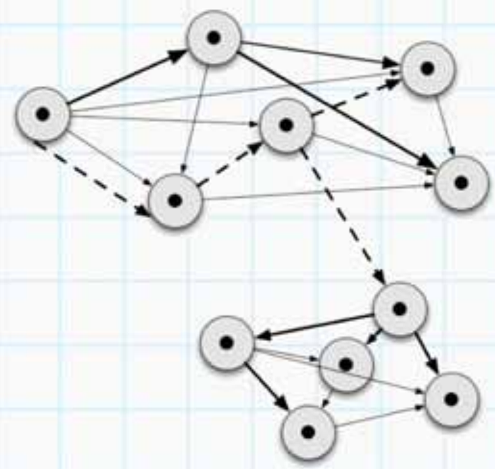
Cognitive Models Matter for Creating and Interpreting Classroom Measurements



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Andy Elby
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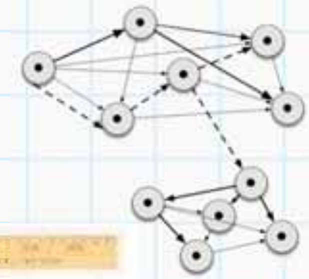
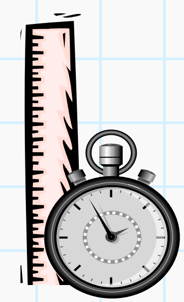
Supported by NSF REC grant #0087519

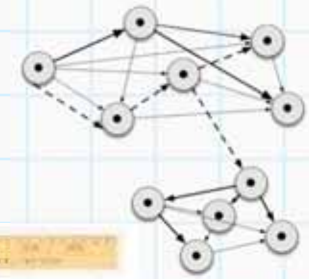
Overview



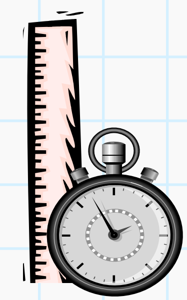
- Overviewing Assessment
- A Model of Student Thinking
- Implications for our Instructional Goals
- Implications for Assessment: General
- Implications for Assessment: Specific
  - Our exams
  - The MPEX
  - MPEX II
  - Splits on the FCI



Overviewing Assessment

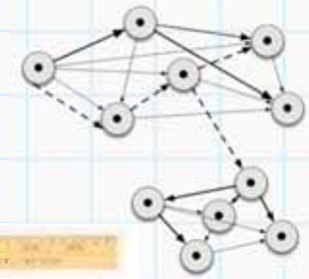


- What are we assessing?
  - Our students
  - Our instruction
- Why are we assessing?*
  - Formative
  - Summative

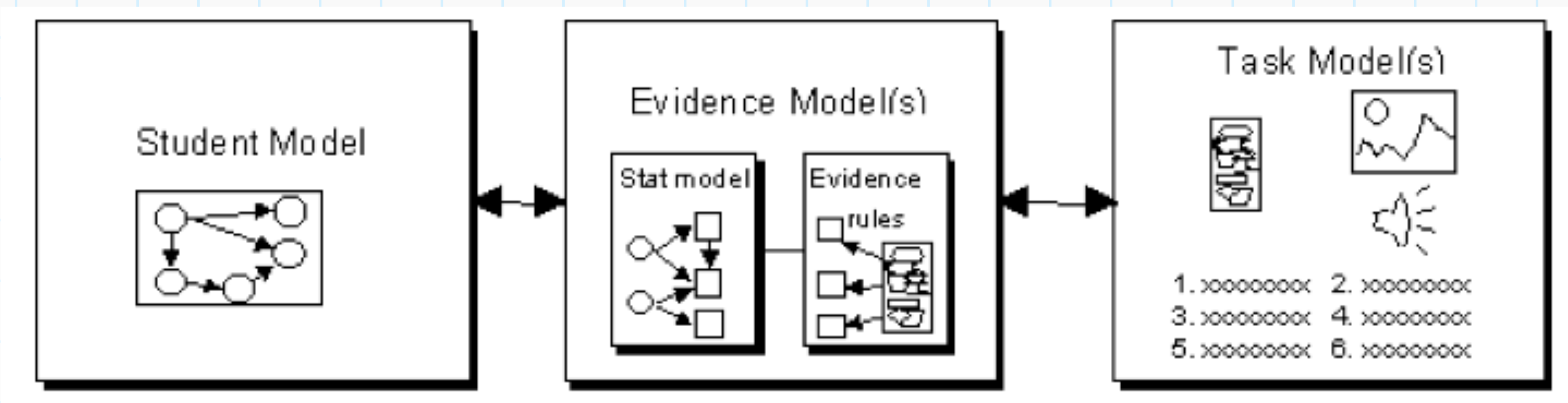


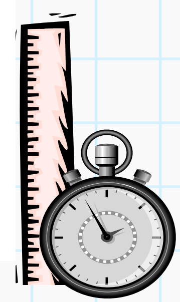
** P. Black and D. Wiliam*

A Model of Assessment*



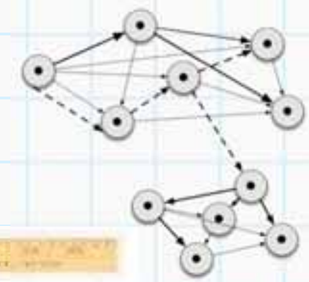
- What are we trying to get at?
- What observations constitute evidence?
- What tasks elicit relevant behavior?



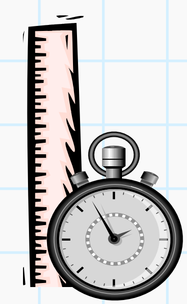


** R. J. Mislevy, L. S. Steinberg, and R. G. Arnold*

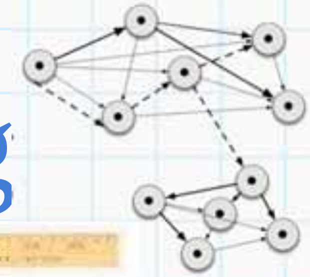
Model elements

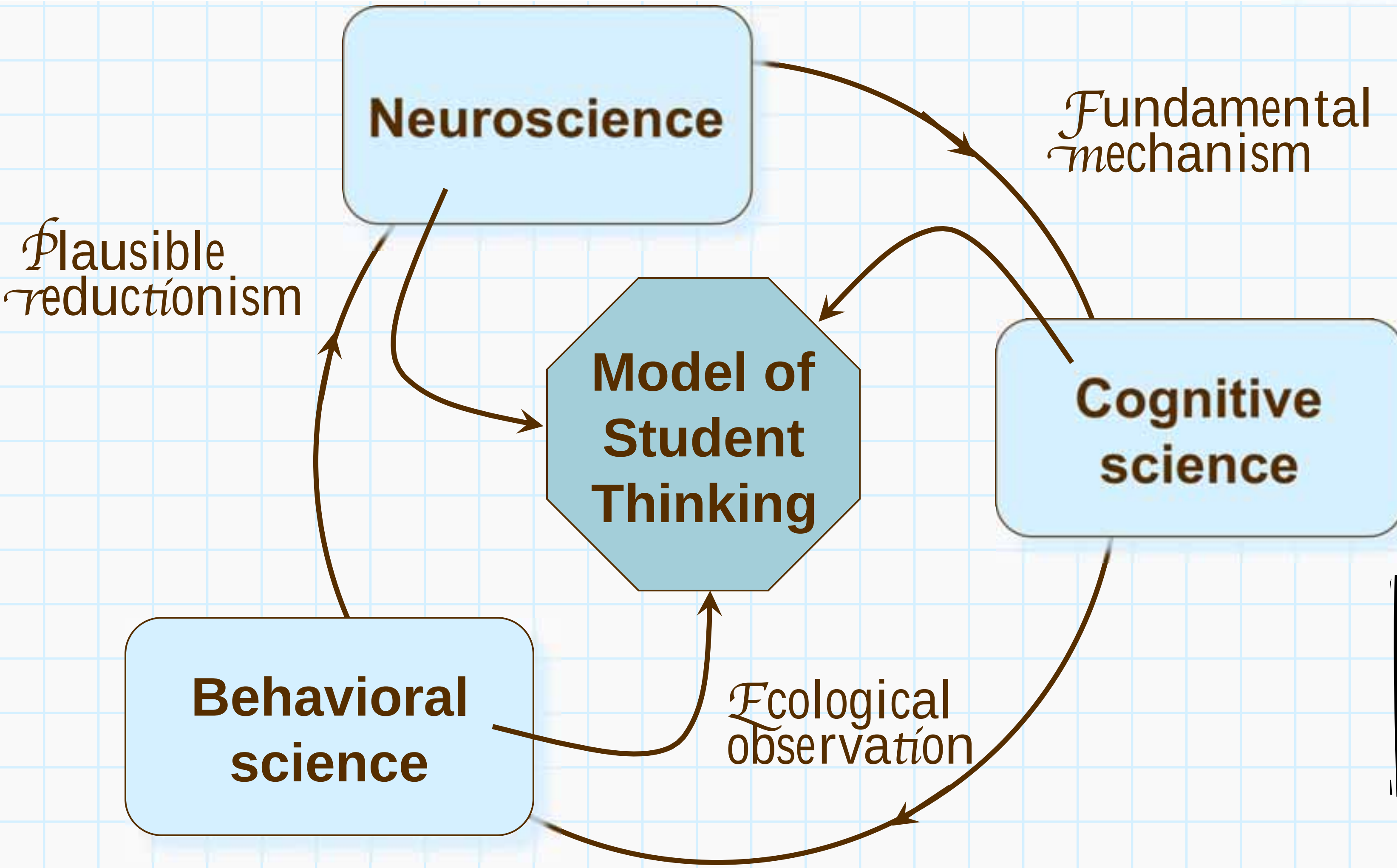


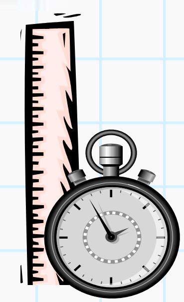
- What are we trying to get at?
  - Model of the content knowledge
  - Model of the student
  - Instructional goals
- What observations constitute evidence?
- What tasks elicit relevant behavior?



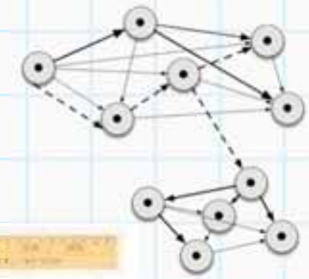
A Model of Student Thinking



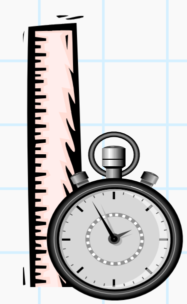




Fundamental ideas of the model



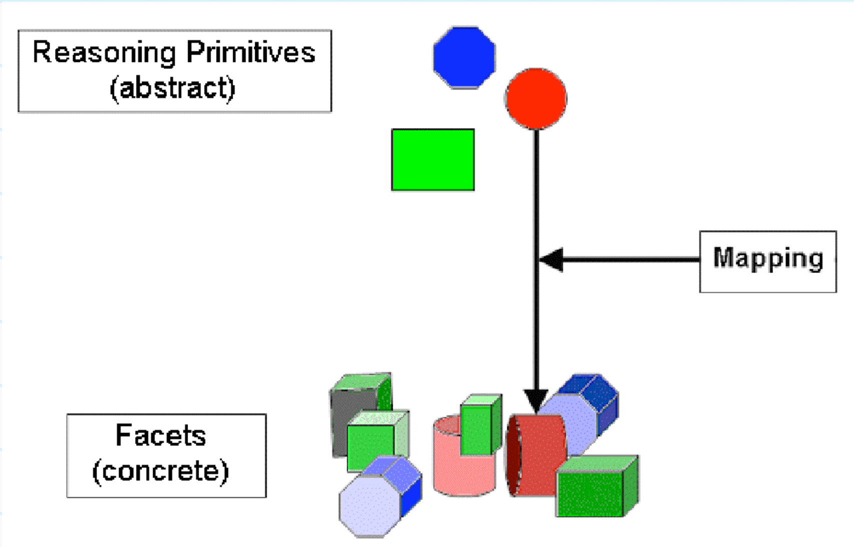
- Constructivism
- Resources
- Compilation (binding)
- Association
- Control



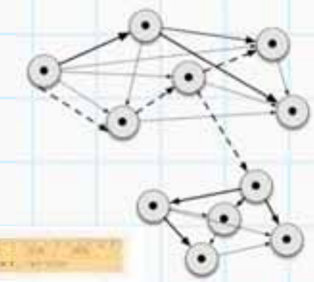
** Many researchers: see Redish Varenna lectures for refs*

Constructivism

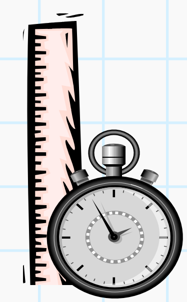
- The basic principle in the model is *constructivism*:
  - People interpret what they see in terms of what they know and create new knowledge by blending and transforming existing knowledge.
- To make use of this, we have to know the elements our students are working with and how they go together — *fine-grained constructivism*.

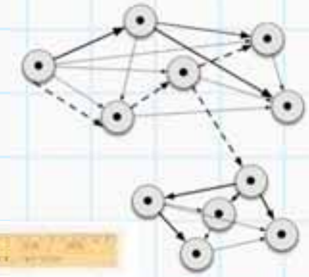


Resources and Binding



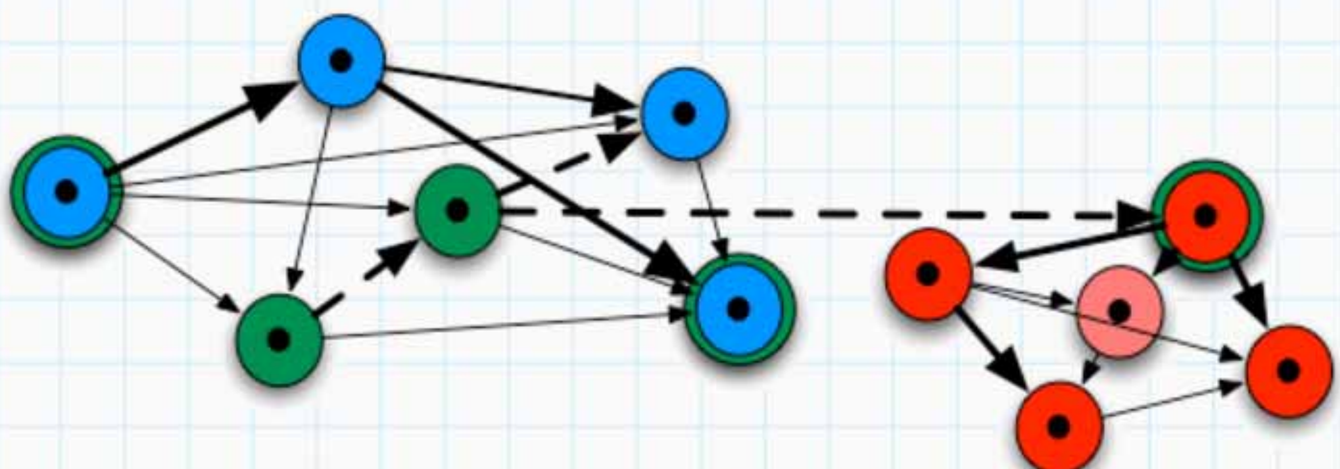
- *Resource* — a basic knowledge element, typically one that appears irreducible to the user.
- *Binding (Compilation)* — when a group of knowledge elements become tightly associated through experience, they may be bound (compiled) so they appear to a user to be a single, irreducible element (e.g., a cup of coffee or the information in a graph).

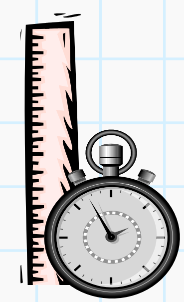




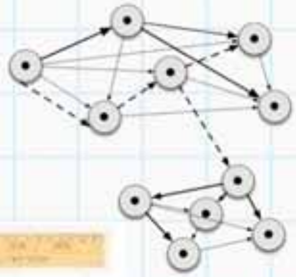
Associations

- Knowledge elements become linked through experience. Activating one resource may lead (with some context-dependent probability) to the activation of other resources (*spreading activation*).

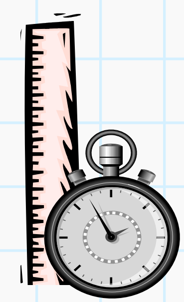




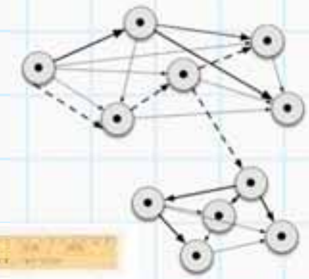
Control



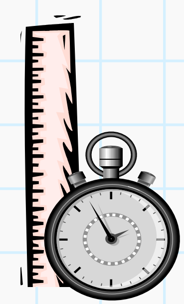
- Neurons have two fundamental properties that determine the structure of the cognitive system:
  - feed-forward / feed-back
  - excitatory / inhibitory
- Together these lead to control structures that at all levels, may enhance or suppress activation paths.



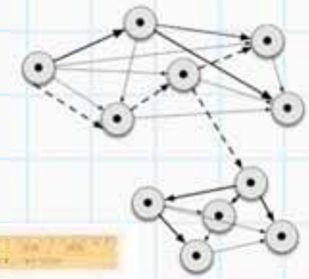
Selective Attention / Framing



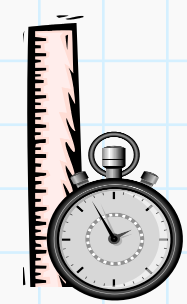
- At the highest level, control is implemented by selective attention through a process we call *framing*.
  - The world has too much stuff to pay attention to at any one time.
  - We organize what we pay attention to in response to cues in the environment and our experience. (This is the process that implements context dependence.)
- *Framing* = decision as to “What’s going on here? What do I need to do / pay attention to?”



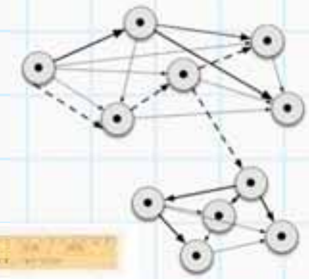
Implications of the model for our Instructional Goals



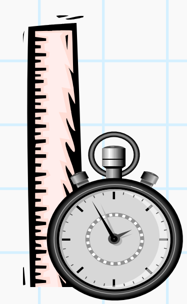
- It's not enough to know what knowledge students have.
- We need to know when (under what circumstances) they activate it.
  - Is it automatic? (Binding)
  - What goes with what? (Associational Patterns)
  - What's appropriate when? (Framing)



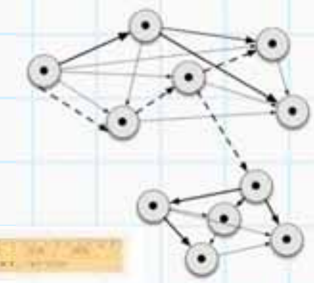
Implications for our Instructional Goals



- Reform I
  - – Building concepts
- Reform II
  - – Building coherence
  - – Building physical intuition
- Reform III
  - – Transforming how we see and create our instructional environments

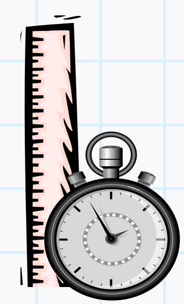


Implications for Assessment: General

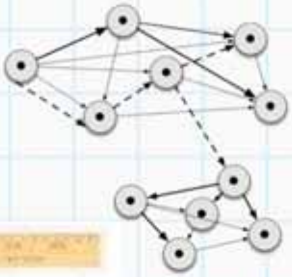


- We need to understand where our students start from.
- We need to understand the components of t
  - This is harder than it looks.We may have bound components so tightly they look trivial to us.
- We need to understand what our students expect and how they frame their classroom activities.
- We need to design specific tasks that elicit the behavior we want to probe.

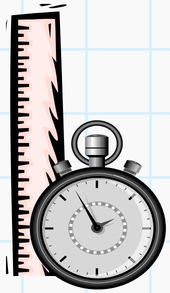
Value of pre-post testing (Hake. PhysLRNR)



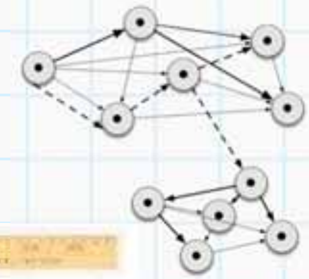
Implications for Assessment: Specific



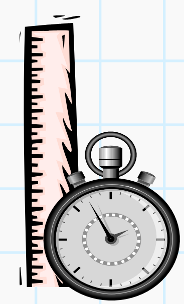
- Exams: Unpacking tasks
- The MPEX: Probing framing
- MPEX II: Designing more appropriate tasks
- Splits on the FCI: Probing intuition building



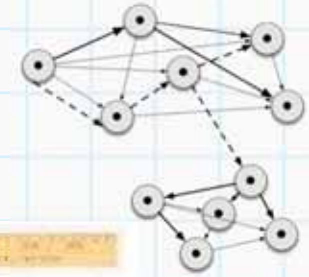
Exams: Unpacking tasks



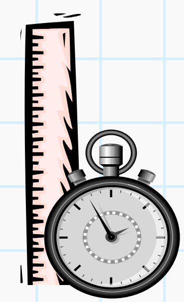
- There are many examples how a fine-grained constructivist model changes the way we think about how to test our students.
  - increased importance of formative assessment
  - probing responses to un- or differently-cued situations
  - creating tasks that test process or intuition

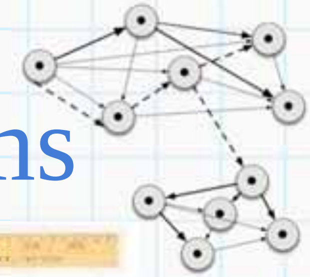


Example:
Are they building a mental picture?



- We often try to help our students solve physics problems by telling them “Draw a picture.”
- What we really mean (but have compiled for ourselves) is “Make a mental picture of the physical situation, run it, and decide what’s important and what’s not.”
- Many of our students don’t understand that this is what we intend. They frame the task as one component of something they have to do to get full points on a problem, not as something that helps them solve it and evaluate their solution.





Representation Translation Problems

- Two carts on an air track are pushed towards each other. They bounce off each other elastically. Identify which graph is a possible display of that variable as a function of time.

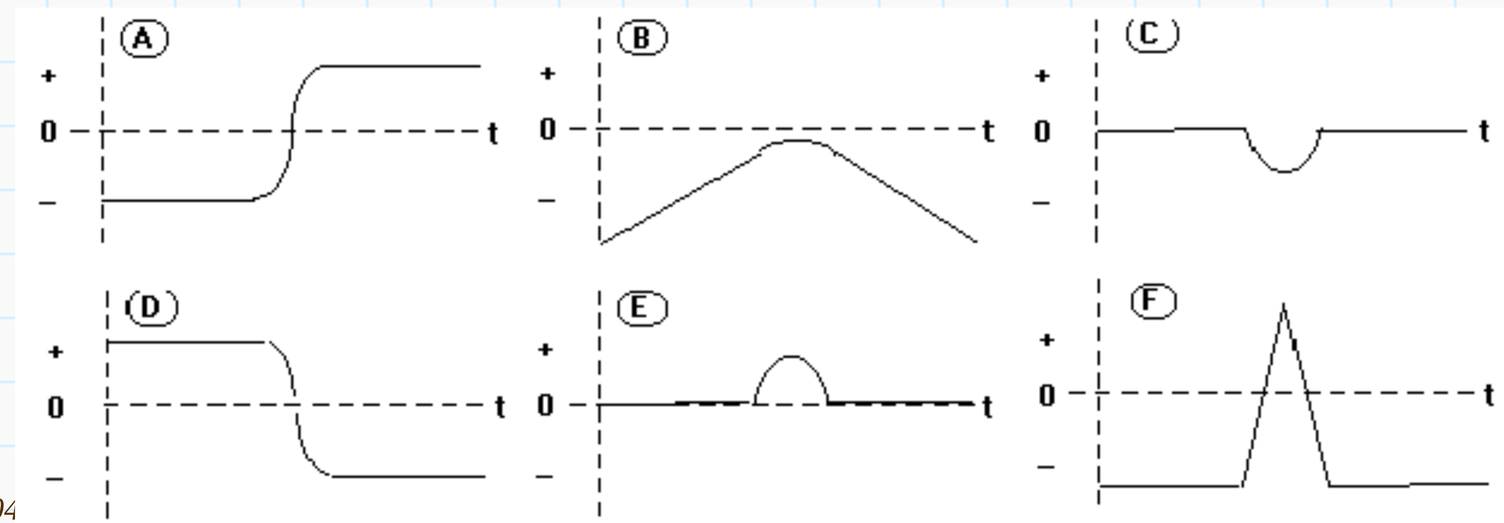
a. the momentum of cart 1

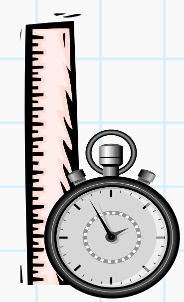
b. the force on cart 2

c. the force on cart 1

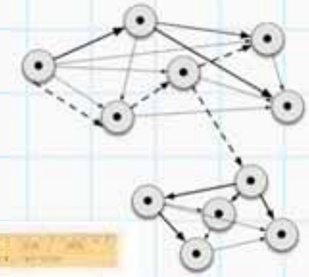
d. the position of cart 1

e. the position of cart 2

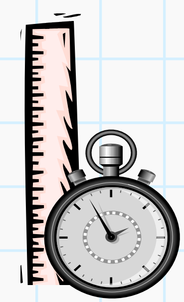




The MPEX: Probing Framing



- The Maryland Physics Expectations Survey (MPEX) was created to identify student expectations of what they would have to do in the class (how they framed it).
- Looked for statements about
  - Concepts
  - Coherence
  - Reality
    (Link to everyday experience and intuition)



MPEX Statements

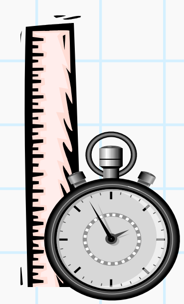
Data: Traditional class
Calculus based physics

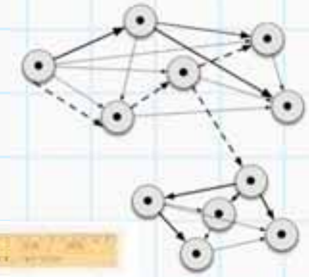
UMd, N~500
Favorable/Unfavorable

- Knowledge in physics consists of many pieces of information each of which applies primarily to a specific situation.
  (Pre: 37%/25%, Post: 29%/36%)

- My grade in this course is primarily determined by how familiar I am with the material. Insight or creativity has little to do with it.
  (Pre: 33%/38%, Post: 37%/30%)

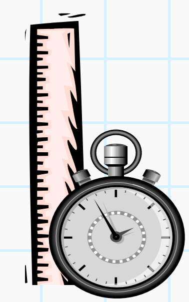
- To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.
  (Pre: 46%/21%. Post: 43%/26%)



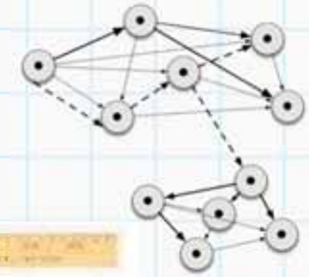


Limitations of the MPEX

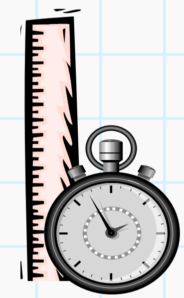
- Validation interviews (~100 hours) show that the students understand the questions and interpret them correctly.
- But the task only activates “what they think they think” — not what they do (or even “what they think they would choose to do”)
- More sharply designed “task choice items” gets more directly at their framing of tasks in a physics class.



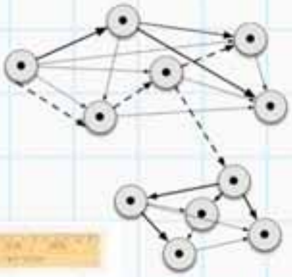
MPEX II



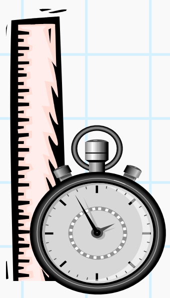
- For the algebra-based physics class, the MPEX was modified
  - to reduce the emphasis on equation use
  - to provide tasks that activate more in detail what it is that students think they might actually <u>do</u> to succeed in their physics class.



Scenario items



- By creating scenarios, we try to activate the student's sense of actually being in a problem-solving situation.
- This should activate memories (and projections) of actual situations and allow students to more directly compare the item with their personal experiences.



- Two students are talking about their experiences in class:
  - *Meena:* Our group is really good, I think. We often spend a lot of time confused and sometimes never feel like we have the right answer, but we all listen to each other's ideas and try to figure things out that way.
  - *Salehah:* In our group there is one person who always knows the right answer and so we pretty much follow her lead all the time. This is a great because we always get the tasks done on time and sometimes early.

a) I agree almost entirely with Meena.

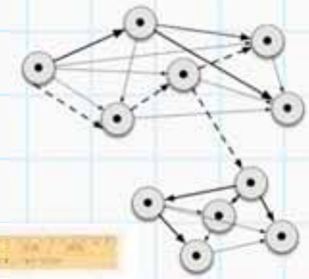
b) Although I agree more with Meena
I think Salehah makes some good points.

c) I agree (or disagree) equally with Meena and Salehah.

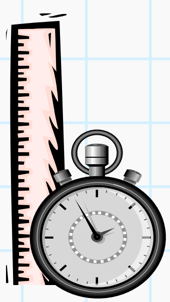
d) Although I agree more with Salehah,
I think Meena makes some good points.

e) I agree almost entirely with Salehah.

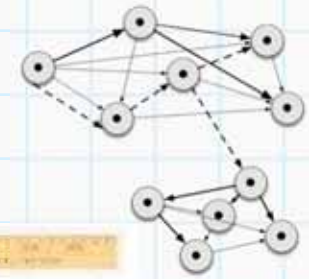
Split Tasks on the FCI: Intuition Building



- Since our model leads us to instructional goals that include intuition building, it does not suffice to have students "know" the expert conceptual "facts".
- We want them to integrate and reconcile that knowledge with their everyday experience.
- This led us to adopt the "split" task of Dancy, Elby, and McCaskey as part of our evaluation for our current project.



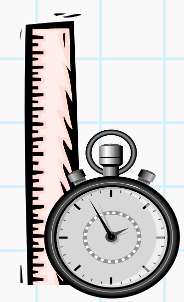
“Splitting”



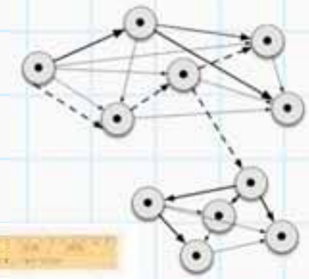
- FCI given to my algebra-based Physics II class at start of second semester.
- Students (N~160) included 1/3 from traditional instruction, 2/3 from our reformed instruction.
- Instructions:

“Please **circle** the answer
that makes the most intuitive sense to you.

Please draw a **square** around the answer
you think scientists would give.”



A typical split



4. A large truck collides head-on with a small compact car. During the collision:

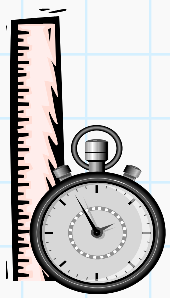
(A) the truck exerts a greater amount of force on the car than the car exerts on the truck

(B) the car exerts a greater amount of force on the truck than the truck exerts on the car

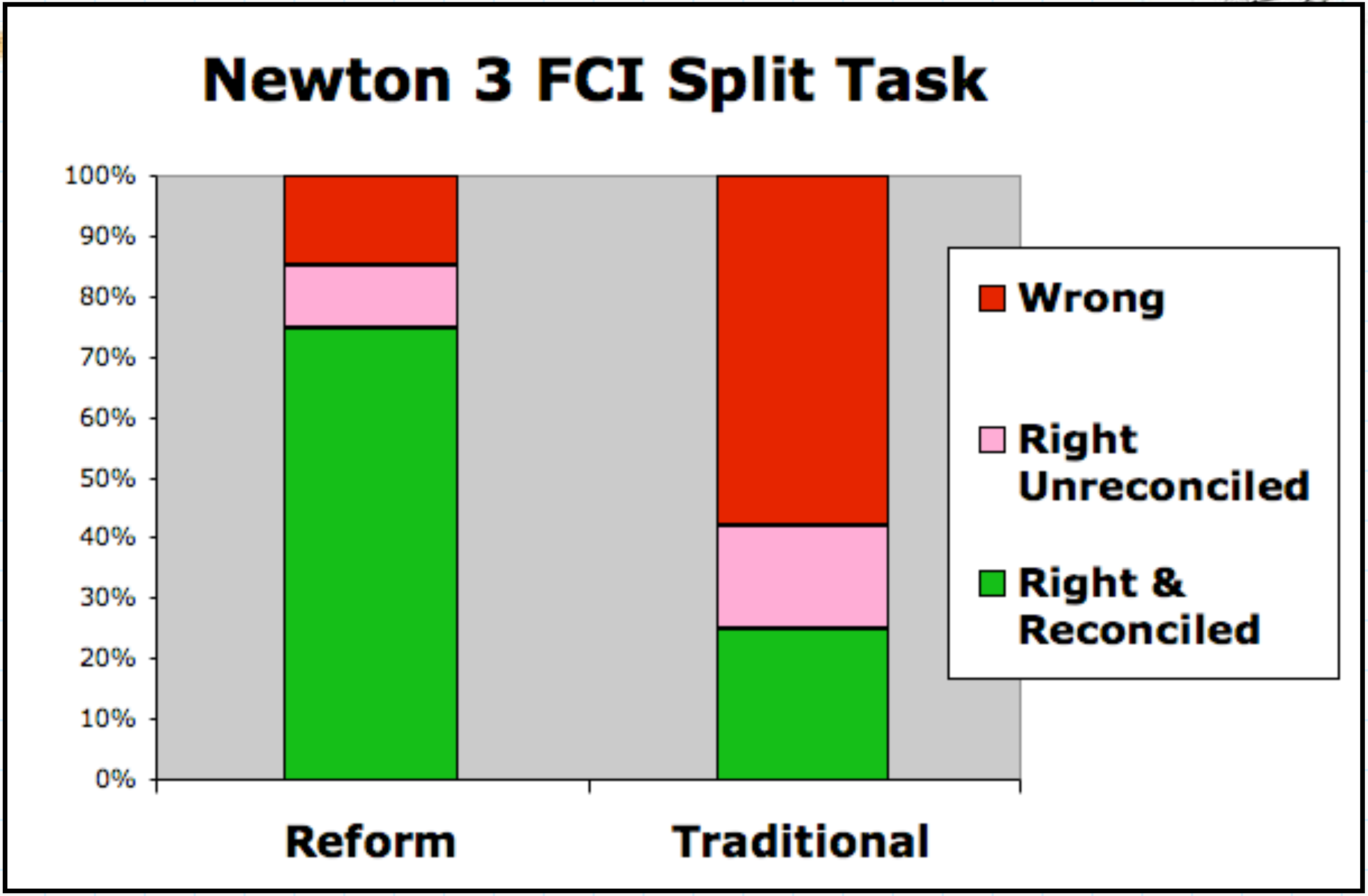
(C) neither exerts a force on the other, the car gets smashed simply because it gets in the way…

(D) the truck exerts a force on the car but the car does not exert a force on the truck

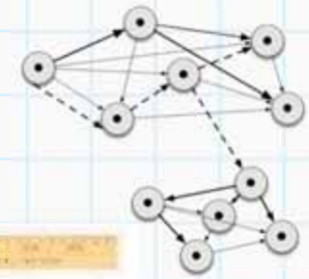
(E) the truck exerts the same amount of force on the car as the car exerts on the truck



Results


Newton 3 FCI Split Task
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Reform
Traditional
Wrong
Right Unreconciled
Right & Reconciled

Conclusions



- Assessment is a complex issue that depends on many things:
  - What you want to assess
  - What your purpose is in assessing
- Understanding “how your students work” helps you understand
  - What might be appropriate goals for instruction
  - How you might design assessments that can play a role in achieving those goals (formative)
  - How you might design appropriate assessments to see how well those goals are met (summative)