Design Approach in a Physics Lab Course

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Physics, Engineering Physics and Astronomy
Are lab courses worth the cost?

- Lab courses in STEM (Science, Technology, Engineering and Mathematics) departments can be expensive
  - Intensive equipment
  - Extensive technical support
- Potential benefits include
  - Content mastery through hands-on experience
  - Problem-solving skills
  - Critical-thinking skills
- Train students to be like professional scientists, not content experts
- Should not reduce lab experience to follow set instructions
Physics undergraduate lab courses

Lab courses

- Close-ended experiments
  - To verify known results
  - Traditional labs, non-design labs
    - Detailed instructions are provided

- Open-ended experiments or projects
  - Freedom to explore a given experiment
  - Design labs
    - Students choose desired topic
    - Students design their own experimental procedures

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Why design-lab approach?

• Does a design lab address more course learning outcomes?
• Does a design lab motivate students?
• Do students in a design lab spend more time sense-making?
Not covered by traditional labs

Physics Lab Learning Outcomes

Technical Lab Skills
- Transfer Knowledge
- Literature Review
- Develop Practical, Hands-on Lab Skills
- Operate Analog and Digital Devices
- Understand Limitations and Uncertainties on Devices
- Work Effectively in Groups
- Work Collegetially and Collaboratively
- Time Management
- Workplace Safety
- Responsibility, Respect, Commitment, Independence, Integrity

Data Analysis
- Use Computer for Data Analysis
- Plot Data
- Curve Fitting
- Estimate and Improve Uncertainties
- Distinguish Systematic and Statistic Uncertainties
- Propagate Uncertainties
- Statistics Tests
- Maintain Quality Lab Notebooks
- Develop Clearly Stated Scientific Arguments
- Write Lab Reports
- Oral Presentation

Collaboration, Safety and Professionalism

Communicating Physics
Why design-lab approach?

• Does a design lab address more course learning outcomes?
• Does a design lab motivate students more?
• Do students in a design lab spend more time sense-making?
Pilot project

• A design lab in 2\textsuperscript{nd} year physics lab course – PHYS 250 (taught by Dr. Alastair McLean)
• Compact Disk Diffraction experiment
Logistics and data collection

• 38 students are divided into 19 groups
• A total of 13 groups did CD diffraction experiment
• Design lab handout was provided to the first 8 groups
• Traditional lab handout was given to the last 5 groups
• Data we collected include:
  • Audio recording in the lab
  • Student data analysis worksheets
  • Student attitude pre and post surveys
  • End of term survey
1.6 Procedure 1: Diffraction from a fixed Vertical Grating

a) Make sure that the CD is parallel to the wall or perpendicular to the table.

b) Make sure that the helium-neon laser that produces the green light is perpendicular to the CD. When the laser light is perpendicular to the CD, the laser light will be reflected off the CD back into laser.

1.6 Design-Lab Activities

a) Before you switch on the laser, measure all the physical quantities you need to predict what the diffraction pattern should look like with the CD in the vertical geometry and the laser light incident horizontally. Specifically where the diffracted beams should be.

b) Turn the laser on and see if the diffracted beams are where you calculated them to be. You will have to establish procedures for ensuring that the CD is parallel to the wall and the laser light is horizontal.
## CD diffraction end of term survey results

<table>
<thead>
<tr>
<th>Number of Students</th>
<th>Design Lab</th>
<th>Traditional Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>In total</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Who consented for data usage</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>With correct physics concept</td>
<td>100%</td>
<td>75%</td>
</tr>
<tr>
<td>Who had positive experience</td>
<td>70%</td>
<td>38%</td>
</tr>
<tr>
<td>Who preferred diffraction lab over other labs</td>
<td>40%</td>
<td>0</td>
</tr>
<tr>
<td>Who thought they were creative</td>
<td>50%</td>
<td>13%</td>
</tr>
<tr>
<td>Who think they did more sense-making than other labs</td>
<td>60%</td>
<td>63%</td>
</tr>
</tbody>
</table>
Summary

• Lab courses should train students to think and act like professional scientists, not just content experts
• Design lab approach addresses more course learning outcomes than traditional-lab approach
• Students in design labs spend more time “sense-making”, important to develop their critical-thinking skills
• Last but not least, students like the design labs more!