USING METACOGNITIVE PROMPTS TO EXPLORE STUDENT REASONING TRAJECTORIES
Em Sowles, Drew J. Rosen, and MacKenzie R. Stetzer (University of Maine)

MOTIVATION
• Students who demonstrate sufficient conceptual knowledge and skills (or mindware [1]) on one physics question often perform inconsistently on an analogous question on the same topic [2-4].
• Such inconsistencies can be explained by Dual-Process Theories of Reasoning (DPTor), which model human reasoning via two distinct modes of cognitive processing (Fig. 1) [5,6].
• The DPTor Framework is characterized by reasoning cycles shown in Fig. 2 [7].
• To date, researchers have not yet investigated and documented the specific reasoning trajectories taken by students when answering a physics question.
• To gain insight into students’ reasoning trajectories, we developed an exploratory sequence of DPTor-aligned mapped prompts and administered the sequence immediately after students answered a physics question containing salient distracting features.

GOAL
• To identify, document, and characterize, to the extent possible, students’ reasoning trajectories as they move from provisional models to submitted responses.

DUAL PROCESS THEORIES OF REASONING
• In the DPToR framework, process 1 is the entry point into any reasoning pathway.
The provisional model is informed by a student’s prior knowledge, beliefs, contextual cues (e.g., salient distracting features), and goals.
• The specific ways in which both processes function and interact (or do not interact) lead to multiple possible reasoning pathways or trajectories (Fig. 2).
• Student reasoning trajectories result from the complex interaction of many factors, including:
  - Provisional model generated
  - Mindware [1]
  - Cognitive reflection skills [8]—tendency and ability to scrutinize provisional mental models.

METACOGNITIVE PROMPTS

1. When you first saw this question, what was the first idea or thought that came to mind, regardless of whether correct or incorrect?
2. At any point before selecting your answer, was there anything that made you doubt your first idea?
3. Did your final answer differ from your first idea that you stated above?
4. When you were answering the original question, which of the following best describes the approach you took?
   - a. Started with an intuitive answer or gut feeling for which answer was correct, and then I used physics arguments to validate my choice.
   - b. Started with an idea of the physics concepts or approaches I needed to draw upon, then used them to arrive at a result, and finally checked to see which answer matched the result I obtained.

TRAJECTORY CHARACTERIZATION

METACOGNITIVE RESPONSE: DOUBTS
• Students who remained correct self-reported significantly fewer doubts than all other groups ($\chi^2(3)=22.92, p<0.001, \text{V}=337$) by inspection of standardized residuals.
• Both consistently correct and consistently incorrect students were relatively quick, consistently incorrect students experienced far more doubts.

METACOGNITIVE RESPONSE: APPROACH
• Students who remained correct were significantly more likely to self-report a process first approach while consistently incorrect students were more likely to self-reported an approach first approach ($\chi^2(3)=18.32, p<0.001, \text{V}=301$) by inspection of standardized residuals.
• Students who switched their responses did not differ significantly from each other, regardless of direction.

REFERENCES

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TAKEAWAYS AND NEXT STEPS
• Findings from this exploratory investigation suggest that the use of metacognitive prompts along with timing data can help researchers characterize student reasoning trajectories.
• A more detailed understanding of these trajectories will aid in the development of effective, research-based instructional materials that better support student reasoning in physics.
• Future tasks will explicitly ask students to indicate their provisional responses to address limitations in our current construction of provisional responses from prompts 1 & 3.