There are good reasons to believe that introductory courses in classical physics are promoting in students a perspective that we call local realism. A realist perspective would be deterministic, where all physical quantities describing a system can be simultaneously specified for all times. Having had their commitment to a realist perspective reinforced through prior instruction may be problematic for students of modern physics, who must then learn, that from a quantum perspective, physical observables are indeterminate outside the context of measurement, and subject to the laws of probability. We are therefore concerned with how students’ perspectives change as they make the transition from learning classical physics to learning quantum physics. We conclude from the available data that specific attention paid to the ontological interpretation of quantum processes during instruction may aid in the cultivation in students of a suitable quantum perspective.

## Students’ Views of Measurement Change Over Time

### CLASS Statement #41: “It is possible for physicists to carefully perform the same experiment and get two very different results that are both correct.”

**& “Why? (Optional)”**

Shifts in Student Responses to CLASS Statement #41 Across an Introductory Physics Sequence:

- 1. Many students agree with statement #41 prior to instruction in classical physics.
- 2. Following instruction in classical physics, the number in agreement decreases significantly, and...
- 3. ...the number of those who disagree increases significantly.
- 4. After a single semester of modern physics, the number of students who agree with #41 increases dramatically, with an even with an even greater percentage in agreement than at the beginning of instruction in classical physics.

Instruction in modern physics causes the reasons behind student responses to change:

<table>
<thead>
<tr>
<th>CATEGORIZATION OF REASONING OFFERED BY STUDENTS IN RESPONSE TO CLASS#41</th>
<th>PRE-MODERN PHYSICS INSTRUCTION (N=877)</th>
<th>POST-MODERN PHYSICS INSTRUCTION (N=637)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td>Relativity, different frames of reference</td>
<td>5% (13)</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td>There can be more than one correct answer to a physics problem</td>
<td>5% (13)</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>Experiment/reality/human error</td>
<td>21% (29)</td>
</tr>
<tr>
<td><strong>D</strong></td>
<td>There is only one correct answer to a physics problem</td>
<td>49% (24)</td>
</tr>
</tbody>
</table>

### Differences in Specific Learning Goals

For the question at right:

- Students from 2170A were instructed that choice ‘B’ is correct.
- Students from 2170B were instructed that choice ‘B’ is correct.

[We note that the correctness of each answer is a question of interpretation.]

### Quantum Attitudes Statement #16: “An electron in an atom has a definite but unknown position at each moment in time.”

<table>
<thead>
<tr>
<th>RH</th>
<th>PQ</th>
<th>Quantum</th>
</tr>
</thead>
<tbody>
<tr>
<td>2170A</td>
<td>2170B</td>
<td>2170A</td>
</tr>
<tr>
<td>2170A</td>
<td>2170B</td>
<td>2170A</td>
</tr>
</tbody>
</table>

Conclusions

- Instruction in classical physics promotes and reinforces a realist perspective
- Students develop a quantum perspective through instruction in modern physics
- These perspectives are not robust concepts, and are sensitive to context
- Student learning can be significantly impacted by an instructor’s choice of learning goals

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2. The Colorado Learning Attitudes About Science Survey (CLASS): http://class.colorado.edu