Applying Cognitive Developmental Psychology to Middle School Physics Learning

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How Can We Measure Qualitative Physics Knowledge?

- Qualitative assessments often focus on misconceptions, but it is useful to assess *missing* conceptions.
- The Rule Assessment Method (Siegler[1]) describes students' conceptual development in multi-factor domains.
  - "Rule levels" form a predictable maturational trajectory for stages of understanding.

How would Rule Assessment be useful to physics educators?

- Rule Assessment can be used to describe stages of learning and effects of instruction.
- Physics concepts are well-suited to this method.

Original Domain: Balance Scale

- Siegler outlined a series of questions to describe children's understanding of the relations between variables.
- Questions sample all combinations of the two factors (mass and distance).

An example balance scale question using the PhET Balancing Act sim:[2]
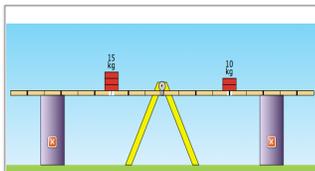
When the supports are removed, what will happen to the balance scale?
   a) Tip Left
   b) Balance
   c) Tip Right

The Rule Assessment Method

- A two-factor domain is made up of psychologically dominant and subordinate factors.
- Six question types can be used to determine students' rule levels.

Balance Scale
Dominant Factor: Mass
Subordinate Factor: Distance

Problem Type	Features	Example	Result
Equal (EQ)	Masses equal Distances equal		Balanced
Dominant (DOM)	Masses different Distances equal		Tips toward greater mass
Subordinate (SUB)	Masses equal Distances different		Tips toward greater distance
Conflict Equal (C-EQ)	Masses different Distances different		Balanced
Conflict Dominant (C-DOM)	Masses different Distances different		Tips toward greater mass
Conflict Subordinate (C-SUB)	Masses different Distances different		Tips toward greater distance

Determining What Students Know

- The Rule Assessment Method assigns students to a rule level by tabulating their results across each problem type.

	Rule Level and Behavior	EQ	DOM	SUB	C-EQ	C-DOM	C-SUB
0	Guess	At chance	At chance	At chance	At chance	At chance	At chance
I	Only notice mass	Correct	Correct	At chance	At chance	Correct	Incorrect
II	Notice distance only if masses are equal	Correct	Correct	Correct	At chance	Correct	Incorrect
III	Notice mass & distance; guess when both factors are different	Correct	Correct	Correct	At chance	Correct	At chance
IV	Solve all problems correctly	Correct	Correct	Correct	Correct	Correct	Correct

Adapting Rule Assessment to New Concepts

- We adapted Rule Assessment for 6th graders learning two-factor physics concepts.

PhET Simulation[2]	Physics Concept	Relationship
Balancing Act	Balance and torque	Torque = mass * distance
Projectile Motion	Projectile motion	Distance = initial speed * hang time
Collision Lab	Inelastic collisions	Momentum = mass * velocity

An Example Case: Collisions

- First, psychologically dominant and subordinated factors must be identified.
- Empirical evidence provided insight into students' learning of these two factors.
- 36 6th graders participated.
  - Conflict Dominant: 16 correct
  - Conflict Subordinate: 8 correct

Collisions
Dominant Factor: Mass
Subordinate Factor: Velocity

Problem Type	Features	Example	Result
Equal	Masses equal Velocities equal		Stick and stop
Dominant	Masses different Velocities equal		Move in the direction of greater mass
Subordinate	Masses equal Velocities different		Move in the direction of greater velocity
Conflict Equal	Masses different Velocities different		Stick and stop
Conflict Dominant	Masses different Velocities different		Move in the direction of greater mass
Conflict Subordinate	Masses different Velocities different		Move in the direction of greater velocity

Future Applications for Physics Education

- Rule Assessment is easily applied from cognitive development to educational research.

- In future studies, the Rule Assessment Method could be applied to a variety of physics concepts. With other assessments or teaching methods, Rule Assessment supports at least three potential categories of investigations:

  1. Reveal students' understanding of a new domain.
  2. Inform instructional decision-making through formative assessment.
  3. A tool for educational research: The Rule Assessment Model can be used to uncover treatment differences in qualitative knowledge when more mathematical tests may not reveal differences.

- We encourage researchers and practitioners to use this technique as a self-contained tool or with other assessments and research methods in physics education. For more information, contact us at hallinen@stanford.edu.

References and Acknowledgements

1. R.S. Siegler, "Developmental sequences within and between concepts." *Monographs of the Society for Research in Child Development*, **46**(2, Serial No. 189), (1981).
2. http://PhET.colorado.edu