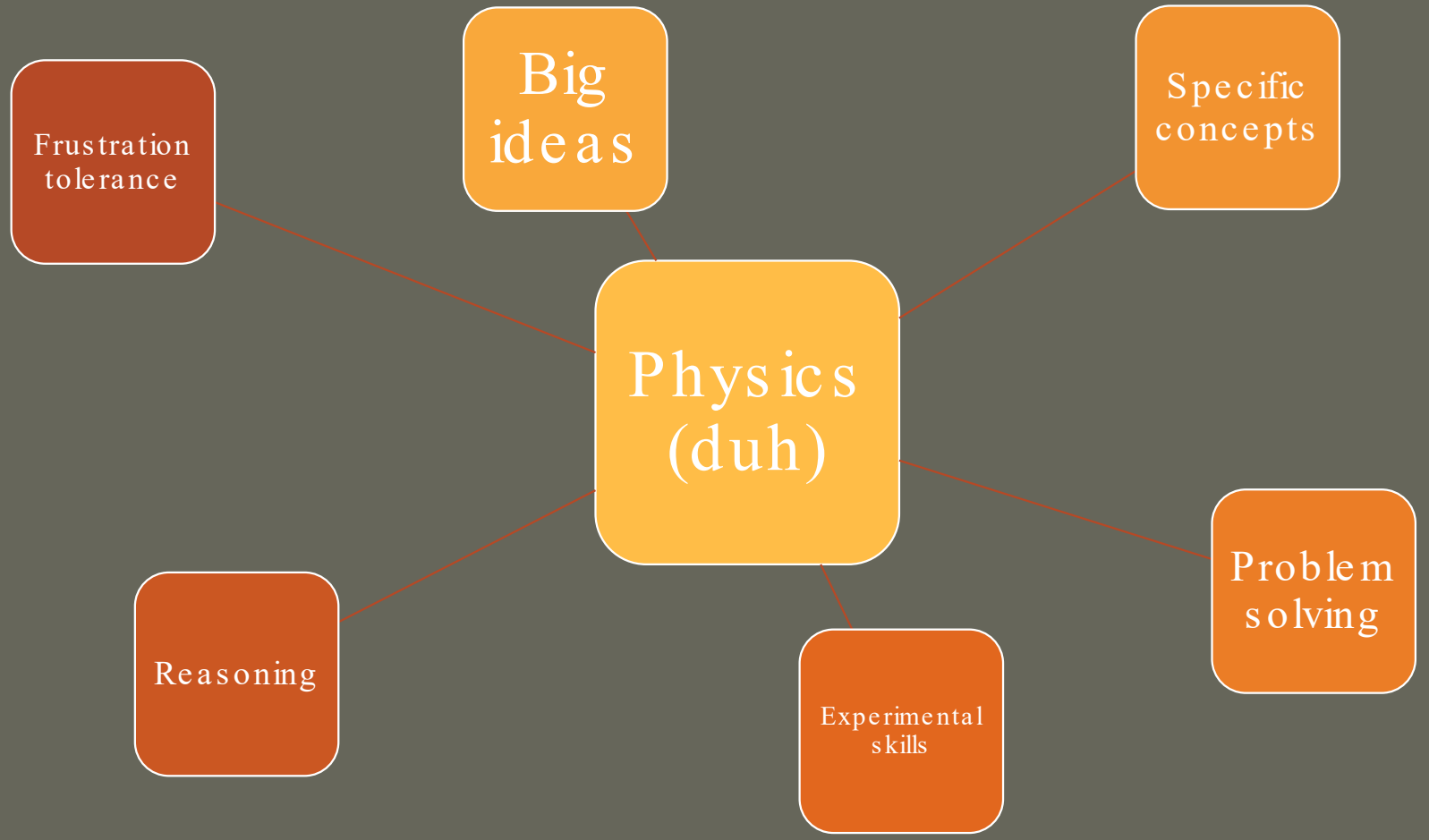
Beyond Plug and Chug: Learning Tasks for Understanding Physics

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What are we hoping our students will learn?



What you measure is what you motivate

Plug and chug style problems

A stone is thrown horizontally with an initial speed of 10 m/s from the edge of a cliff. A stopwatch measures the stone's trajectory time from the top of the cliff to the bottom to be 4.3 s. What is the height of the cliff if air resistance is negligibly small?

What's the problem?

An ability to apply mathematical procedures to solve a given problem

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a conceptual understanding of the underlying physics

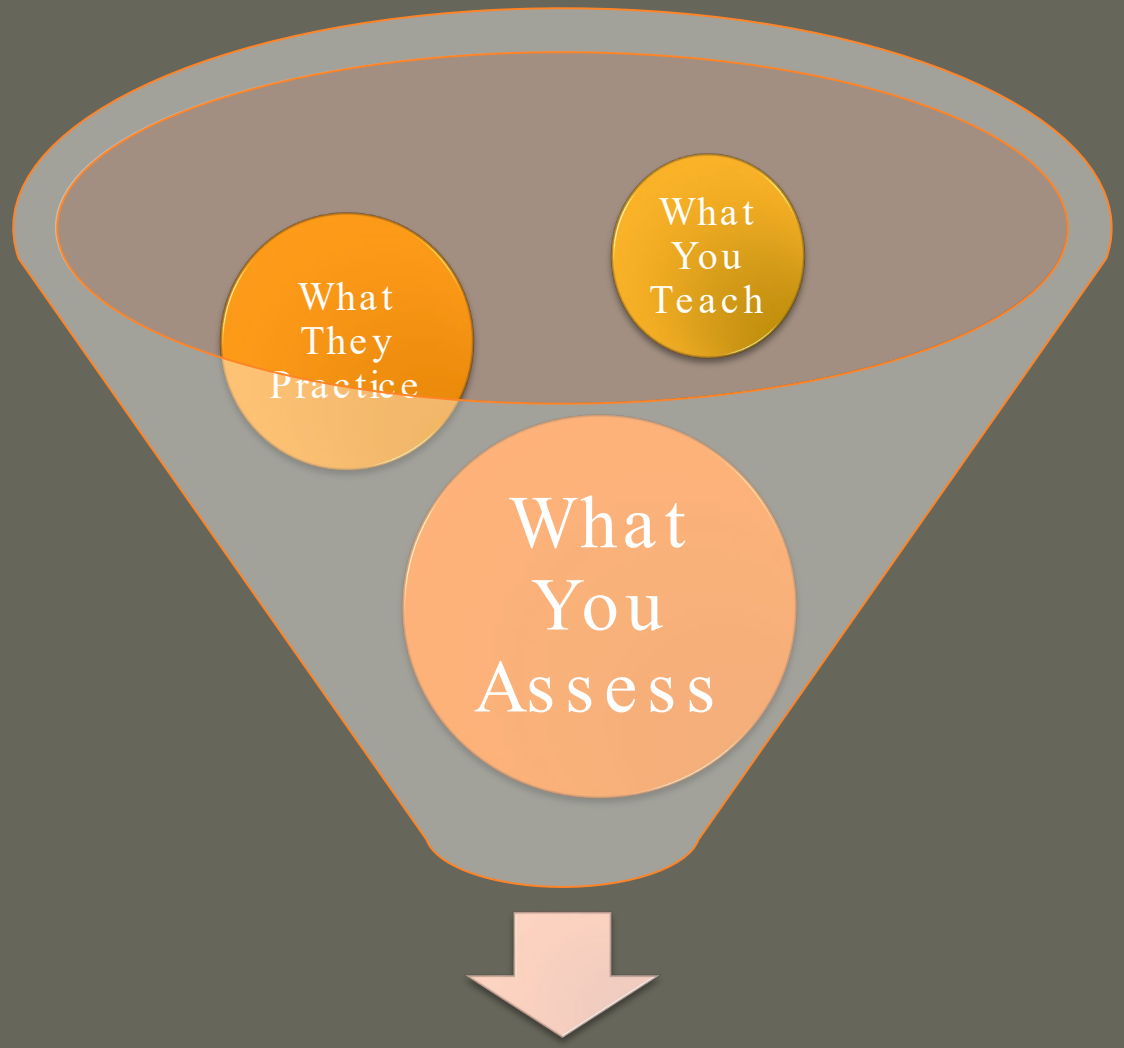
AND

An ability to conceptually understand and reason about the physics

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an ability to solve a quantitative problem

(See Hammer, D. (1989). Two approaches to learning physics. The Physics Teacher, 27, 664-670. https://doi.org/10.1119/1.2342910.)



What They Learn

3 Categories of Learning Tasks: Qualitative, Semiquantitative, and Quantitative

- Quantitative: requires algebraic manipulation and/or calculation to reach an answer
  - EX: A stone is thrown horizontally with an initial speed of 10 m/s from the edge of a cliff. A stopwatch measures the stone's trajectory time from the top of the cliff to the bottom to be 4.3 s. What is the height of the cliff if air resistance is negligibly small?
- Semiquantitative: requires reference to a mathematical model but does not require algebra or calculation
  - EX: A stone is thrown horizontally off of the edge of a cliff and hits the ground a moment later. If the cliff was twice as tall, how much longer would it take to hit the ground?
- Qualitative: can be answered without explicit regard for a mathematical model
  - EX: A stone is thrown horizontally off of the edge of a cliff and hits the ground a moment later. If the stone were dropped instead of thrown, what about its motion would change?

A Taxonomy Of Learning Tasks

Quantitative	Semiquantitative	Qualitative	
Working Backwards	Multiple Representations	Conflicting Contentions	Error Analysis
Goal-less problem	Proportional Reasoning	Qualitative Reasoning	Compare Cases
Dimensional Analysis	Graph and Switch	Write & Switch	Create a Plan
Estimation / Fermi Problems	What Changes?	Make a Prediction	ELI5
Data to Model	Boundary Case Analysis	Construct an Argument	Concept Mapping
Plug and Chug	Anomalous Data	Assumption Audit	Examples/ Nonexamples

Example

- Quantitative (Plug and Chug): A 0.15 kg bob is spun horizontally on 20 cm string with a tangential velocity of 0.8 m/s. What is the tension in the string?
- Semiquantitative (Proportional Reasoning): A bob is spun horizontally on a string at a constant speed. What happens to the tension in the string if the speed is doubled?
- Qualitative (Conflicting Contentions): A bob is spun horizontally on a string at a constant speed. Brooks says that if the string is cut, it will fly out because the spinning was pushing it out. Ally says it will fall in because centripetal force always points in. To what extent is each student right, and why?

Example

- Quantitative (Goal-less Problem): Given a diagram of a block on a ramp with friction and a pulley, determine everything you can about this system.
- Semiquantitative (Boundary Case Analysis): A block rests on a rough inclined plane. It is attached via a string over a pulley to another block. The hanging block is released from rest and the system accelerates. Explain how the motion of the system changes: 1) if the hanging block's mass is much much greater than the block on the ramp; 2) if the hanging block's mass is much much less than the block on the ramp; 3) if friction were negligible; 4) if the pulley had a large moment of inertia.
- Qualitative (Make a Prediction): Given a diagram of a block on a ramp with friction and a pulley, what would you need to know to predict if the system would accelerate?

Takeaways

- Resource: Spreadsheet with all the learning tasks (so far) categorized with examples from kinematics, dynamics, energy, and momentum. Link: https://docs.google.com/spreadsheets/d/1NJPm_PVlOYerLeeIl4ML2qkjGKQg79yZF4dMQfTE168/edit?usp=sharing
- What You Teach ↔ What They Practice ↔ What You Assess ↔ What They Learn
- Change up the questions you ask, and you may be surprised but the knowledge your students can display (for better and for worse)