Large Scale Assessment for Upper-division Electricity and Magnetism

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The Goal

To craft an upper-division conceptual assessment that exploits the logistical advantages of a multiple-choice (MC) test without sacrificing the insights into student reasoning afforded by an free-response test.

The Assessment

The Colorado Upper-division Electrostatics (CUE) Diagnostic [1]

- Free-response format elements captures student reasoning
- Complex rubric - requires significant training to grade; limits scalability

The History

Previous work suggests the best agreement between scores on free-response and multiple-choice questions occurs when …

- partial credit is allotted for the multiple-choice distractors which represent different levels of understanding [2]
- distractors are crafted based on previous research on student difficulties [3]

The Approach

- Provide reasoning elements that reflect common student ideas that appear on the free-response version of the CUE
- Allow students to select multiple reasoning elements
- Award partial credit based on the accuracy and consistency of the student's selections.

Conclusions & Future Work

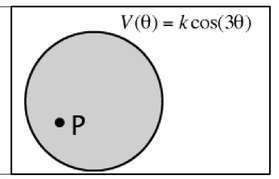
- Preliminary analysis of one semester suggests agreement between average scores on the multiple-choice and free-response CUEs.
- In the multiple-choice format the CUE continues to offer insight into student ideas and reasoning.
- Measures of discrimination and item difficulty for individual items show some differences which require further investigation.
- Future works will focus on additional data collection in order to increase statistical power.

What has changed?

Free-response CUE

DO NOT SOLVE the problem, we just want to know:
•The general strategy (half credit)
•Why you chose that method (half credit)

Q1. An insulating sphere with radius R, with a voltage on its surface $V(\theta)=k\cos(3\theta)$. Find $\vec{E}$ or V inside the sphere at point P.

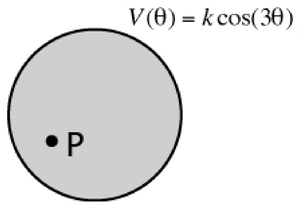


Multiple-choice CUE

Q1. An insulating sphere with radius R, with a voltage on its surface $V(\theta)=k\cos(3\theta)$. Find $\vec{E}$ or V inside the sphere at point P.

Select only one: **The easiest method would be …**

A. Direct Integration
B. Gauss's Law
C. Separation of Variables
D. Multipole Expansion
E. Ampere's Law
F. Method of Images
G. Superposition
H. None of the Above



because… (select **ALL** that support your choice of method)

a. ☐ you can calculate $\vec{E}$ or V using the integral form of Coulomb's Law
b. ☐ symmetry allows you to calculate $\vec{E}$ using a spherical Gaussian surface
c. ☐ the boundary condition is azimuthally symmetric (i.e., symmetric in φ)
a. ☐ there is not appropriate symmetry to use other methods
b. ☐ you can use $\vec{E}(\vec{r}) = -\vec{\nabla}(k\cos 3\theta)$ and evaluate this at point P
c. ☐ $\nabla^2 V = 0$ inside the sphere and you can solve for V using Legendre Polynomials

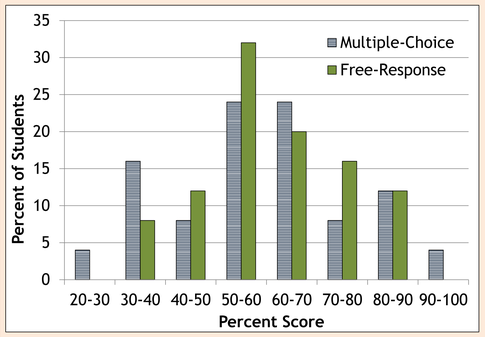
If you would like to elaborate further, please do so below.

Did it work?

Apples-to-apples comparison of the MC and free-response versions of the CUE from 1 semester (N=50)

- Students from a single upper-division electrostatics course at a large R1 university. Instructor was an experienced physics education researcher.
- Half took the MC version, half took the free-response version (N=25 in each group), matched based on midterm scores

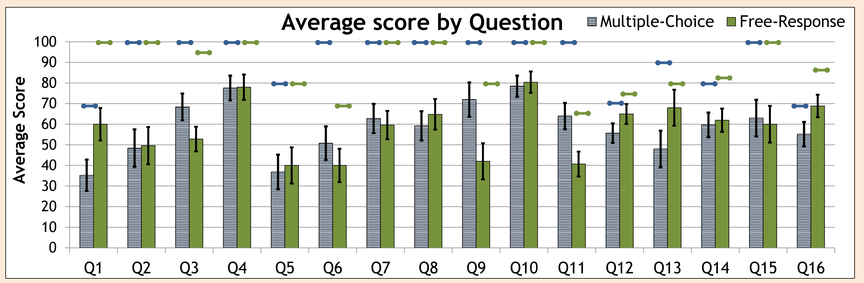
Overall



	Multiple-Choice	Free-Response
Avg. Score	58.9±3.5%	60.5±2.8%
Avg. Time	35±1.6 min	37±1.6 min

Distributions of total CUE score (left) from both versions of the exam can be treated as normal (Anderson-Darling test, $p>0.85$) and as having equal variance (Brown-Forsythe test, $p>0.9$).

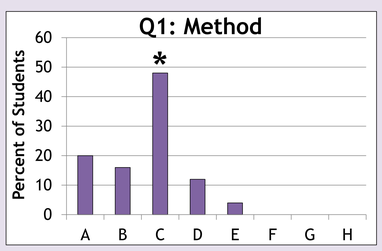
Item Difficulty

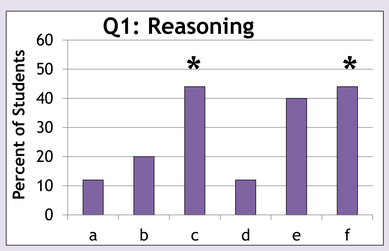


- Horizontal dashes represent the 75th percentile (3rd quartile) for each question. Error bars represent 1σ error.
- Differences between the two formats are statistically significant for Q1, Q9, Q11, and Q16 (Mann-Whitney U-test, $p\leq 0.05$)

What about student thinking?

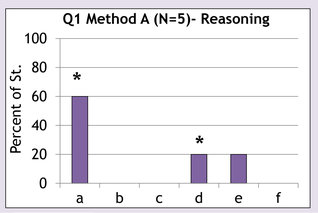
This new multiple-choice format still allows us to gain insight into student ideas

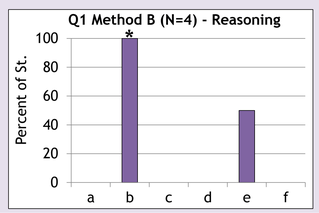


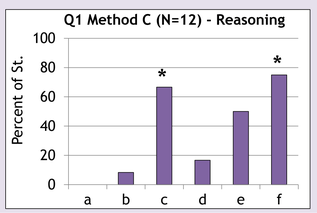


- Distributions of student responses to Q1 of the MC CUE (shown above) provide information about the nature of student ideas. The correct method and corresponding reasoning elements are indicated by asterisks.

- The reasoning elements selected by students selecting a particular method provide information about the consistency of student ideas. Reasoning elements which are consistent with a particular method are indicated with asterisks.
- The majority of students select reasoning elements consistent (or at least, not inconsistent) with their choice of method.







References
[1] S. Chasteen, *et. al. PRST-PER*, **8**, 020108 (2012)
[2] S. Lin and C. Singh, *PERC*, 1413, pp. 47 (2011)
[3] L. Bao and E. Redish, *PRST-PER*, **2**, 010103 (2006)

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Interested in giving the Multiple-choice CUE to your students? Sign up for more info! ↓