COMPARISON OF LABATORIALS WITH TRADITIONAL PHYSICS LABORATORIES

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OVERVIEW

1. Motivation for Labatorials
2. The Labatorial Concept
3. Methodology
4. Qualitative Results
5. Quantitative Results
6. Conclusion
The physics lab has long been a distinctive part of physics education.

- Kirkup et al., 1998; Hanif et al., 2008; Sharma et al., 2014; Aceituno et al., 2015

There is, however, little research done on the educational influence of physics labs on students.

- Sokoloff et al., 2007
It is known that many students believe that traditional physics labs are *uninteresting* and *tiresome*.

- Sokoloff et al., 2007
Traditional Labs

• In traditional labs, students:
  • Collect data
  • Carry out calculations
  • Plot graphs of their results
  • Verify a relationship

• Can be important in developing experimental skills

• However, recipe experiments include limited challenges and often choke students’ creativity
  ➢ Hanif et al., 2008; Ahrensmeier, 2013; Sharma et al., 2014

• In a major study, there was no statistically measurable benefit on course performance from enrolling in associated lab course
  ➢ Wieman & Holmes, 2015
What is a Labatorial?

• Alternative approach to physics labs aiming to alleviate common concerns about traditional labs

• Developed at the University of Calgary, inspired by University of Washington’s ‘Tutorials in Introductory Physics’ system
  ➢ Ahrensmeier et al., 2009; McDermott & Shaffer, 2002

• Labatorial students proceed through Tutorial-like worksheets (now also possibly including calculation problems and simulation questions)

• Worksheets driven by core experiment(s) for which students:
  • Make predictions about the outcome
  • Perform the experiment (may have instructions or need to design simple protocol)
  • Collect data
  • Interpret the results

• Labatorials highlight physics concepts from lectures and encourage students to present and share their ideas with one another
What is a Labatorial?

- 4 to 6 checkpoints per worksheet
- When student group reaches a checkpoint, they review the answers with the instructor
- All group members must have same answer
- If students answered incorrectly or are not proceeding in the right direction, the instructor leads students to find the correct answer by themselves, exploring and discussing alternate ideas
In this talk we examine and compare the advantages and disadvantages of labatorials and traditional labs in terms of the student experience and conceptual change.
The Pilot Study

• The context: Introduction to Experimental Mechanics

• Drafts of the six labatorials worksheets were designed and tested by graduate students in Fall 2018

• A pilot study in Winter 2019 was conducted to:
  • Validate the labatorial worksheets
  • Refine interview questions and conceptual questions added to final
The Study

• Only 54 students enrolled:
  • Experimental group: 3 labatorial sections (30 students)
  • Control group: 2 traditional sections (24 students)

• Initial equivalence of the two groups established using a pre-test of six questions from the Force Concept Inventory
  ➢ Hestenes et al., 1992
# Labatorial and Traditional Lab Interviewees

<table>
<thead>
<tr>
<th>Group</th>
<th>Pseudonym</th>
<th>Major</th>
<th>Prior Physics Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labatorial</td>
<td>Catherine</td>
<td>Biology</td>
<td>10 years ago in HS</td>
</tr>
<tr>
<td></td>
<td>Quincy</td>
<td>Environmental Science</td>
<td>Recently in college</td>
</tr>
<tr>
<td></td>
<td>Emma</td>
<td>Exercise Science</td>
<td>No physics in HS</td>
</tr>
<tr>
<td></td>
<td>Derek</td>
<td>Behavioural Neuroscience</td>
<td>Recently in college</td>
</tr>
<tr>
<td></td>
<td>Jessica</td>
<td>Exercise Science</td>
<td>10 years ago in HS</td>
</tr>
<tr>
<td></td>
<td>Stacy</td>
<td>Biochemistry</td>
<td>10 years ago in university</td>
</tr>
<tr>
<td>Traditional Lab</td>
<td>Adrian</td>
<td>Exercise Science</td>
<td>10 years ago in HS</td>
</tr>
<tr>
<td></td>
<td>Oscar</td>
<td>Biology</td>
<td>Recently in HS</td>
</tr>
<tr>
<td></td>
<td>Amir</td>
<td>Chemistry</td>
<td>No physics in HS</td>
</tr>
<tr>
<td></td>
<td>Evelyn</td>
<td>Behavioural Neuroscience</td>
<td>Recently in HS</td>
</tr>
<tr>
<td></td>
<td>Lauren</td>
<td>Behavioural Neuroscience</td>
<td>Recently in HS</td>
</tr>
<tr>
<td></td>
<td>Zion</td>
<td>Aerospace Engineering</td>
<td>Recently in university</td>
</tr>
</tbody>
</table>
Data Collection

• Interviews (semi-structured):
  • **Student interviews**: conducted between Lab 1 and 2 and after Lab 6
  • **TA interviews**: conducted after the course ended

• Quantitative sources:
  • **Pre-test and post-tests**: graded by me (rubric-based)
  • **Final exam**: co-graded

• Other qualitative sources:
  • **TA surveys**: filled out after labatorial session/report grading
  • **Student writing products**: collected from interviewees after the course
  • **Observations**: recorded as a passive observer in class sessions
# Student Interviews

<table>
<thead>
<tr>
<th>Types of Support</th>
<th>Promoters of Learning</th>
<th>Inhibitors of Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Labatorials</strong></td>
<td>• Peer support</td>
<td>• Peer instruction</td>
</tr>
<tr>
<td></td>
<td>• TA support</td>
<td>• Labatorial structure</td>
</tr>
<tr>
<td></td>
<td>• Grading support</td>
<td>• Deeper engagement</td>
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<tr>
<td></td>
<td></td>
<td>• Real-world connections</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Peer over-dependence</td>
</tr>
<tr>
<td><strong>Traditional Labs</strong></td>
<td>• Peer support*</td>
<td>• Peer interactions</td>
</tr>
<tr>
<td></td>
<td>• TA support*</td>
<td>• Intro theory</td>
</tr>
<tr>
<td></td>
<td>• Procedural support</td>
<td>explanation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Real-world connections*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Focus on error</td>
</tr>
<tr>
<td></td>
<td></td>
<td>avoidance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Recipe-like instructions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Understanding later</td>
</tr>
</tbody>
</table>
1. How does the experience of learning differ between labatorials and traditional labs?
The Learning Experience in Labatorials

- Interviewees indicated sense of camaraderie with peers and with TA
  - Catherine: *The nice thing about [the lab] is that even with the TA [...] it felt like a team effort toward understanding.*

- Checkpoints helped encourage students to share doubts with TA and feel supported

- Positive changes in student perspectives on physics
  - Catherine: *My takeaway is that physics is doable, and it is interesting, and it is applied to daily life, and it’s not just found in an amusement park or... Everything that you do follows these rules and these principles, and there is a reason why this learning is important.*
The Learning Experience in Traditional Labs

- Group work experience more akin to working individually rather than collaboratively driven
  - Lauren: *It’s like [you’re] checking with your partner, but still working individually.*

- The traditional lab TA played a largely managerial role
  - Zion: *He was [...] going around, looking everywhere, seeing how students are doing and all that, but he wasn’t interacting with the students. He was just looking, and if he saw something wrong, he would say, ‘Well this is wrong, you should probably not do it this way, you should do it that way.’ And that’s it, that’s all he did. He didn’t really do much other than that.*

- Recipe nature of labs alleviated grade-related pressure
Conclusion 1

*How can the learning experience differ between labatorials and traditional labs?*

• In considering the learning experience of the students between both groups, threading across the interviews is the core theme of **support**.

• Through various mechanisms of support or **scaffolding**, students utilizing labatorials are feel more comfortable in the lab through the lessening of their various sources of stress.
2. In what ways do labatoriums and traditional labs promote the development of conceptual understanding?
Conceptual Learning in Labotorials

• Students were deeply cognitively engaged, actively collaborating and engaging in peer-instruction
  • Catherine: *To feel like you’re in a safe enough space ... ‘I actually don’t know what I’m doing. Could you explain to me why you understand this?’* We all had moments like that. We were even, but *we all came out of more knowledgeable*.

• Interventions at checkpoints helped scaffold students’ understanding while ensuring that they did not build on misconceptions

• Prediction questions of the labotorials also important for developing students’ conceptual understanding.
  • Quincy: *All the predictions, they just helped you write out and then discuss with your teammate about your own ideas. And then when you go through the lab, they start to change because not exactly everything you think is right. After you go through all the experiments and all the work and find the final result, you will understand that, ‘Ok, I was thinking wrong at first, and now I need to think in that way for things to make more sense.’*
Conceptual Learning in Traditional Labs

- Seeing concepts applied hands-on helped make the connection between theory and reality

- Students would occasionally check each others’ results, and discussions typically did not exceed procedural aspects of the lab

- Students focus on error avoidance during the lab
  - Zion: *You would have to do a little extra work if you really want to understand it. And if you don’t you’re going to follow a bunch of steps [...] and then that’s it.*
Conclusion 2

In what ways do labatorials and traditional labs promote the development of conceptual understanding?

• The extensive scaffolding inherent in labatorials helps students elicit, confront, and resolve their misconceptions and thus allows development of conceptual understanding to occur.

• The absence of conditions for conceptual change in traditional labs encourages students to simply follow instructions and proceed without thinking about what they are doing.
3. How do students’ learning outcomes compare between the two lab approaches?
### Comparing Overall Performance

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Shapiro-Wilk p-value</th>
<th>t-test p-value</th>
<th>η² Value</th>
<th>Mann-Whitney U p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-Tests</td>
<td>Labatorial</td>
<td>30</td>
<td>77.50</td>
<td>8.69</td>
<td>0.906</td>
<td>0.569</td>
<td>0.006</td>
<td>0.937</td>
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<td></td>
<td>Traditional</td>
<td>24</td>
<td>75.76</td>
<td>13.60</td>
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<tr>
<td>Final Exam</td>
<td>Labatorial</td>
<td>30</td>
<td>67.69</td>
<td>17.04</td>
<td>0.216</td>
<td>0.196</td>
<td>0.032</td>
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<td>Traditional</td>
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<td>73.42</td>
<td>14.50</td>
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<td>Concept Questions</td>
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<td>14.91</td>
<td>0.129</td>
<td>0.422</td>
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<td></td>
<td>Traditional</td>
<td>24</td>
<td>74.13</td>
<td>15.54</td>
<td>0.047</td>
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</tr>
</tbody>
</table>

- t-test p-values are all not significant
- Consistent with non-significant Mann-Whitney U results
- η² values suggest a small effect of lab group on performance

Conclusion: Neither group performed better than the other overall.
Comparing Overall Performance

5. Quantitative Results

- Average Post-Test Grade
- Final Exam Grade
- Average of Final Exam Conceptual Question Scores

Histograms showing the frequency distribution for different lab types.
Comparing Performance By Question

<table>
<thead>
<tr>
<th></th>
<th>Final Q9</th>
<th>Final Q15</th>
<th>Final Q10</th>
<th>Final Q17</th>
<th>Final Q5</th>
<th>Final Q14</th>
<th>Post Q1.2</th>
<th>Final Q8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>t-test</strong></td>
<td>0.006 (UEV)</td>
<td>0.003</td>
<td>0.008</td>
<td>0.050 (UEV)</td>
<td>0.068</td>
<td>0.049 (UEV)</td>
<td>0.034 (UEV)</td>
<td>0.019 (UEV)</td>
</tr>
<tr>
<td><strong>η²</strong></td>
<td>0.138</td>
<td>0.206</td>
<td>0.075</td>
<td>0.072</td>
<td>0.096</td>
<td>0.056</td>
<td>0.033</td>
<td>0.006</td>
</tr>
<tr>
<td><strong>Fisher</strong></td>
<td>0.011</td>
<td>0.001</td>
<td>0.055</td>
<td>0.044</td>
<td>0.036</td>
<td>0.133</td>
<td>0.273</td>
<td>0.577</td>
</tr>
<tr>
<td><strong>Mann-Whitney U</strong></td>
<td>0.009</td>
<td>0.010</td>
<td>0.010</td>
<td>0.075</td>
<td>0.057</td>
<td>0.054</td>
<td>0.052</td>
<td>0.096</td>
</tr>
<tr>
<td><strong>Stronger Group</strong></td>
<td>Traditional</td>
<td>Traditional</td>
<td>Labatorial</td>
<td>Traditional</td>
<td>Traditional</td>
<td>Labatorial</td>
<td>Labatorial</td>
<td>?</td>
</tr>
<tr>
<td><strong>Question Type</strong></td>
<td>Short calculation</td>
<td>Short calculation</td>
<td>Concept</td>
<td>Short calculation</td>
<td>Short calculation</td>
<td>Concept</td>
<td>Concept</td>
<td>Long calculation</td>
</tr>
</tbody>
</table>

- For some questions (typically conceptual), labatorial students appear to perform better.
- For others (typically numerical), traditional lab students appear to perform better.
Triangulation With Surveys, Reports, and Observations: Hierarchical Summarization

- Synthesize Across Labs
- Triangulate Across Data Sources
- Synthesize Between Groups
- Synthesize Across Students/TAs
- Summarize for Each Student/TA
- Code by Color
Conceptual Outcomes Triangulation

**Strategy:**

1. **Count occurrences** of conceptual **gain** or **difficulty** in each data source

2. **Visualize** these in a quadrant system to better ascertain patterns (using **color**)

5. Quantitative Results
Conclusion 3

How do students’ learning outcomes compare between the two lab approaches?

• No significant difference in performance overall between the groups

• Differentiation by question type:
  • Labatorial group: mastery of concepts targeted in the lab
  • Traditional group: mastery standardized procedures, memorization-based calculations
Summary of Key Results

• By virtue of extensive scaffolding, labatorial students are able to get more engaged in learning in the lab, regularly getting involved in peer discussions and making an effort to understand the concepts.

• In traditional labs scaffolding was less prominent than in labatorials in all respects. The focus on the lab instructions and error avoidance had adverse effects on student learning.

• Upon considering results as a whole, there are clear dichotomies between labatorials and traditional labs that emerge regarding the forms of support in the lab, the pedagogical approaches taken, and the resultant impact of these on students’ conceptual learning.
# Summary: Thematic Dichotomies

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Lab Type</th>
<th>Lab Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Labatorials</td>
<td>Traditional Labs</td>
</tr>
<tr>
<td>Lab Focus</td>
<td>Conceptual</td>
<td>Experimental</td>
</tr>
<tr>
<td>Student Focus</td>
<td>Learning</td>
<td>Error Avoidance</td>
</tr>
<tr>
<td>Teamwork Style</td>
<td>Collaborative</td>
<td>Independent</td>
</tr>
<tr>
<td>Accountability</td>
<td>Group</td>
<td>Individual</td>
</tr>
<tr>
<td>TA Involvement</td>
<td>Guidance</td>
<td>Managerial</td>
</tr>
<tr>
<td>Real-World Connection</td>
<td>Relevance</td>
<td>Tangibility</td>
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<tr>
<td>Lab Structure</td>
<td>Scaffolding</td>
<td>Instructions</td>
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<tr>
<td>In-Lab</td>
<td>Understanding While Doing</td>
<td>Doing Without Understanding</td>
</tr>
<tr>
<td>Learning Outcomes</td>
<td>Conceptual Understanding</td>
<td>Formulaic Procedures</td>
</tr>
</tbody>
</table>
Thank you for listening! 😊
References


