design deep questions to assess the lessons. Because *C* and *I* modes enhance deep learning, their advantages only show up with deeper questions.
- 13 primary and secondary teachers teaching various topics learned from this online Module as Professional Development (PD).

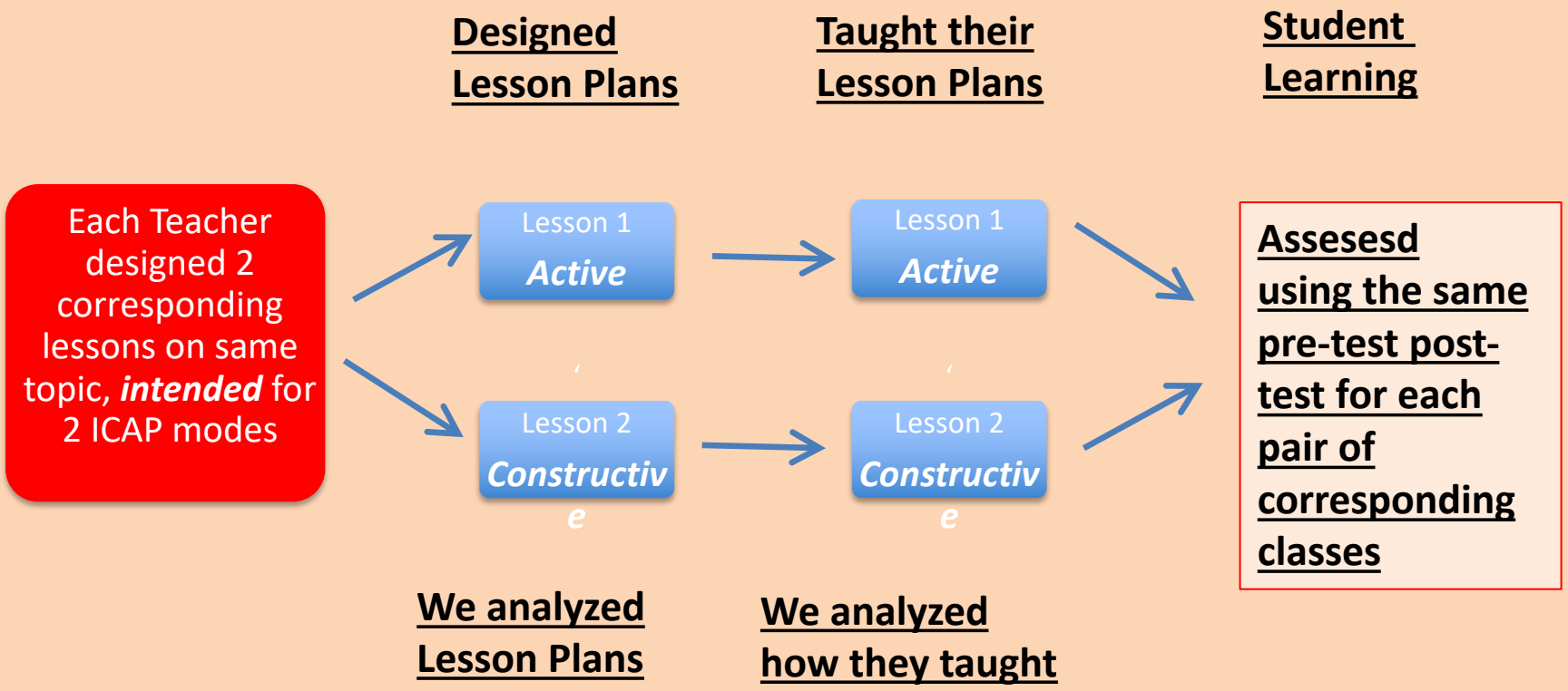
Teachers' Learning of the ICAP Module:

pre-posttest scores (N=43 teachers)

Modest post-test scores for harder questions



(2) After 13 Teachers learned about ICAP, they designed pairs of activities in their lesson plans.



Note: We did not give any careful feedback on their lesson plans because we wanted to see if the online Module alone (without further F2F PD) was sufficient for them to know how to design and teach.

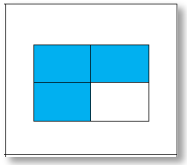
Ex. of a teacher-designed corresponding paired worksheets on same topic at two different ICAP Modes, one worksheet for each class.

Active (Card sorting)

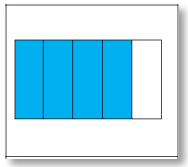
Fill in each section with a group of equivalent representations.

0.75

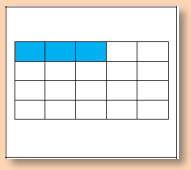
75%



80%



$\frac{3}{20}$



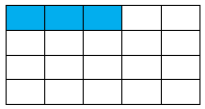
15%

$\frac{3}{4}$

0.8

Interactive (Generate in 3 formats collaboratively)

With your partner, create at least 3 equivalent representations for each section (fraction, decimal, percent, picture/diagram). Create as many as you can.

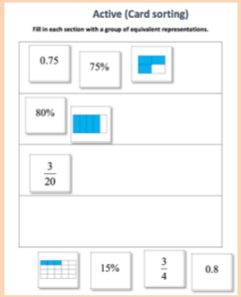
$\frac{3}{4}$			
0.8			
9%			
			

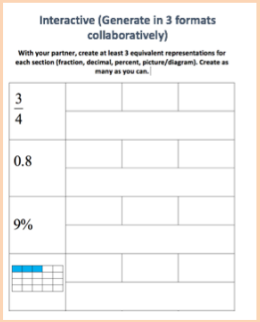
How did the teachers do in designing and upgrading their own classroom activities?

- **Variety:** Teachers designed 105 worksheet activities.
- **How do we evaluate** how well they have designed their worksheets given the variability in activities (domain, tasks, etc)?
- A very challenging problem.
- **One common source of data across 88 of the 105 worksheets is the instructional directives:**
- Ex. of written directives shown:

  ”***Fill in*** each section with…”

  ” With your partner, ***create*** at least 3…”





We were able to easily code the Verb Directives into the ICAP modes. Examples of *Active* and *Constructive* modes

Active	***Constructive***
Calculate, Add	Predict, Infer
Describe	Justify
Find	Brainstorm
Identify	Explain
Practice	Pose questions
Choose	Come up with
Rewrite	Represent

Out of a sample of 111 Verbs, 58 (~half) were manipulative/*Active.* Can code by ICAP mode easily based on whether Ss are asked to generate new knowledge or not. Occasionally need context to discriminate: Connect 2 nodes vs Connect 2 ideas

Examples:

- **"Label** the triangle like the following:"
- **"Measure** out the $NaHCO_3$"

Even without context, we can more or less determine the mode of a verb.

- Add
- Annotate
- Attack
- Avoid
- Bend
- Break down
- Calculate
- Categorize
- Check
- Choose
- Circle
- Click
- Complete
- Confirm
- Consider
- Copy
- Cover
- Cross out
- Delete
- Describe
- Email
- Expand
- Factor
- Fill in/out
- Find
- Fold
- Follow
- Guess
- Identify
- Identify
- Include
- Keep notes
- Keep track
- Label
- List
- Match
- Measure
- Move
- Name
- Number
- Order
- Paraphrase
- Pick
- Place
- Practice
- Re-organize
- Recall
- Record
- Refer to
- Review
- Rewrite
- Round to
- Show
- Stimulate
- Take down
- Tape
- Type
- Use

They used half as many generative/*Constructive* verbs (27 *Constructive* vs 58 *Active*)

- **Ask questions**
- **Brainstorm**
- **Build**
- **Come up**
- **Comment**
- **Compare**
- **Connect**
- **Construct**
- **Create**
- **Decide**
- **Defend**
- **Determine**
- **Draw**
- **Explain**
- **Graph**
- **Justify**
- **Plot**
- **Predict**
- **Put/explain/write in own words**
- **Represent**
- **Set goal**
- **Sketch**
- **Solve**
- **State**
- **Suggest**
- **Support**

Examples:

- "Use the information your team gathered yesterday to **generate** a ratio chart and a graph of your running/walking rate."
- "Using supplies provided, **create** a model protein that shows all 4 levels of protein structure. "

They used very few collaborative/*Interactive* verbs (a total of 9 distinct ones, or ~8%), none emphasized co-generation (yet they designed 47 *Interactive* activities)

Collaborative:

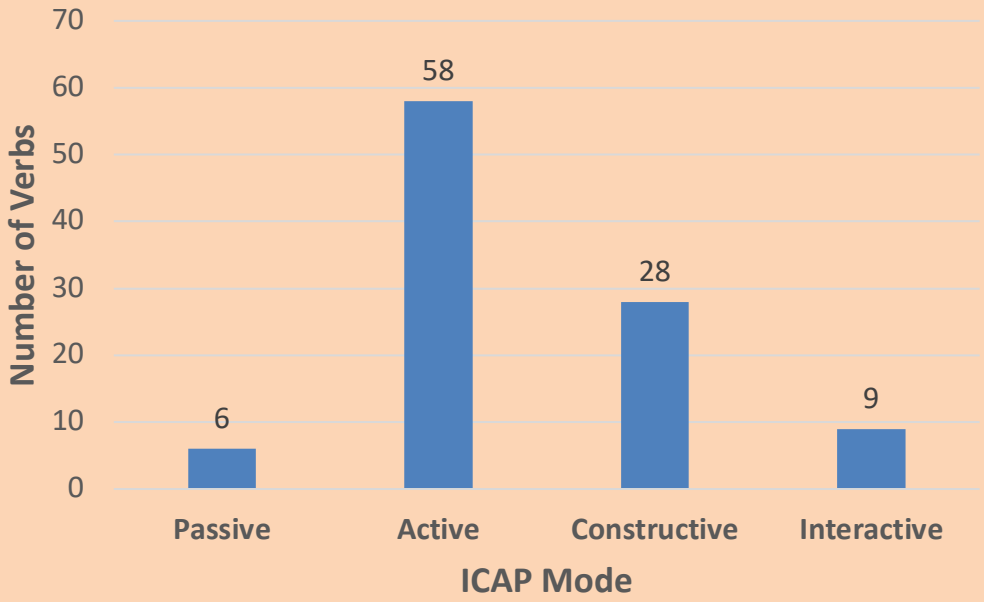
- **Agree upon**
- **Answer with partner**
- **Debate**
- **Discuss**
- **Exchange**
- **Help**
- **Participate**
- **Share**
- **Work with group/partner**

Examples:

- "Before continuing, as a group, **discuss** and **agree upon** predictions to answer the following:"
- "**Share** the results with the people in your group."

➔ Their directives for Interactive/Collaborative activities are flawed: they are not sufficiently detailed or concrete to

Even after learning about ICAP, secondary & primary teachers from our study used more than twice as many *Active* verbs (58) in the directives of their written instruction for activities, than *Constructive* verbs (28). (Chi et al, 2018)



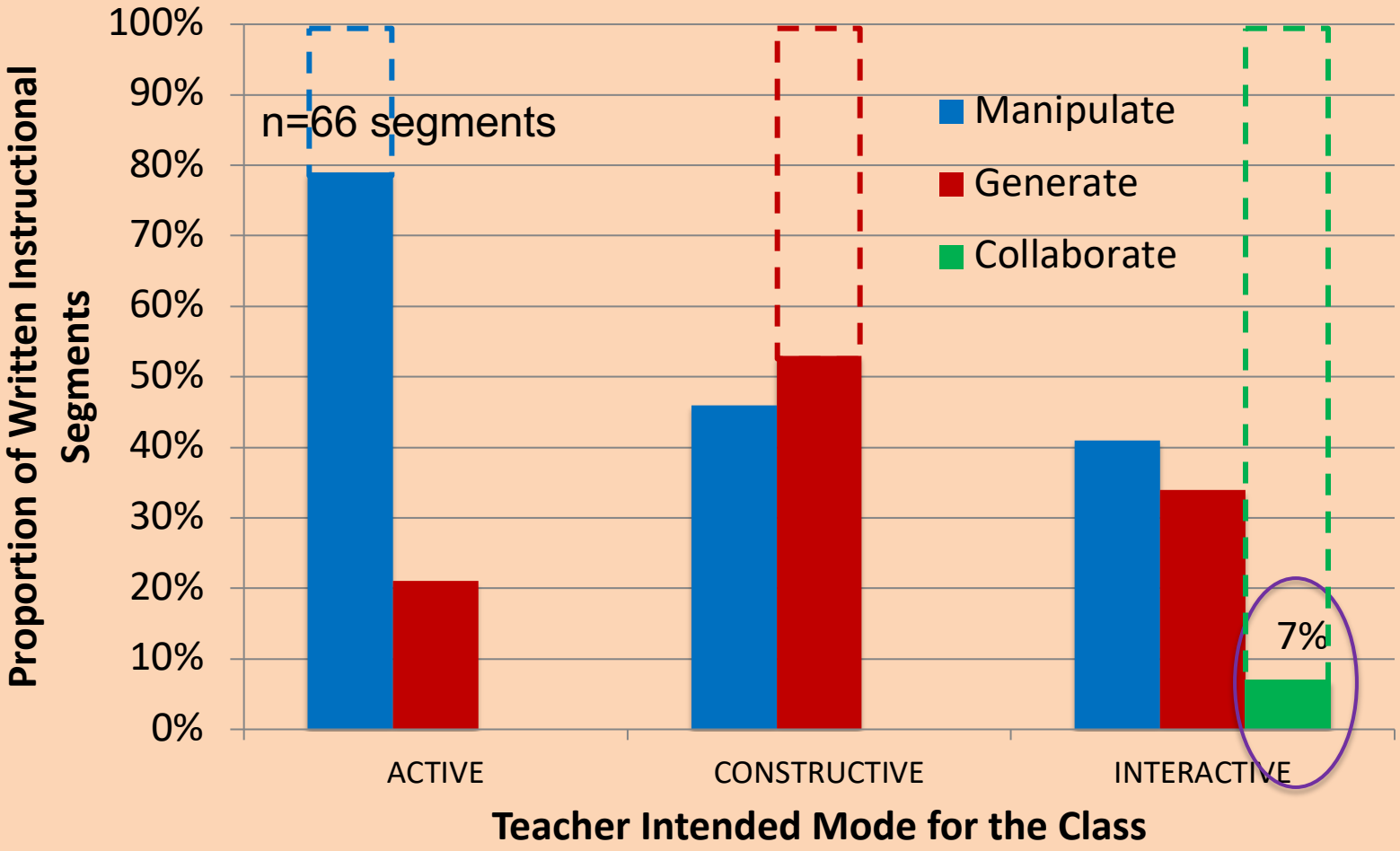
Few *Interactive* verbs.

➔ T most comfortable and used verbs for *manipulative* activities.

(1c) Were the teachers accurate for the *Active* and *Constructive* classes that they designed?

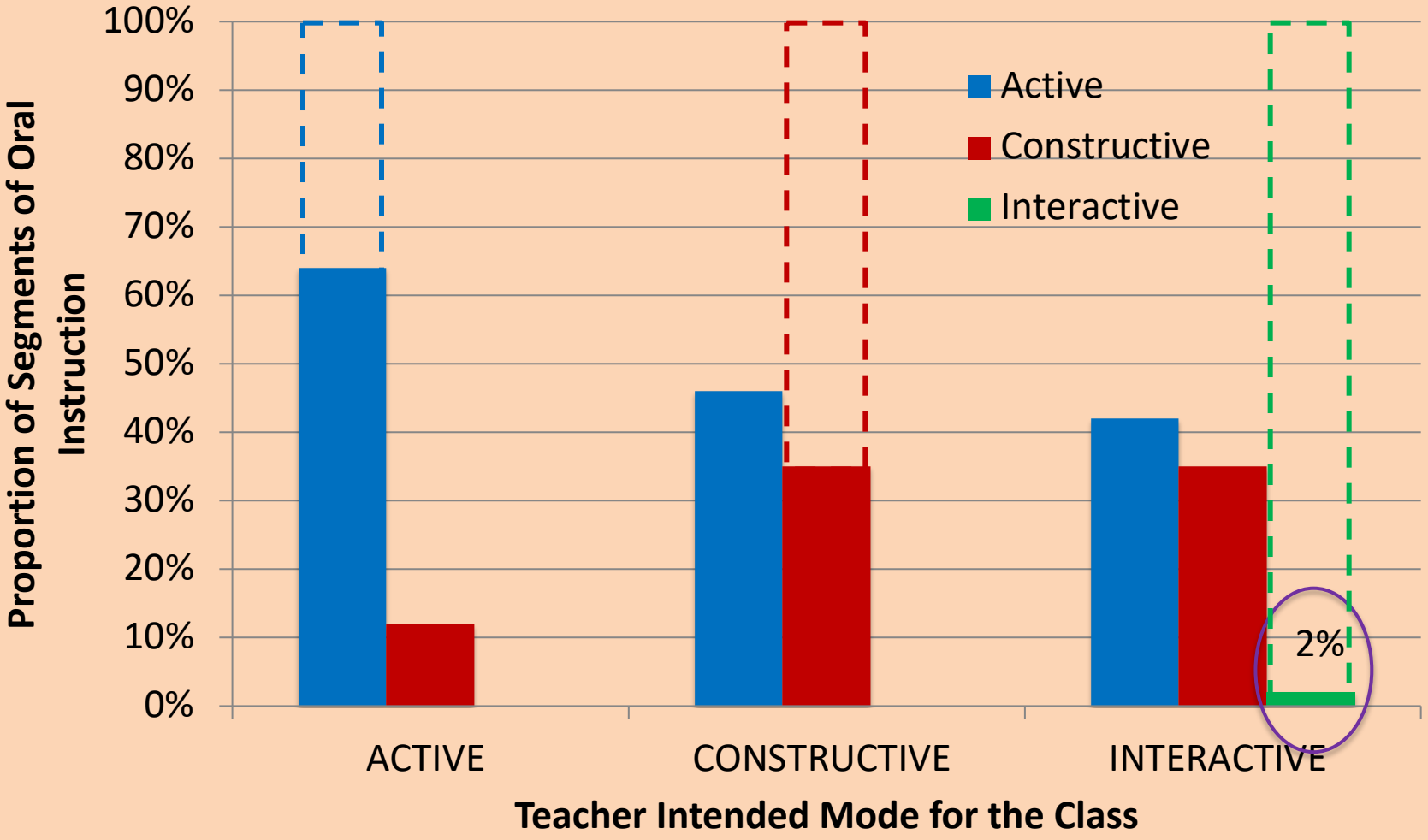
- So we know teachers were biased in using more manipulative/Active verbs.
- But were they accurate?
- Accuracy means: Did they design the appropriate activities for a class they had intended to be at a specific ICAP mode?
- That is, does the mode of the VERB match the mode of the class (as intended by design)?
- We use “mode of the class” as the criterion to assess their accuracy b/c the teachers’ post-test assessment is for a class.

Verbs in Written Directive for each Intended Class Mode: Reflecting teachers' design accuracy



Verbs in Oral Directive while Teaching Implement Activity in Real Time for Each Intended Class Mode

Same pattern of results as for written directives, but Oral was worse in each mode. Most accurate in *Active*, least accurate in *Interactive.*



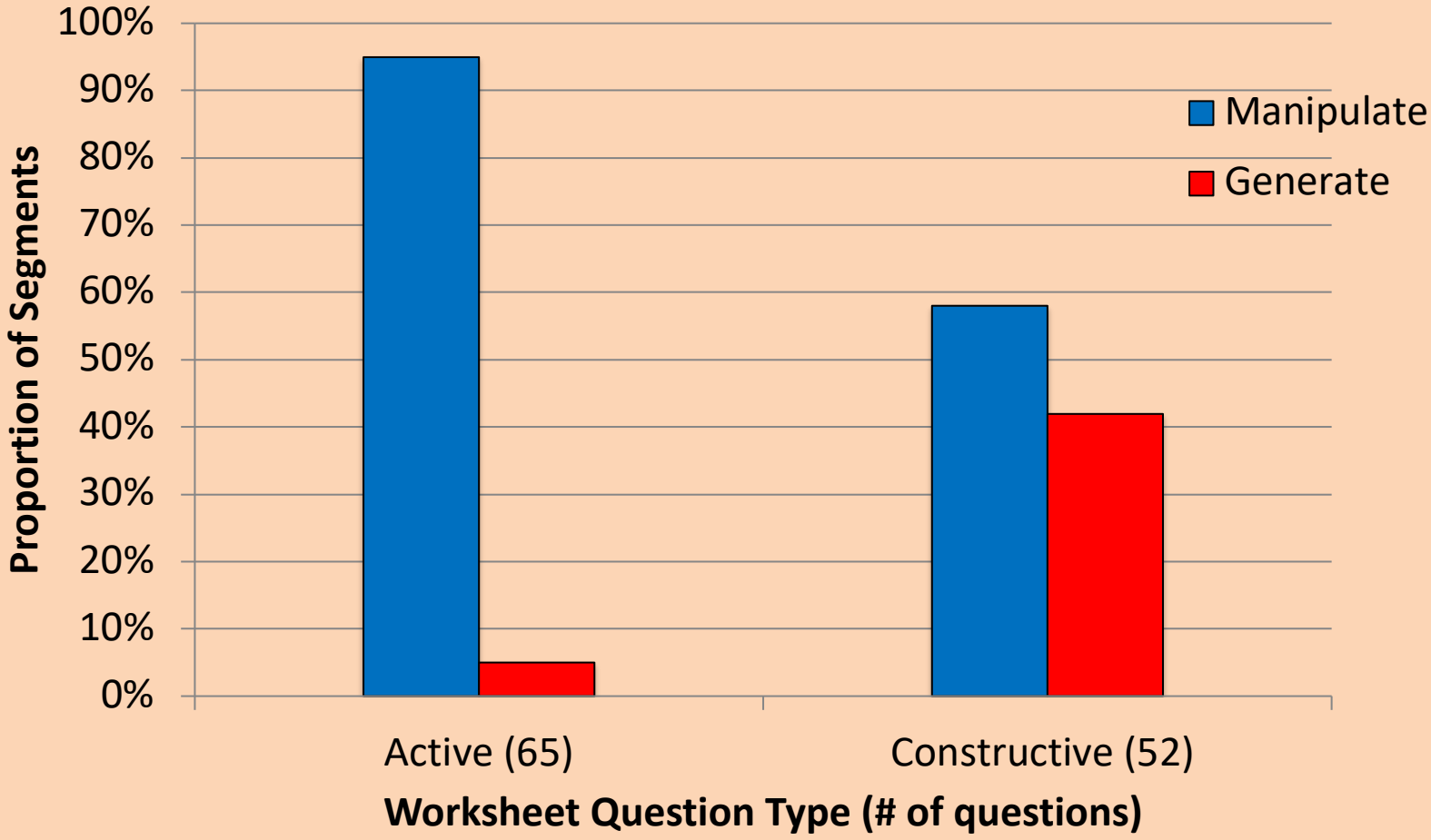
(3) Student Enactment: Did the students respond in the mode requested by the activity questions?

- Overall, how did students enact their responses to worksheet questions and problems?
- We coded 754 responses embedded in 65 Active, Constructive, and Interactive worksheets.
- [Too hard to code for *co-generation* in worksheets, because we cannot tell what contribution was made by who.]
- So we only coded for Manipulative and Generative Ss enactments.
- Then we compared the mode of the questions and the mode of the responses.

For explicit questions embedded in the worksheets, there were 65 *Active* Q & 52 *Constructive* Q:

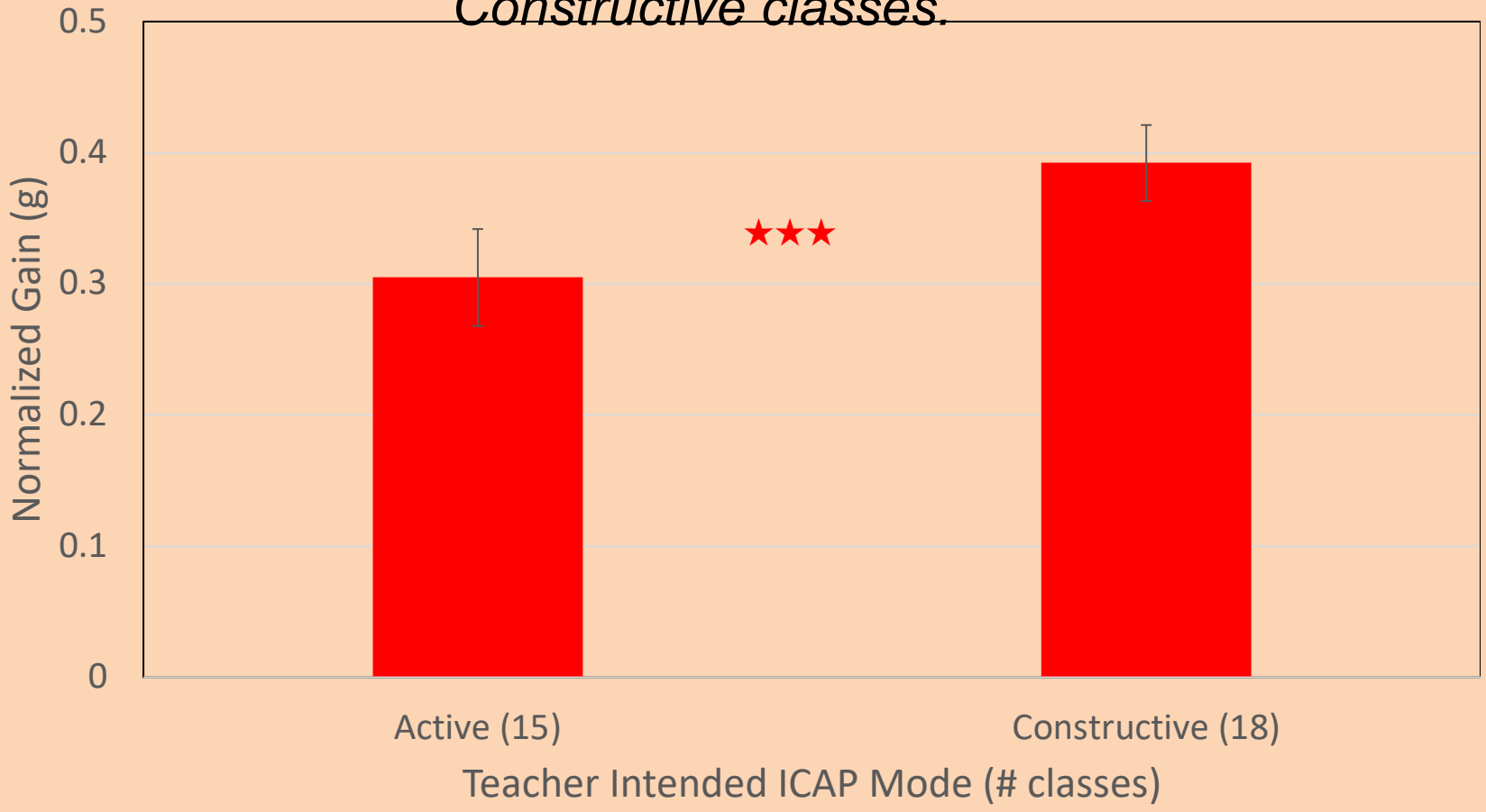
How did Students enact/respond to specific worksheet questions

- Students were significantly more likely to answer *generatively* (42%) when a *Constructive* question was asked than an *Active* Q (5%).
- Important to design *Constructive* questions==> Promising!



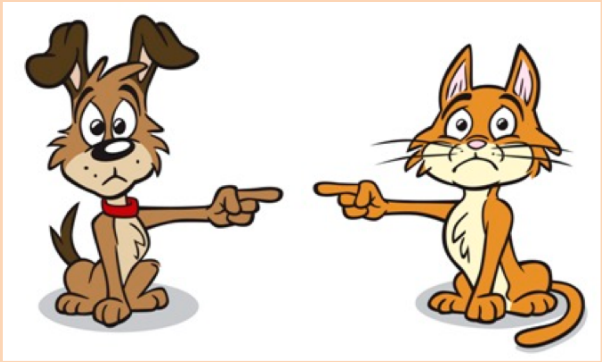
(4g) Learning outcomes:
How does enactment translate to learning?

Pooling all classes of same mode, ignore *Interactive* mode:
Despite teachers' in accuracies & minimal improvement in their design and implementation, Ss' learning signif.greater in the *Constructive classes.*



Remaining Challenge

- We showed earlier that teachers gave very few verbs on *how to collaborate/interact.*
- They used vague verbs such as: “Discuss”, “Share.”
- These verbs only refer to “working with a partner,” they don’t explain *how to work with a partner.*



- Whose fault was it that they did not use proper verbs to explain how to collaborate?

- Turns out it was our fault. We did not give explicit explanation to teachers on *How to teach students how to collaborate in a productive way* (i.e., in a way such that both partners are co-generative).

Using ICAP modes to define collaborative dialog patterns,
We've identified many alternative patterns of interactions that are *not* co-generative (or co-constructive), maybe 90% are not.
ICAP's prediction is based only on co-constructive kind of interactions.

1

P—P A—A C—C

***Parallel* working together,**

- *Passively* working side by side,
- Each partner manipulating *actively*,
- Each generating without consideration of the partner's contrib

3

C↔A C↔P A↔P

One partner *dominates*:

- *They are interacting but only* one partner is generative or manipulative,
- the other partner is manipulative or passive (e.g. agree/*active* or zone-out);

2

A↔A A↔P

Non-constructive interaction (green arrows):

- Each is manipulating & interacting (e.g. passing a mouse back-n-forth; copying each other's answers)
- One is manipulative, other agrees

4

C ⟷ C

Optimum Interacting (co-constructive):

- Both partners are *constructive (builds on own, and*
- each partner builds-on/ extends partner's contributions.

Not yet clear how we can train or enable the optimum co-constructive dialog

Summary of main findings & lessons learned for doing translation work

- ICAP is a theory suggesting that we should engage students at the two higher modes: *Constructive* and *Interactive*
- Teaching Ts to implement ICAP in the classrooms, we found that Ts do *not* design enough *Constructive* activities. Instead, they designed mostly *Active* worksheets. They need more training.
- Students also respond more often in an *Active/manipulative* mode rather than a *Constructive/generative mode.*
- However, even though teachers' improvement in their activity design was modest, students did learn significantly more from the *Constructive* classes than the *Active classes.*
- Even though students do not respond in the same mode as the mode of the question, they are still more likely to respond generatively to *Constructive questions* (42% of the times) than *Active* questions (5% generative responses to Active questions).

Summary continue…

- Our study also reveals other results: E.g., Teachers had weakest understanding of collaborative/*Interactive* activities because our definition of co-generative interaction is difficult to achieve (& our instruction was inadequate).
- Challenge remain: How to explain to teachers so they can
  - teach their students how to collaborate;
  - & recognize how their students are collaborating.

Relevant ICAP papers

- Chi, M.T.H. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science,* 1(1), 73-105.
- Fonseca, B. & Chi, M. T. H. (2011). The self-explanation effect: A constructive learning activity. In Mayer, R.E. & Alexander, P.A. (Eds.), *The Handbook of Research on Learning and Instruction.* New York, NY: Routledge Taylor and Francis Group. (pp. 296-321).
- Menekse, M., Stump, G., Krause, S. & Chi, M. T. H. (2013). Differentiated overt learning activities for effective instruction in engineering classrooms. *Journal of Engineering Education,* 102, 346-374.
- Chi, M. T. H. & Wylie, R. (2014). ICAP: A hypothesis of differentiated learning effectiveness for four modes of engagement activities. *Educational Psychologist, 49, 1-*25.
- Chi, M. T. H. & Menekse, M. (2015). Dialogue patterns in peer collaboration that promote learning. In Resnick, L. B., Asterhan, C., & Clarke, S. (Eds.), *Socializing Intelligence Through Academic Talk and Dialogue* (pp. 253-274). Washington, DC: AERA.
- Chi, M.T.H., Adams, J., Bogusch, E. B., Bruchok, C., Kang, S., Lancaster, M., Levy, R., Li, N., McEldoon, K., Stump, G. S., Wylie, R., Xu, D., & Yaghmourian, D. L. (2018). Teachers translating a theory of cognitive engagement into practice. *Cognitive Science, 42,* 1777-1832.

ICAP

Interactive Constructive
Active Passive