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)

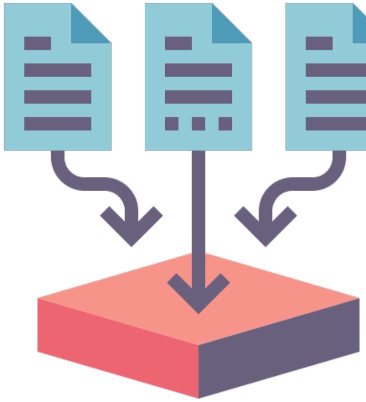
- Initial equivalence of the two groups established using a pre-test of six questions from the Force Concept Inventory
  - Hestenes et al., 1992

Labatorial and Traditional Lab Interviewees

Group	Pseudonym	Major	Prior Physics Experience
Labatorial	Catherine	Biology	10 years ago in HS
	Quincy	Environmental Science	Recently in college
	Emma	Exercise Science	No physics in HS
	Derek	Behavioural Neuroscience	Recently in college
	Jessica	Exercise Science	10 years ago in HS
	Stacy	Biochemistry	10 years ago in university
Traditional Lab	Adrian	Exercise Science	10 years ago in HS
	Oscar	Biology	Recently in HS
	Amir	Chemistry	No physics in HS
	Evelyn	Behavioural Neuroscience	Recently in HS
	Lauren	Behavioural Neuroscience	Recently in HS
	Zion	Aerospace Engineering	Recently in university

Data Collection

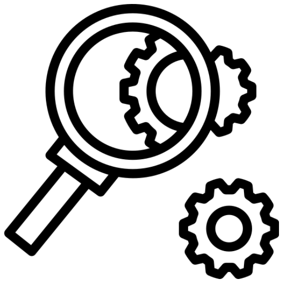
- Interviews (semi-structured):
  - **Student interviews**: conducted between Lab 1 and 2 and after Lab 6
  - **TA interviews**: conducted after the course ended



- 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

	Types of Support	Promoters of Learning	Inhibitors of Learning
Labatorials	• **Peer support** • TA support • Grading support	• Peer instruction • **Labatorial structure** • Deeper engagement • Real-world connections	• **Peer over-dependence**
Traditional Labs	• Peer support* • TA support* • **Procedural support**	• Peer interactions • **Intro theory explanation** • Real-world connections*	• **Focus on error avoidance** • Recipe-like instructions • Understanding later



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.*

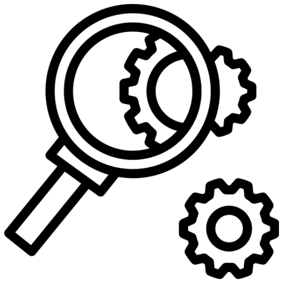
- The traditional lab TA played a largely managerial role
  - Zion: *He was [...] going around, looking everywhere, seeing how students are doing and all that, but he wasn't interacting with the students. He was just looking, and if he saw something wrong, he would say, 'Well this is wrong, you should 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 labatorials and traditional labs promote the development of conceptual understanding?

Conceptual Learning in Labatorials

- 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 labatorials 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?

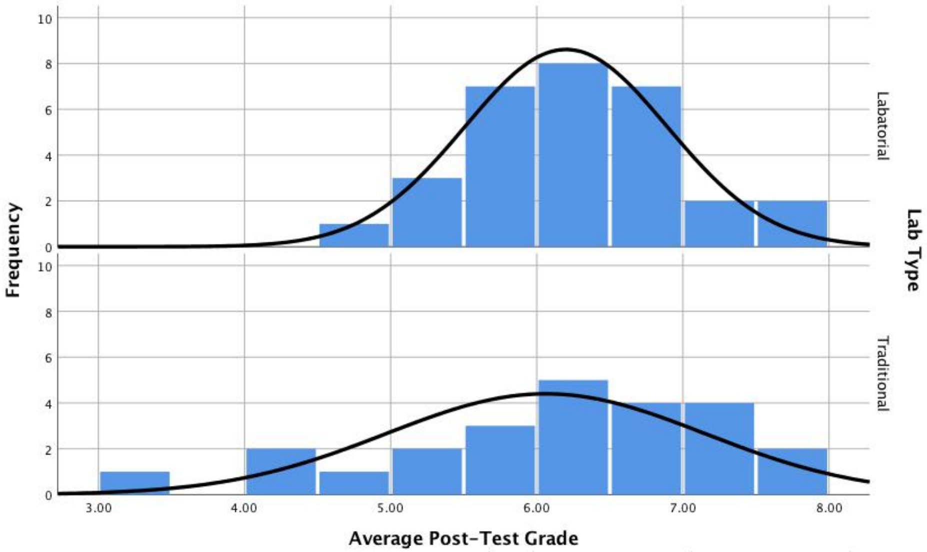
Comparing Overall Performance

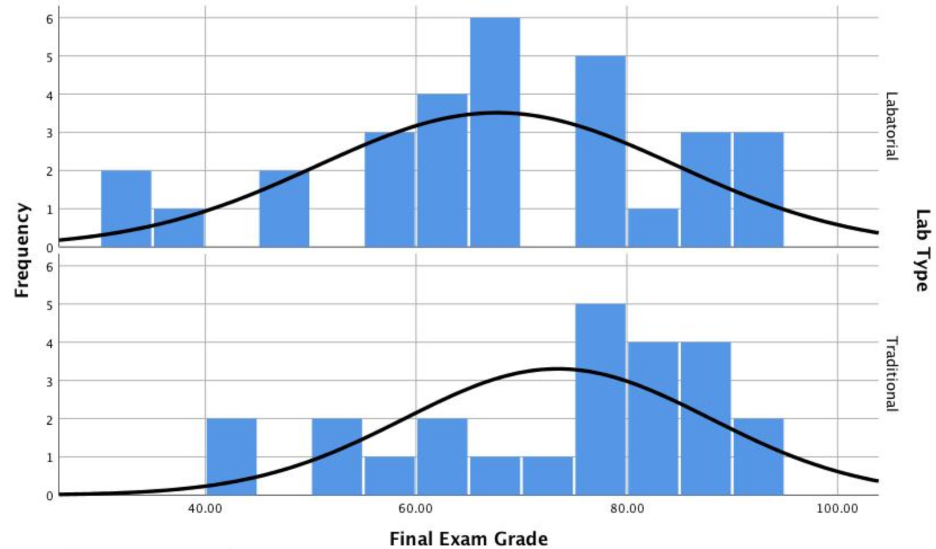
Test	Group	N	Mean	Standard Deviation	Shapiro-Wilk p-value	t-test p-value	η^2 Value	Mann-Whitney U p-value
Post-Tests	Labatorial	30	77.50	8.69	0.906	**0.569**	**0.006**	**0.937**
	Traditional	24	75.76	13.60	0.138			
Final Exam	Labatorial	30	67.69	17.04	0.216	**0.196**	**0.032**	**0.233**
	Traditional	24	73.42	14.50	0.026			
Concept Questions	Labatorial	30	77.50	14.91	0.129	**0.422**	**0.013**	**0.372**
	Traditional	24	74.13	15.54	0.047			

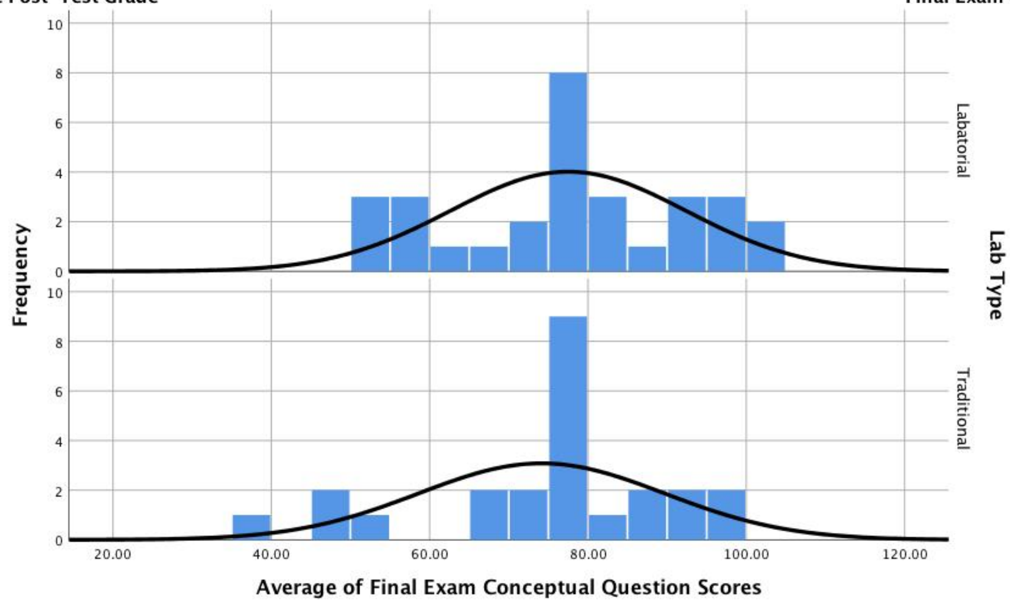
- t-test p-values are all not significant
- Consistent with non-significant Mann-Whitney U results
- η^2 values suggest a small effect of lab group on performance

Conclusion: Neither group performed better than the other overall.

Comparing Overall Performance





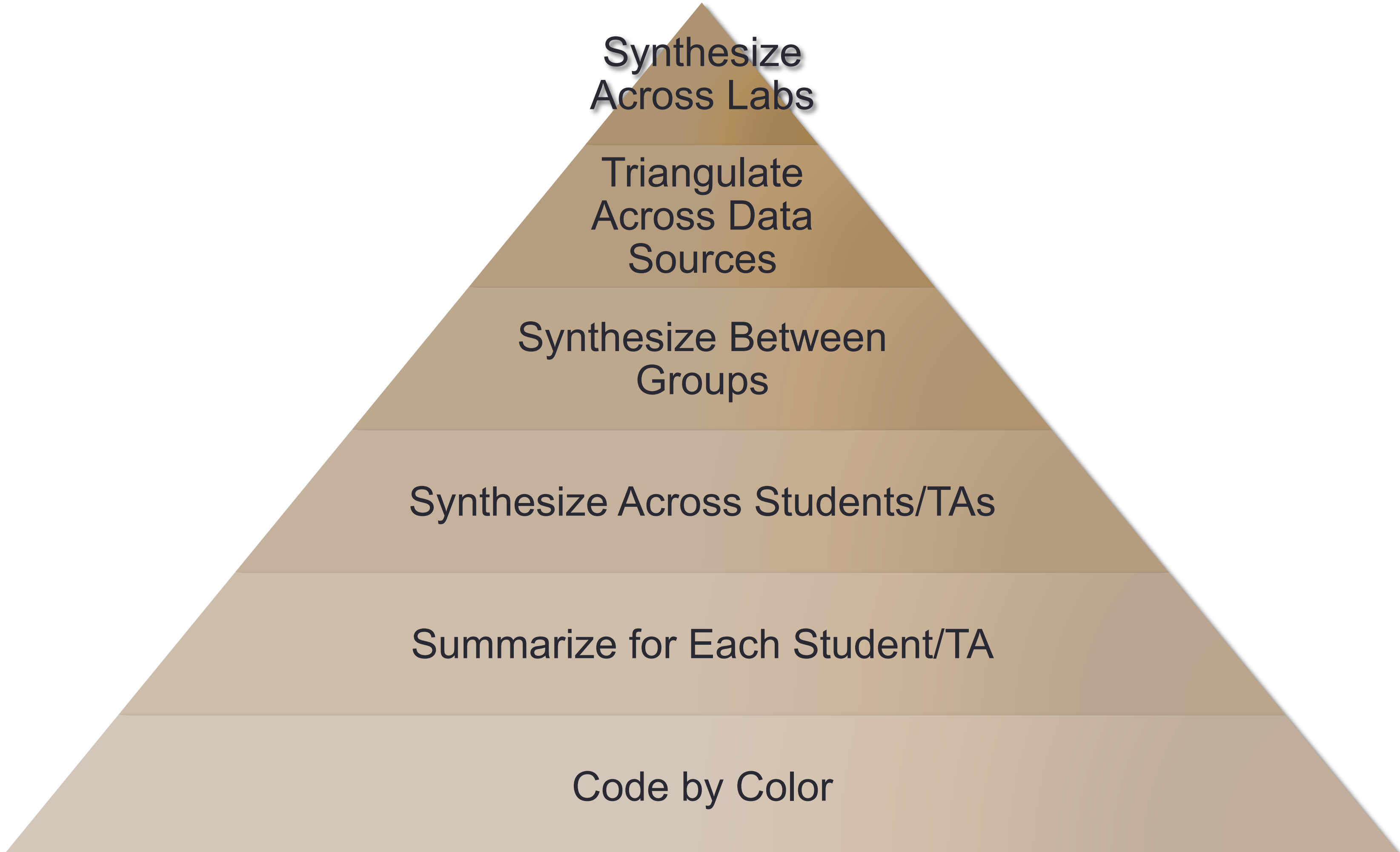


Comparing Performance By Question

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

- 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



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)

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

	Lab Type	
Dimension	Labatorials	Traditional Labs
Lab Focus	Conceptual	Experimental
Student Focus	Learning	Error Avoidance
Teamwork Style	Collaborative	Independent
Accountability	Group	Individual
TA Involvement	Guidance	Managerial
Real-World Connection	Relevance	Tangibility
Lab Structure	Scaffolding	Instructions
In-Lab	Understanding While Doing	Doing Without Understanding
Learning Outcomes	Conceptual Understanding	Formulaic Procedures

Thank you for listening! ☺

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