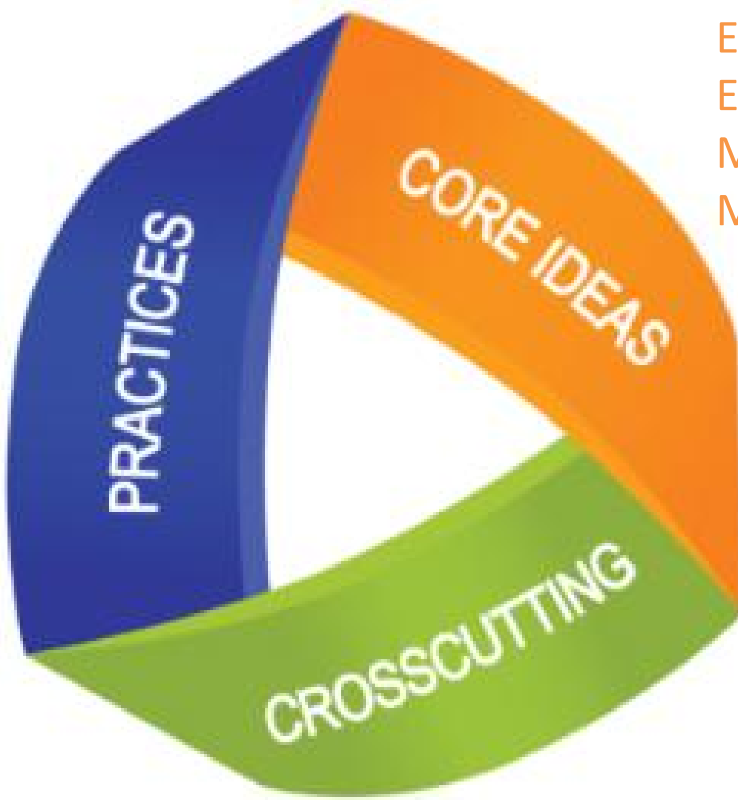
Identifying how the inclusion of a "condition" affects students' Epistemological frames

Matthew Mikota
James T. Laverty

K-12 Framework

Examples are:
Asking Questions
Developing Models
Using Mathematics
Engaging in an argument from evidence.



Examples include:
Energy
Motion and Stability
Matter and its interactions

Examples include:
Cause and Effect
Scale and proportion
Systems and Stability
Models

National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.

Kansas State University

Three Dimensional Learning Assessment Protocol (3D-LAP)

- Protocol to evaluate assessments
- Determines if questions elicit evidence of
  - Scientific practices
  - Core ideas
  - Crosscutting concepts.

Three Dimensional Learning Assessment Protocol Sample (3D-LAP)

Criteria for Developing and Using Models.

1) Question gives an **event**, **observation** or **phenomenon** for the student to explain or make a prediction about.
2) Question gives a **representation** or asks student to **construct a representation**
3) Question asks student **to explain or make a prediction** about the event, observation or phenomenon.
4) Question asks student to **provide the reasoning** that links the representation to their explanation or prediction

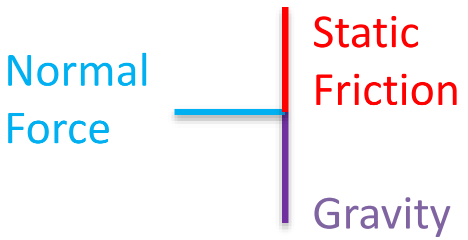
From J. T. Laverty, Ebert-May, S. E. Jardeleza, and M. M. Cooper, Characterizing college science assessments: The three-dimensional learning assessment protocol

Overall Project Goals

Identify how the inclusion of a “condition” affects students’ Epistemological Frames?

Example Condition

You are asked to design a Gravitron for the county fair, an amusement park ride where the rider enters a hollow cylinder, **radius of 4.6m**, the rider leans against the wall and the room spins until it reaches an angular velocity(ω) at which point the floor lowers. The **coefficient of static friction is 0.2** . You need this ride to work for people whose **mass's range from 25-160 kg** (i.e. they should be able to ride safely without falling off the wall). If **ω=3 rad/s** will anyone slide off the wall.



To stay on the wall, Static Friction and gravity are the two forces to solve for. **To not fall of the wall, Static friction must be greater then gravity.**

Thus $(\boldsymbol{F_s}) \geq \boldsymbol{F_g}$

So $\omega^2 \mu_S$MR≥MG.

After plugging the given values in we receive

9(0.2)(4.6)≥9.8 which says

8.28≥9.8

The following is false and thus the static friction isn't enough to keep the person on the wall.

Methods

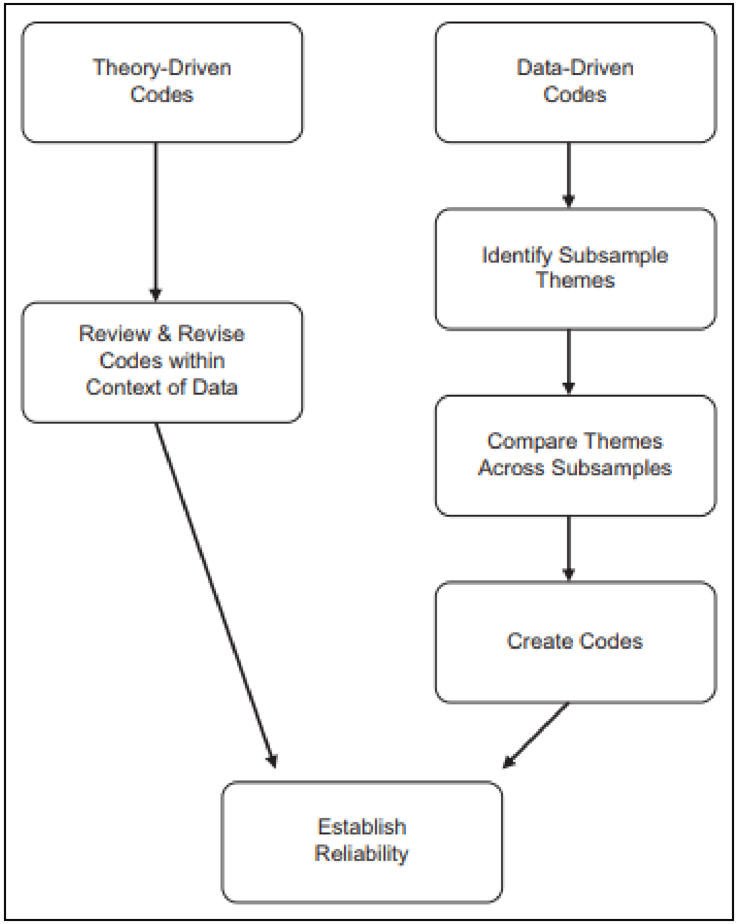
28 Students

Think-Aloud interviews

Exam Style format

Method: Thematic Analysis

Coding is the primary process used in thematic analysis as it analyzes the raw data recognizing important moments.



Epistemological Frames

TABLE I. Four common framings and their primary (i.e., warrants) and secondary indicators.

	Calculation	Physical mapping	Invoking authority	Math consistency
Class of warrant used	Correctly following algorithmic steps gives a trustable result	Goodness of fit between mathematical and physical observations or expectations attests to a result	Authoritatively asserting a result or a rule gives it credence	Similarity or logical connection to another math idea offers validation
Other common indicators	Focus on technical correctness	Often aided by a diagram	Quoting a rule	Analogy with another math idea
	Math chaining: need this to get that	Demonstrative gesturing	Absence of mechanistic chaining	Categorization
		Mechanistic chaining	Little acknowledgment of substructure	

T. J. Bing and E. F. Redish, Analyzing problem solving using math in physics: Epistemological framing via warrants, Phys. Rev. ST Phys. Educ. Res. 5, 020108 (2009).

Sample Student Response

7. You are asked to design a Gravitron for the county fair, an amusement park ride where the rider enters a hollow cylinder, radius of 4.6 m, the rider leans against the wall and the room spins until it reaches angular velocity, at which point the floor lowers. The coefficient of static friction is 0.2. You need this ride to sustain mass between 25-160 kg to be able to ride safely and not slide off the wall. If the minimum ω is 3 rad/s will anyone slide down and off the wall at these masses? Explain your reasoning using diagrams, equations, and words.

$F = ma$

$F_f = F_g$

$F_N \cdot \mu = F_g$

$a \cdot m \cdot \mu = m \cdot a$

$13.8 \cdot 0.2 \geq 9.8$

2.76

49 rad/s

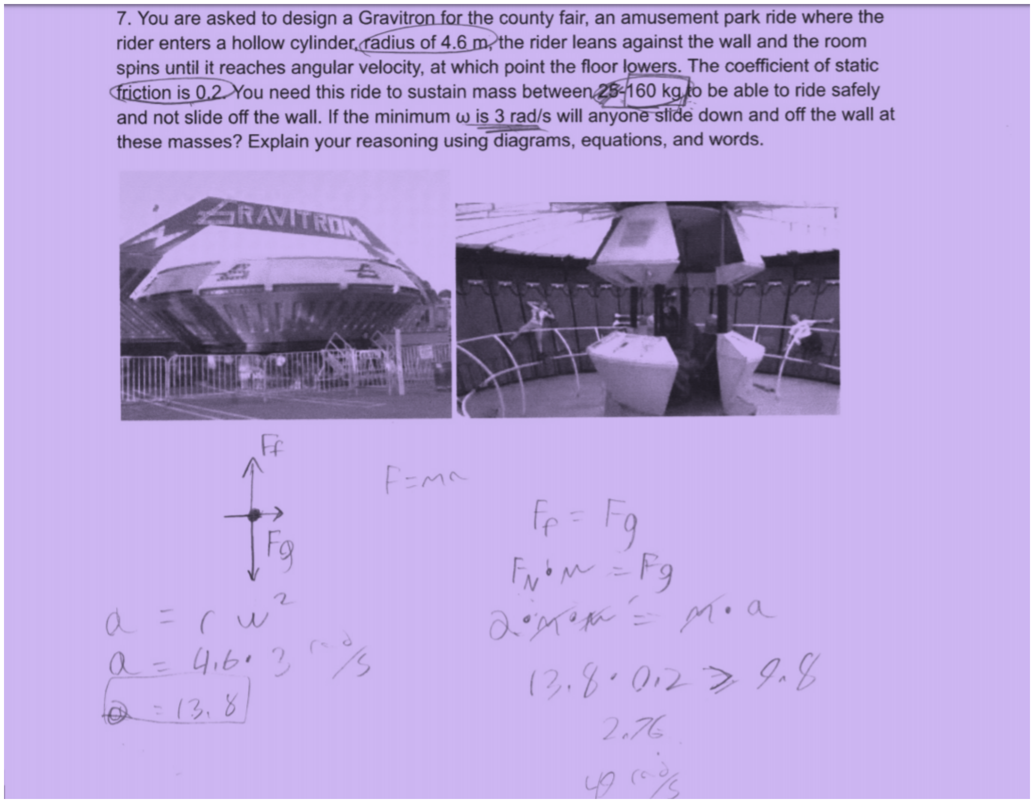
$a = r\omega^2$

$a = 4.6 \cdot 3 \text{ rad/s}$

$a = 13.8$

"I know in the free body diagram there is a downward force due to gravity and the normal force, and friction."

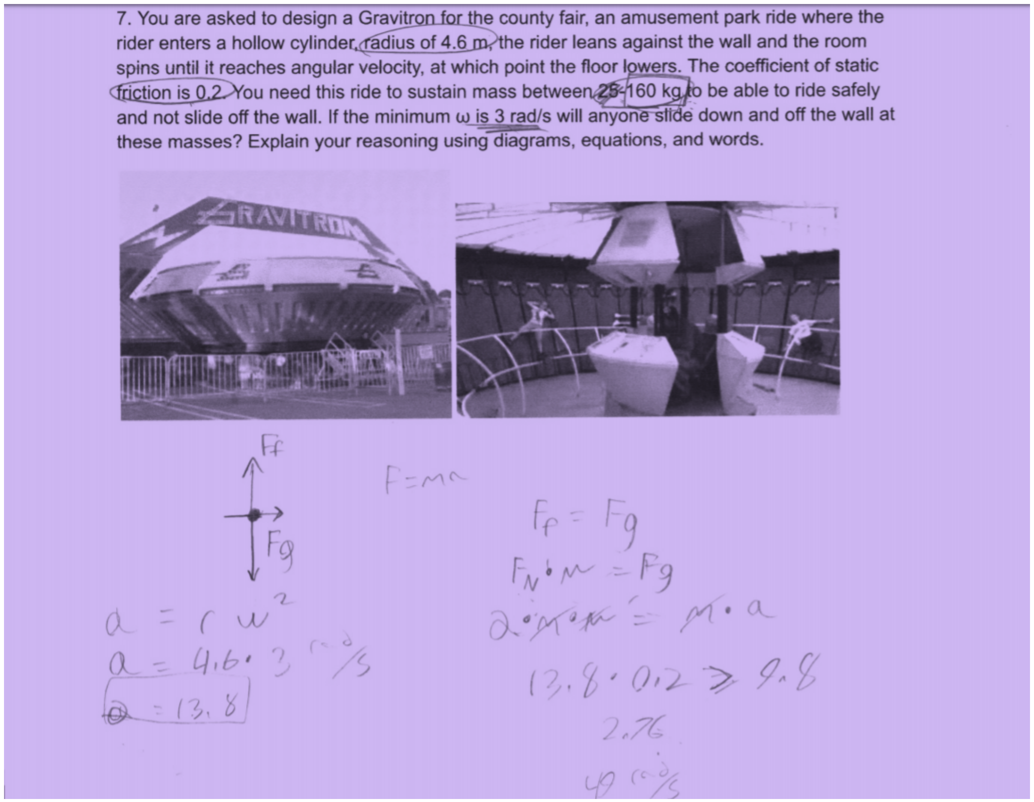
Sample Student Response


7. You are asked to design a Gravitron for the county fair, an amusement park ride where the rider enters a hollow cylinder, radius of 4.6 m, the rider leans against the wall and the room spins until it reaches angular velocity, at which point the floor lowers. The coefficient of static friction is 0.2. You need this ride to sustain mass between 25-160 kg to be able to ride safely and not slide off the wall. If the minimum ω is 3 rad/s will anyone slide down and off the wall at these masses? Explain your reasoning using diagrams, equations, and words.

"I know in the free body diagram there is a downward force due to gravity and the normal force, and friction."

Begins with a diagram suggesting Physical mapping

Sample Student Response



7. You are asked to design a Gravitron for the county fair, an amusement park ride where the rider enters a hollow cylinder, radius of 4.6 m, the rider leans against the wall and the room spins until it reaches angular velocity, at which point the floor lowers. The coefficient of static friction is 0.2. You need this ride to sustain mass between 25-160 kg to be able to ride safely and not slide off the wall. If the minimum ω is 3 rad/s will anyone slide down and off the wall at these masses? Explain your reasoning using diagrams, equations, and words.

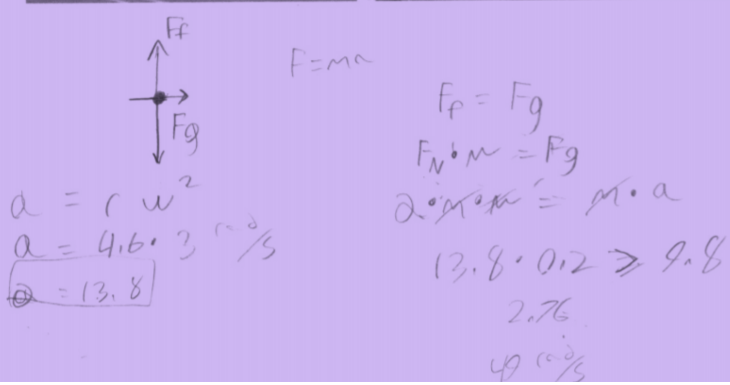
"I know in the free body diagram there is a downward force due to gravity and the normal force, and friction."
Begins with a diagram suggesting Physical mapping

"Since it is at a 90 degree angle of it will be converted into the friction force"

Kansas State University

Sample Student Response

7. You are asked to design a Gravitron for the county fair, an amusement park ride where the rider enters a hollow cylinder, radius of 4.6 m, the rider leans against the wall and the room spins until it reaches angular velocity, at which point the floor lowers. The coefficient of static friction is 0.2. You need this ride to sustain mass between 25-160 kg to be able to ride safely and not slide off the wall. If the minimum ω is 3 rad/s will anyone slide down and off the wall at these masses? Explain your reasoning using diagrams, equations, and words.

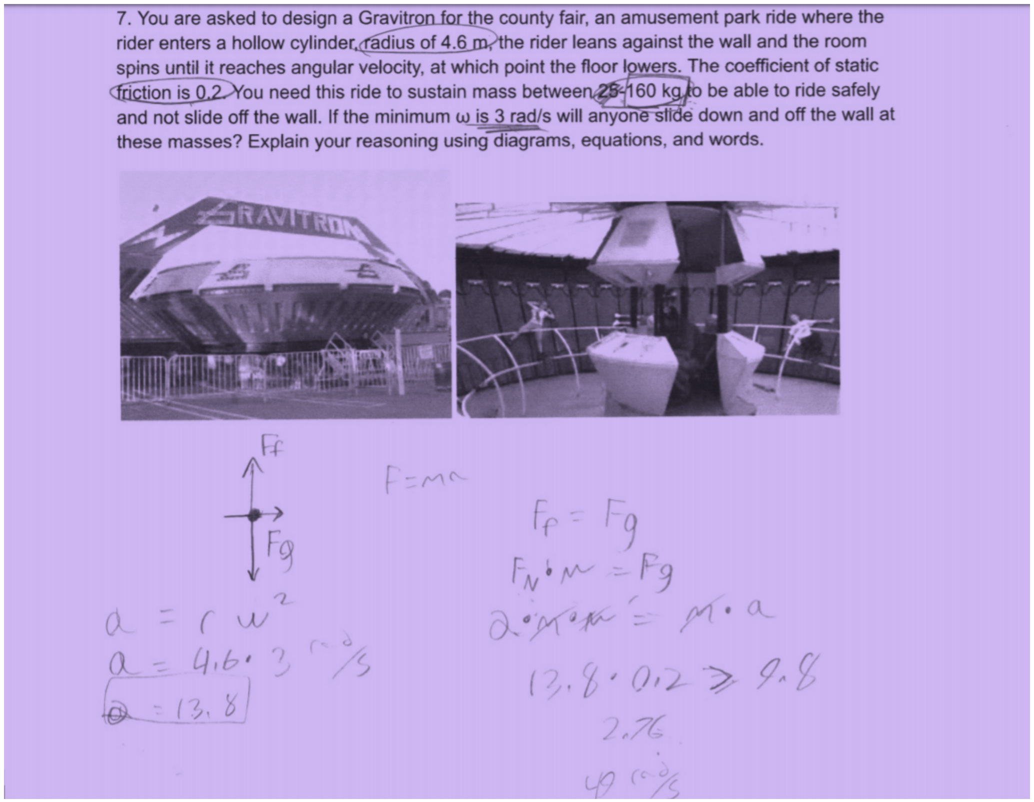


"I know in the free body diagram there is a downward force due to gravity and the normal force, and friction."
Begins with a diagram suggesting Physical mapping

"Since it is at a 90 degree angle of it will be converted into the friction force"

Mechanistic chaining suggesting Physical Mapping

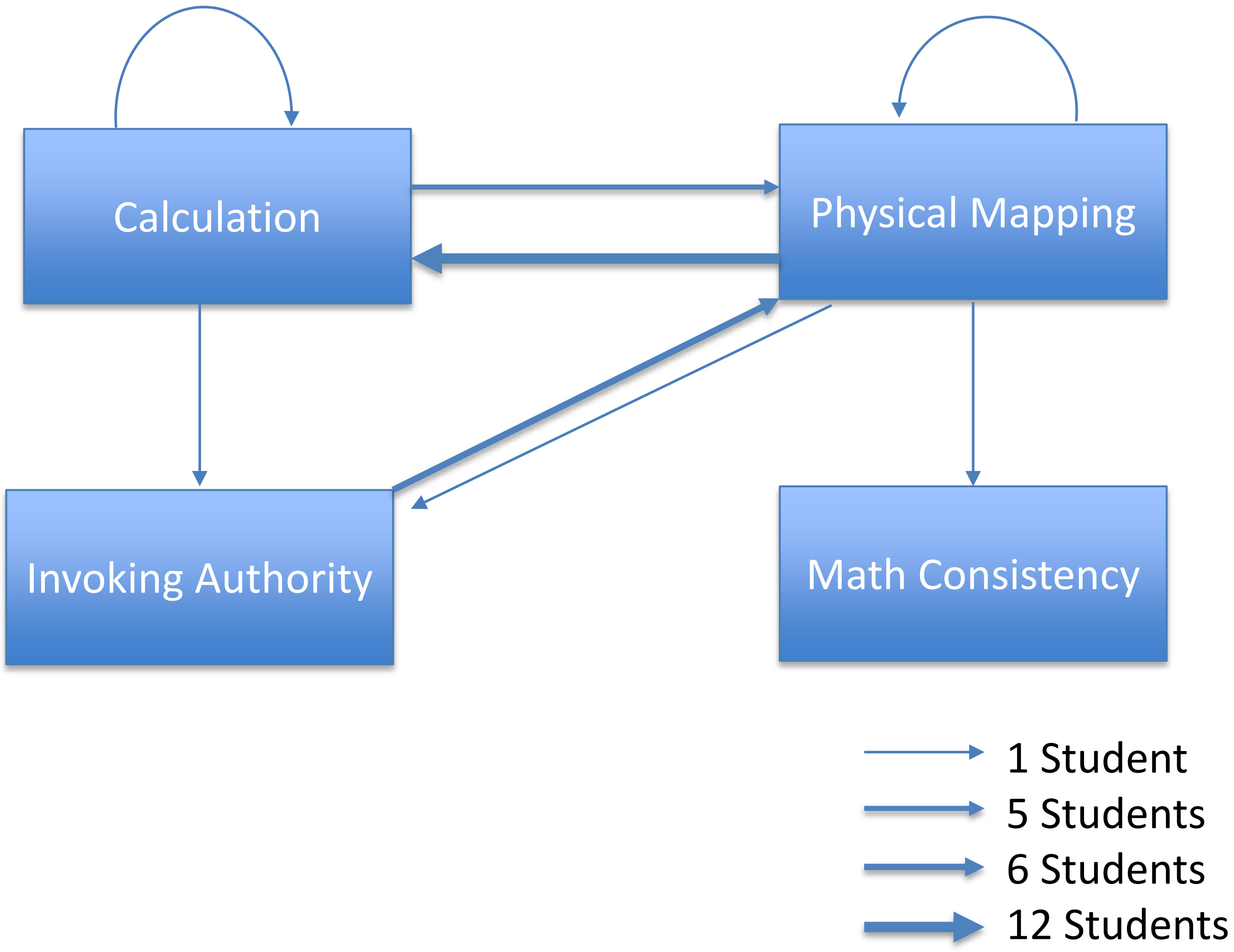
Sample Student Response



7. You are asked to design a Gravitron for the county fair, an amusement park ride where the rider enters a hollow cylinder, radius of 4.6 m, the rider leans against the wall and the room spins until it reaches angular velocity, at which point the floor lowers. The coefficient of static friction is 0.2. You need this ride to sustain mass between 25-160 kg to be able to ride safely and not slide off the wall. If the minimum ω is 3 rad/s will anyone slide down and off the wall at these masses? Explain your reasoning using diagrams, equations, and words.

Begins by solving for acceleration, and then uses this to solve for his later forces.

Math Chaining and technical correctness suggesting Calculation


Calculation
Physical Mapping
Invoking Authority
Math Consistency
1 Student
5 Students
6 Students
12 Students

Conclusions

A question containing a "condition" causes students to shift between Epistemological Frames.

The frame shifts vary by student, however, typical reactions involve shifts between Physical Mapping and Calculation.

Future Goals

Interrater Reliability to validate results

Analyze frame shifts and reasoning behind frame shifts

Adapt these questions to teach frameshifting or for use in assessing students' ability to frame shift

Acknowledgments

J.T. Laverty
Lydia Bender
Christopher Hass
Hien Khong
Amali Priyanka Jambuge
Kansas State University
National Science Foundation
Dr. Bret Flanders
Dr. Loren Greenman

Kansas State University Physics Education Research

Bibliography

National Research Council, A Framework for K-12 Science Education (National Academies Press, Washington, DC, 2012).

J. T. Laverty, S. M. Underwood, R. L. Matz, L. A. Posey, J. H. Carmel, M. D. Caballero, C. L. Fata-Hartley, D. Ebert-May, S. E. Jardeleza, and M. M. Cooper, Characterizing college science assessments: The three-dimensional learning assessment protocol, PLoS One 11, e0162333 (2016).

T. J. Bing and E. F. Redish, Analyzing problem solving using math in physics: Epistemological framing via warrants, Phys. Rev. ST Phys. Educ. Res. 5, 020108 (2009).

Research is a fishing trip!