

What the “FCI invalidity” results really show

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“FCI invalidity” results?

- Steinberg & Sabella (TPT, 1997)
 - FCI 3rd law items vs. Attached carts (free response)
- Sanjoy Mahajan (AAPT, 2000)
 - Tutoring sessions with Cambridge students (FCI ~ 90%) reveal deep conceptual difficulties.
- Laura McCullough (AAPT, 2001)
 - Gender-conscious versions of FCI questions (e.g., “bird drops fish” vs. “airplane drops bowling ball”) lead to different answers.

2

Possible interpretation of these results

- **The FCI inaccurately measures whether students have certain force concepts.***

*Not necessarily the views of the researchers who obtained those results.

- “This rewording uses a better context for testing Newton’s 1st law.”
- “For that student, the FCI gave a false positive on Newton’s 2nd law.”

Could we make a more valid FCI?

3

Analogy to illustrate our central point:

2 assessments of voters’ beliefs about tax levels

- Should taxes & spending go up, down, or stay the same for:
 - Education
 - Medicaid
 - Military pay
 - ...

- Overall, should taxes go up, down, or stay the same?

4

Analogy to illustrate our central point

Does inconsistency between the blue and orange assessments indicate that one is flawed?

- YES, IF... voters “have” a dominant **belief** about tax levels.
 - One assessment failed to reveal that belief.
- NO, IF... voters’ views about taxes are context-dependent.
 - Both assessments provide insights into those context dependencies.

Judgments of assessment “validity” depend on the cognitive framework we adopt.

5

Our main point

Do the “FCI invalidity” results really indicate FCI invalidity?

- YES, IF... students “have” a dominant set of **(mis)conceptions**.
 - One of the assessments didn’t reveal the student’s true conceptions.
- NO, IF... students’ conceptual knowledge depends on context.
 - The FCI and “contradictory” assessments both provide information about those context dependencies.

Answer depends on cognitive framework.

6

Secondary point

When triangulated with other data, “FCI invalidity” results count as evidence for using a **primitives/resources framework** instead of a **misconceptions framework** to describe students’ conceptual knowledge.

--Argued in paper; no time here--

7

Misconceptions framework: Overview

- Students’ intuitive ideas consist mainly of alternative beliefs or theories, e.g.,
 - *In a collision, heavier object exerts more force*
 - *In a collision, faster object exerts more force*
- **Learning:** Correct conceptions are introduced, misconceptions become marginalized.
 - Fluctuations are possible.
- **Optional assumption:**
 - Either the correct conception **or** a given set of misconceptions eventually becomes dominant.

8

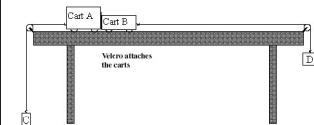
Primitive/resources: Overview

- Much intuitive knowledge consists of fine-grained mini-generalizations, *primitives*.
 - Examples referring to an interaction between A and B:
 - More agency from A
⇒ More reaction from B.
 - “Two-way street” (mutuality)
 - Prims are neither right nor wrong.
- **Context-sensitive triggering.** Can lead to dynamic, shifting conceptualizations.
- **Learning:** Structuring & remapping (not replacing) prims.

9

Applying frameworks to “FCI invalidity” result

Steinberg & Sabella free response item:
Identify the horizontal forces acting on A and B, and rank those forces.

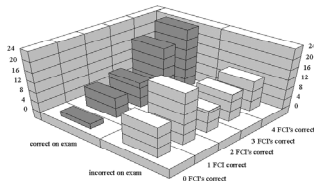


vs.

The 4 FCI items about

10

Results



- 1/3 of students who ace all 4 FCI items right got the velcro wrong.
- 1/3 of students who got only 1 FCI item correct got the velcro correct.
- 1/2 of students gave “inconsistent” responses to the velcro item and the FCI item most like it.

11

Do these results indicate FCI invalidity?

- YES, IF... students have a dominant “theory” about interactions, either Newton’s 3rd law or a stable set of misconceptions such as
 - *Heavier object exerts more force*
 - *Faster object exerts more force*
 - *The bigger interaction force points in the direction of motion.*
- The FCI (and/or the velcro item) failed to reveal the student’s true theory.

1

2

Do these results indicate FCI invalidity?

- NO, IF...students' conceptual knowledge is context dependent, e.g.
 - Unsettled, fluctuating (mis)conceptions.
 - Loosely structured primitives, e.g.,
More agency from A
⇒ More reaction from B.
- The “inconsistencies” reflect real context dependence in their knowledge.

1

3

Another example:

- Sanjoy Mahajan (AAPT 2000) compares FCI scores to free responses during tutoring.
Example:

You drop a steel ball from a height of one or two metres. It lands on a scale and bounces up to nearly the original height. (Neglect air resistance.) Draw free body diagrams for the ball at four times:

- (1) holding it,
- (2) falling,
- ➡ (3) motionless on the scale (namely, just as it starts its upwards journey); and
- (4) rising.

vs.

Overall FCI scores

14

Results

- “FCI is too easy for Cambridge students.” Pre-instruction:
 - Range = 83% → 100%
 - Average = 92%
- **But**, on bouncing problem, “wildly incorrect” diagrams.
 - *Most common answer:*
Upwards ‘reaction’ force $R = mg$
 - *Common reasoning:*
 - zero force → zero velocity
or
 - [Generalizing from high school]
Reaction forces are mg ...

15

Do these results indicate FCI invalidity?

- YES, IF... the student has a dominant theory such as
 - “Aristotelean” view that force is proportional to velocity
 - Forces get used up
(e.g. force is like energy)
- NO, IF... different problem contexts trigger different conceptual resources.
 - Possible activated primitives:
Blocking, bouncing, balancing
(a momentary state of equilibrium)

16

Conclusions

- **Main point:** Cognitive framework used for analyzing students' knowledge affects how “FCI Invalidity” results are interpreted.
 - *Two-edged sword:* Same reasoning that “saves” the FCI from invalidity also implies that high FCI scores do not necessarily indicate a full Newtonian understanding.
 - Saying “Success on the FCI is not enough” has implications for cognitive models, not just for testing methods.
- **Secondary point (argued in paper):** Some “Invalidity” results support a primitives and NOT a misconceptions framework.
 - <http://lrpe.umephy.maine.edu/research/>
 - <http://www2.physics.umd.edu/~elby/>