Determining a Hierarchy of Correctness Through Student Transitions on the FMCE

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Background

Purpose: To determine a hierarchy of "correctness" on a commonly used multiple-choice assessment in introductory physics courses.

- Data were collected from over 7,000 students
- We omit *J* as an answer choice because it provides no understanding of a student's understanding.

Item Response Theory

- **Assumption:** Students who choose correct responses on most questions are more likely to choose more sophisticated incorrect answers than students who choose few correct responses [2]
- 2-parameter nested logit model for a multiple choice test [3,4]

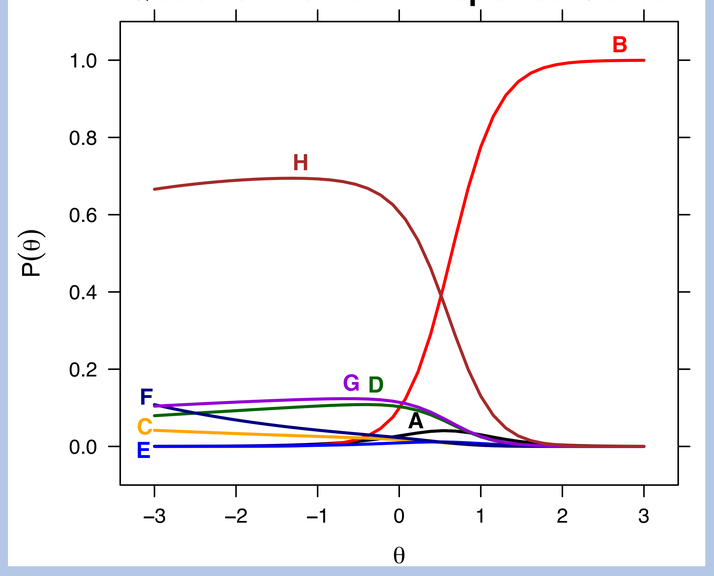
$$\textbf{Correct: } P(\theta) = \frac{1}{1+e^{-a(\theta-b)}}$$

- *a*: related to slope of the item response curve (IRC)
  - Discriminates student understanding
- *b*: Difficulty of the question
  - Right shift means harder question
  - Left shift means easier question

$$\textbf{Incorrect: } P_k(\theta) = \left(1 - \frac{1}{1+e^{-a(\theta-b)}}\right) \frac{e^{a_k(\theta-b_k)}}{\sum e^{a_i(\theta-b_i)}}$$

- Correctness of answer choices determined by higher a_k value

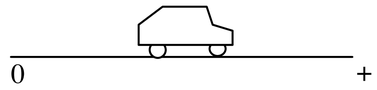
Question 18 Item Response Curve



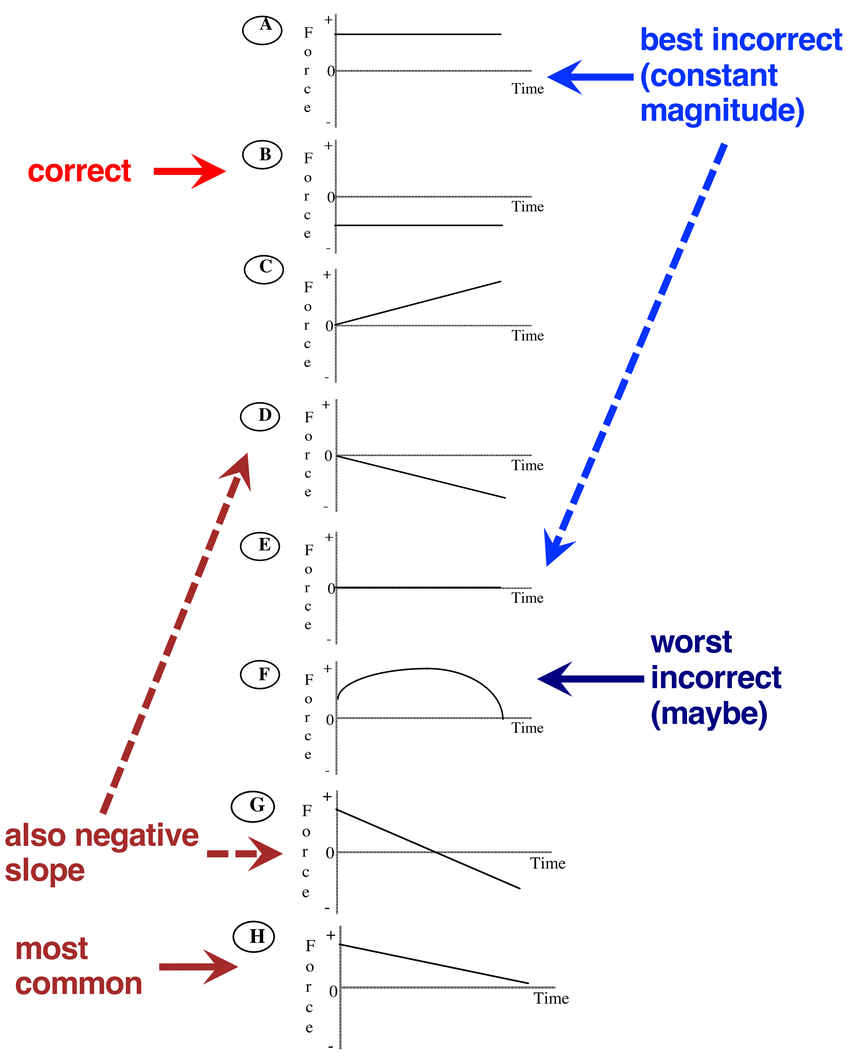
$$B > A > D = G = H > C > F$$
$$a_k: \; 0 > -1.43 = -1.47 = -1.52 > -1.87 > -2.11$$

Force and Motion Concept Evaluation [1]

Assume that friction is so small that it can be ignored. A force is applied to the car. Choose the one force graph (**A** through **H**) that for each statement below which could allow the described motion of the car.



__18. The car moves toward the right and is slowing down at a steady rate (constant acceleration).



Hypotheses

H_0: The number of transitions from one answer choice to another is the same in both directions

H_a: More students transition in one direction between two answer choices than in the other

McNemar-Bowker Chi-Square Test for Asymmetry

- **Assumption:** Students are more likely to choose more sophisticated responses after instruction than before instruction.
- Using the False Discovery Rate (FDR) correction, the adjusted *p*-value determines whether or not a transition is statistically significant [5,6]

Pretest \ Posttest	Q18	A	B	C	D	E	F	G	H
	A	4	28	2	9	0	2	4	26
	B	14	717	6	33	5	4	12	87
	C	7	37	6	10	1	4	12	46
	D	16	208	13	87	10	14	63	236
	E	1	11	1	4	2	1	0	8
	F	10	45	3	16	2	16	22	72
	G	22	250	13	59	7	21	93	281
	H	92	1420	52	227	26	72	281	1904

Statistically Significant Transitions		
Response Comparison	Adjusted *p*-value	Percent of Population
B > H	< 0.001	22.3%
B > G	< 0.001	3.9%
B > D	< 0.001	3.6%
A > H	< 0.001	1.7%
B > F	< 0.001	0.7%
B > C	< 0.001	0.6%
E > H	0.01	0.5%
A > G	0.002	0.4%

Statistically Insignificant Transitions		
Response Comparison	Adjusted *p*-value	Percent of Population
G = H	1	8.3%
D = H	1	6.9%
D = G	1	1.8%

$$B > \{H, G, D, F, C\}; \quad D = G = H$$
$$A > \{H, G\}; \quad E > H$$

Unified Ranking

$$B > A > D = G = H$$

Future Research

- Determining the models for each answer choice via interviews
- Synthesize results into a unified ranking system
- Use additional analyses to rank responses with different assumptions

References

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