Uncovering the Unknown Unknowns of Peer Instruction Questions

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"Wow! I wish I'd written that question..." Many instructors struggle to write Peer Instruction (PI, or Think-Pair-Share, TPS) questions that present the ideas of their discipline using thought-provoking representations that engage learners in a wider variety of intellectual tasks. How much variety exists in your question banks? How would you go about evaluating this and even if you did, how would you know what you're missing? We present a framework for uncovering the variety in the discipline representations, intellectual tasks, and difficulty levels employed in hundreds of multiple-choice questions produced by faculty in our workshops over the years. We then exploit this framework to generate new questions using underutilized variables. In this way, we create questions that better afford learners an opportunity to develop their discipline fluency.

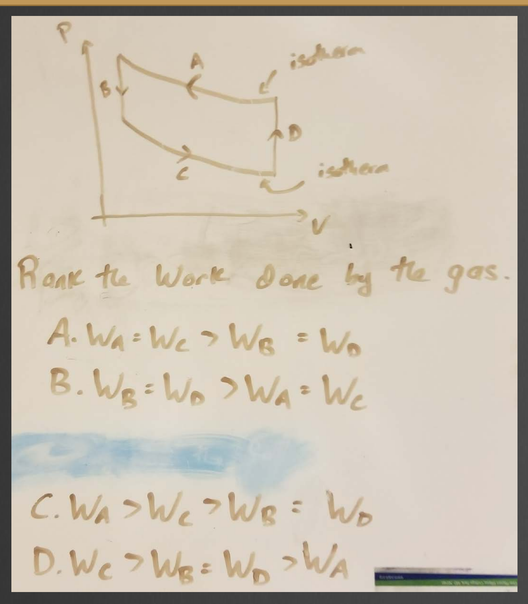
Background & Theory

- need for insightful and systematic characterization of information contained in existing database of 500+ classroom-tested PI/TPS questions
- inspired by work of C. Linder and collaborators
  - To achieve discipline fluency, it is necessary (though not sufficient) that learners become fluent with a variety of representations. [1,2]
  - It is pedagogically more powerful to use multiple representations than to rely on a single one to do the work of many. [3]
  - The power of research-validated active learning methods like PI/TPS may lie in how they naturally facilitate the unpacking and disambiguation of the affordances of a set of representations. [3]

Data

- 353 faculty-authored multiple-choice PI/TPS questions
  - Center for Astronomy Education Teaching Excellence Workshops, 2005-2015
  - AAPT/APS/AAS Workshops for New Faculty in Physics and Astronomy, 2015-2017

Typical Question Created By Faculty



- variables characterized using this framework
  - representations: 1, 3
  - tasks: 9 (1, 2, 3, 4, 11, 12, 14)
  - QCR = 3

References & Acknowledgments

1. C. Linder, *Eur. J. Sci. & Math. Ed.*, **1**(2), 43 (2013)
2. J. Airey & C. Linder, *J. Res. in Sci. Teach.*, **46**(1), 27 (2009)
3. T. Fredlund, C. Linder, J. Airey, & A. Linder, *Phys. Rev. ST – Phys. Ed. Res.*, **10**, 020129 (2014)

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Framework

- uncovers the variety in the intellectual tasks, discipline representations, and difficulty levels
- descriptive AND *generative*
- easily extended to other types of instructional materials and methods
- easily generalized to other disciplines

Representations + Intellectual Tasks

Representations	Intellectual Tasks
1. words	1. visualize
▪ written	2. draw/sketch
▪ spoken	3. model
2. pictures & diagrams	4. compare
▪ photographs	5. identify
▪ static images	6. predict
▪ figures	7. extrapolate
▪ sketches	8. count
3. graphs & charts	9. rank
4. tables	10. sort
5. mathematical formalism	11. match
6. numbers	12. quantitative reasoning
7. animations & simulations	13. calculate
▪ moving pictures and/or diagrams with no user interaction	14. apply/analyze
▪ simulators with user interaction mechanism(s)	15. write
8. recordings of reality	
▪ video	
▪ audio	
9. gestures	
▪ facial expressions	
▪ body movements	

Question Complexity Rubric (QCR)

- ranks question's degree of conceptual and cognitive complexity
- represents level of intellectual engagement required to unpack and explain the reasoning behind the correct answer

Code	Degree of Cognitive Complexity	To convince someone else of the correct answer, unpacking and explaining requires...	Type of Reasoning	Schematic Visualization
1	trivial	...stating only a single fact or element of declarative knowledge.	recall	
2	low	...only one step of reasoning.	simple	
3	medium	...multiple sequential steps of reasoning.	chain	
4	high	...multiple pathways of sequential reasoning steps involving two or more concepts or topics.	compound	

Research Progression

- initially: determine questions' variables
  - characterize and catalog representations and tasks used and identify levels of complexity
- progression: not many high-complexity questions overall and some topics are missing particular representations and/or intellectual tasks
  - identify variables missing from different topics
  - generate new questions to fill gaps
  - learn how to create high-level QCR questions for different topics
- currently: develop and apply a systematic framework that does all of the above and helps...
  - generate questions that combine tasks and representations in ways not seen in the data
  - generate new pathways of intellectual engagement for moving learners toward fluency
  - explore the potential of more pedagogically powerful questions

Discussion & Conclusions

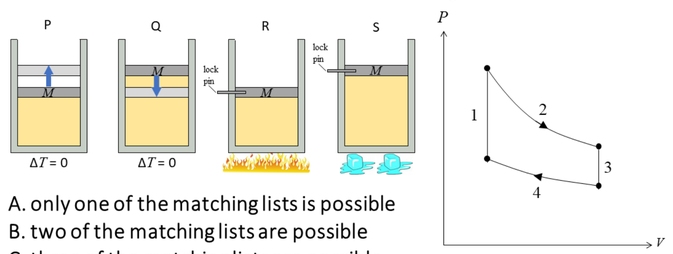
- Instructors who use a limited set of representations cannot move learners to fluency: students' abilities to unpack reasoning and practice discernment are hampered by the lack of variety. [3]
- this framework...
  - uncovers the underutilized variables in multiple-choice PI/TPS questions for different topics
  - generates **fluency-inspiring questions** which...
    1. require learners to map and transfer information between multiple different representations
    2. engage learners in multiple intellectually rigorous tasks
    3. promote complex discourse to justify an answer

✓ *Learning environments that make use of **fluency-inspiring questions** afford learners more powerful opportunities to unpack complex concepts, practice critical discernment, and develop discipline fluency.*

Fluency-Inspiring Question

- generated by applying this framework
  - representations: 1, 2, 3, 5, 6
  - tasks: 8 (1, 3, 4, 11, 12, 14)
  - QCR = 4

The "matching lists" below connect a numbered step in the heat engine process (1-4, shown in the PV graph) with one of the four piston diagram (P-S, where M is a non-negligible mass) and the amount of work done by the gas on the piston (W) during that step of the process. How many of the "matching lists" are possible?



A. only one of the matching lists is possible
B. two of the matching lists are possible
C. three of the matching lists are possible
D. four of the matching lists are possible
E. more than four of the matching lists are possible