Developing a Conceptual Assessment for Advanced Undergraduate Electrodynamics

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Assessment Development

- Consensus Learning Goals
- Question Development
  - Expert Reviews & Student Interviews
  - Classroom Testing

Large-scale Implementation

Sample Question

steady current

4.(A) Electric field zero or nonzero?
4.(B) \( \nabla \cdot \mathbf{j} \) zero or nonzero?

Validation Studies

- 3 semesters / 8 institutions / N = 271
- Good discrimination power
  (Ferguson's \( \delta = 0.98 \); > 0.9 considered good)
  - \( r = 0.52 \) (p < 0.01) final exam scores
  - \( r = 0.46 \) (p < 0.01) final course grades
- IRR: Difference in total scores < 1%
### Preliminary Results

```
<table>
<thead>
<tr>
<th></th>
<th>CU Transformed</th>
<th>Non-CU</th>
<th>CU &amp; Non-CU Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>CU</td>
<td>A-1</td>
<td>B-1</td>
<td>C</td>
</tr>
<tr>
<td>Non-CU</td>
<td>A-2</td>
<td>B-2</td>
<td>D</td>
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<tr>
<td>PER</td>
<td>A-1</td>
<td>B-2</td>
<td>E</td>
</tr>
<tr>
<td>Traditional</td>
<td>A-1</td>
<td>B-2</td>
<td>F</td>
</tr>
</tbody>
</table>
```

### Student Reasoning

```
\[ \nabla \cdot \mathbf{j} = -\frac{\partial \rho}{\partial t} = 0 \]

Entire history of the CURrent:
146/376 = 39% correctly stated \( \nabla \cdot \mathbf{j} = 0 \)
```

### Student Reasoning

```
\[ \nabla \cdot \mathbf{j} = -\frac{\partial \rho}{\partial t} = 0 \]

\( \nabla \cdot \mathbf{j} = -\frac{\partial J_x}{\partial x} - \frac{\partial J_y}{\partial y} - \frac{\partial J_z}{\partial z} \)
```

### Student Reasoning

```
Incorrect Reasoning
N=79 (out of 153) %
Magnitude of J increasing to the right 47
Field lines becoming more dense 13
Charge density as source of divergence 8
Non-zero net flux of J through a surface 6
Source/sink exists somewhere 5
Other/blank/no reasoning provided 21
```

### Benefits of Assessment

- **Students**
  - Self-diagnosis / Exam preparation
  - PER Researchers
  - Evaluating pedagogical reforms
  - Insights into student difficulties
  - Fine-tune curriculum development
- **Instructors**
  - Learning goals being achieved?
  - Inform instructional focus
  - Compare w/ different semesters/institutions

### Course-Scale Learning Goals

Students should be able to...
- ... achieve physical insight through the mathematics of a problem.
- ... choose and apply the appropriate problem-solving technique.

### Topic-Scale Learning Goals

Students should be able to...
- ... derive boundary conditions on E- & B-fields from Maxwell’s equations.
- ... calculate the dipole moment of a given charge distribution.