Interview validation of the Physics Lab Inventory of Critical thinking (PLIC)

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Current Assessment Format

Goal

The purpose of the PLIC is to assess critical thinking skills of students in college-level, introductory lab courses.

Design

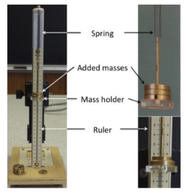
The PLIC is a closed-response survey. A traditional format of "choose one multiple choice" would be inadequate for our purpose, and so the design and format were modeled after Wilcox and Pollock's coupled multiple-choice assessment.[1]

SAMPLE QUESTION: Students are asked to make a judgment and then to justify it. Based on their response, different follow-up questions appear.

SetUp

Mass on a spring, with assumptions and equipment. Model is simple harmonic motion, from Hooke's law

$$T = 2\pi\sqrt{\frac{m}{k}}$$



Group 1

Total mass: 30 g

Time for 5 oscillations (s)	Period (s)
2.78	0.556
2.68	0.536
2.76	0.552
2.70	0.540
2.67	0.534
2.82	0.564
2.66	0.532
2.72	0.544
2.56	0.512
2.51	0.514

T (average) = 0.5384 ± 0.00531 s

⇒ k = $\frac{4\pi^2 m}{T^2}$ = 4.086 ± 0.0807 N/m

Total mass: 50 g

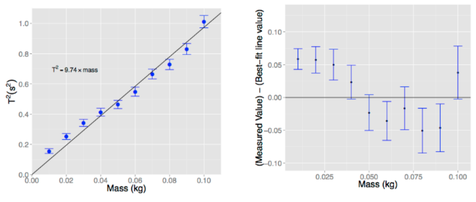
Time for 5 oscillations (s)	Period (s)
3.39	0.678
3.35	0.670
3.40	0.680
3.42	0.684
3.40	0.680
3.45	0.690
3.31	0.662
3.55	0.710
3.60	0.720
3.46	0.692

T (average) = 0.6846 ± 0.00553 s

⇒ k = $\frac{4\pi^2 m}{T^2}$ = 4.181 ± 0.0675 N/m

Calculate spring constant of 2 masses.

Group 2



Graph square of period for 10 different masses.

Two fictional groups have different methods to test the simple model of a mass on a spring. Students are asked to assess the methods, the fictional data, suggest next steps and compare the two groups.

Thinking Behaviors

The PLIC is a multi-layered, multiple choice assessment. Through think-aloud validation interviews, we identified three main thinking behaviors exhibited by students as they take the assessment.

Cuing to Key Words

- Select options with keywords learned in class, such as:
  - Percent error
  - "Human error"
- Common when answering questions related to Group 1 methodology.

To switch students from cuing to key words to carefully evaluating the options, familiar material needs to be presented in an unfamiliar way (such as data in Group 2 rather than Group 1)

Discerning

- Considering all options presented, and selecting only a few due after careful evaluation.
- Different students prioritize different answers, such as those related to:
  - "Human error"
  - Data collection
  - Model breakdown
- The answers selected reflect the sophistication (novice-like or expert-like) of their critical thinking.
- Some students, when exhibiting this behavior, change their initial judgment or assessment after seeing all other options presented.

When students are discerning in their choices can we assess their critical thinking.

Selecting all Options

- Selecting all options that appeal, regardless of priority or importance.
- All closed response option for the PLIC are "correct" in some way, and so this behavior is not associated with critical thinking and may be a symptom of the assessment design.

To switch students from selecting all options to carefully evaluating the options, students must be told to select a limited number of answers (no more than three)

Major			Academic Level				Gender		Race/Ethnicity			
Physics	Non-Declared STEM	Other Declared STEM	Freshman	Soph.	Junior	Grad	F	M	African-American	Asian/ Asian-American	White	Other
N = 8	**N = 2**	**N = 2**	**N = 6**	**N = 3**	**N = 1**	**N = 2**	**N = 6**	**N = 6**	**N = 2**	**N = 3**	**N = 5**	**N = 2**

Demographic breakdown of all 12 students interviewed for this study.

Developing the Assessment

The development framework for this assessment followed guidelines from Adams and Wieman[2], with validation process from Wilcox and Lewandowski[3], and protocol from [4]. Arrows indicate the iterative nature of this process, where we may return to previous steps depending on findings.

Phase 1: Conception

- Choose topic.
- Delineation of the purpose of the test.
- Choose topic, collect and create data.
- Initial data created by a physicist conducting the actual experiment,
- Initial questions based on on their self-questions related to their choice of methods, data and collection.

Phase 2: Open-Response

- Development of open-response version.
- Student interviews conducted.
- Student written responses gathered from introductory class.
- Experts consulted.
- Results previously presented.[5]

Phase 3: Closed-Response

- Development of the closed-response version.
- Currently using the online survey software *Qualtrics*.
- Field testing though think-aloud validation interviews.
- Develop scoring.

We are currently in Phase 3.

Phase 4: Operational Use

- Assemble and evaluate the test for operational use.
- Large-scale validation, reliability and validity testing.
- Easy access for teachers, professors and instructors, with automation for setup, reminders and report-back scoring.

References

[1] B. R. Wilcox and S. J. Pollock, Phys. Rev. ST Phys. Educ. Res. 10, 020124 (2014).
[2] W. K. Adams and C. E. Wieman, International Journal of Science Education 33, 1289 (2011), http://dx.doi.org/10.1080/09500693.2010.512369.
[3] B. R. Wilcox and H. J. Lewandowski, Phys. Rev. Phys. Educ. Res. 12, 010123 (2016).
[4] A. Madsen, S. B. McKagan, and E. C. Sayre, American Journal of Physics 85, 245 (2017), http://dx.doi.org/10.1119/1.4977416.
[5] N. G. Holmes and C. E. Wieman, in Physics Education Research Conference 2016, PER Conference (Sacramento, CA, 2016) pp.156–159.

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