



WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

Using Whiteboards to Support Scientific Practices in Introductory Labs

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Course Transformation at UW

Algebra-based Physics 1 & 2
(Each ~500 students/semester)

Prelectures



Lectures

Active Learning

Discussions



Labs



Department of Physics

Guiding Principles for New Labs

➤ Open-Ended Design

- “Capstone” of each lab is a **design challenge** with multiple possible solutions

➤ Communication

- **Whiteboards** facilitate collaboration & communication
- Mid-lab “**symposium**” provides forum to share ideas

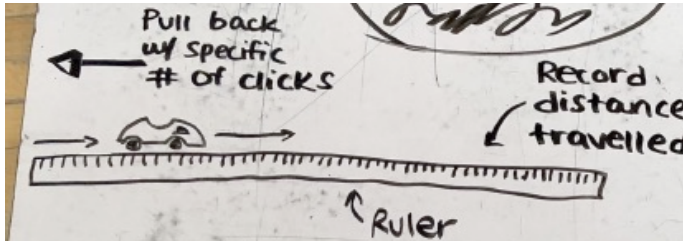
➤ Conceptual Scaffolding

- First half of lab **builds up** & **reinforces** principles that will be used in design challenge



Grading Dimensions

Diagram of Setup



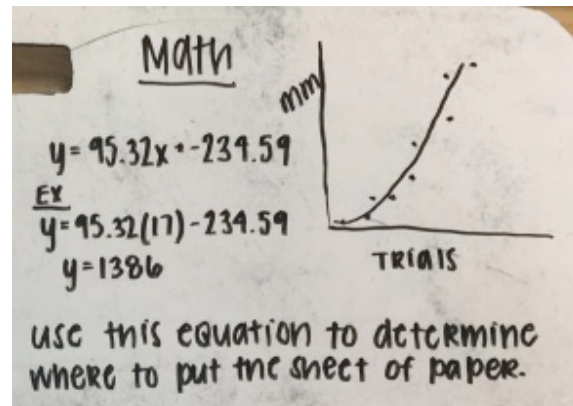
Uncertainty & Assumptions

Uncertainty
 measurement uncertainty: $\pm 0.005\text{ m}$
 random uncertainty (standard deviation from best fit line): $\pm 0.028\text{ m}$
 minimize by increasing number of trials & remaining others

Description of Approach

Approach
 - wind up car an even # of clicks 2-24
 - 24 trials (12 click variations, 2 sets of each)
 - measure distance travelled
 - averaged 2 measurements
 - graphed points ($y = \text{distance}$, $x = \text{clicks}$) on Excel
 - determined best fit via Excel
 - determined uncertainty via Excel
 - chose strip length by standard deviation (uncertainty)

Mathematical Procedure



Results

Results

clicks	avg = distance (cm) / #clicks	cm/click
10 clicks	avg = 45.24 cm	4.52 cm/click
15 clicks	avg = 132.06 cm	8.80 cm/click
20 clicks	avg = 276.75 cm	13.84 cm/click

* We believe that no single average cm/click value best describes the motion of the car. Rather, the average cm/click value will increase with the total number of clicks.

Suggestions for future improvement
 - to decrease car release variability, use a mechanism to release
 - use many different cars with more trials per variable.



Sample Whiteboard

Diagram of Setup

① launcher car set up to launch at x amount of clicks.
Ruler: 1m

② car set up to launch on vertical set up against wall.

Math

$m = 0.029 \text{ kg}$

$U_s \geq \frac{1}{2}mv^2 + mgy$

1 2 3 4

$\frac{mv^2}{r} = mg \rightarrow v^2 = g \cdot r$

Method

① Determine Kinetic Energy

- use timer to determine seconds it takes for car to travel 1m.
- Take 5 Trials for each Launch click.
- calculate m/s to determine velocity for each trial.
- Take average of 5 trials for each click.
- Use eq. $K = \frac{1}{2}mv^2$ to solve for K energy.

click	K
1	0.029 J
2	0.063 J
3	0.099 J
4	0.133 J

② Determine Potential Energy

- set up track along wall & measure max height car reaches with each click.
- Conduct 5 Trials for each click (adjust ruler as you change clicks).
- Take average of 5 Trials for each click.
- Use eq. $U = mgy$ to solve for P. Energy.

click	U
1	0.0469 J
2	0.0733 J
3	0.102 J
4	0.136 J

Results

$U_s \geq \frac{1}{2}mv^2 + mgy$

$\frac{1}{2}(0.029)(1.8 \cdot 125)^2 + (0.029)(9.8)(0.125)$

$U_s \geq 0.0711$

2 clicks Launch

$0.073 \geq 0.0711$
(our U value for 2 clicks)

Uncertainty

- * Human error in timing speed car travels 1m (affects velocity).
- * We assumed car will move at same speed every time.
- * Assume no external forces (friction).
- * Ways to minimize error:
More trials, try with different cars.
More accurate way to measure velocity.



Post-semester Survey (Sp '18)

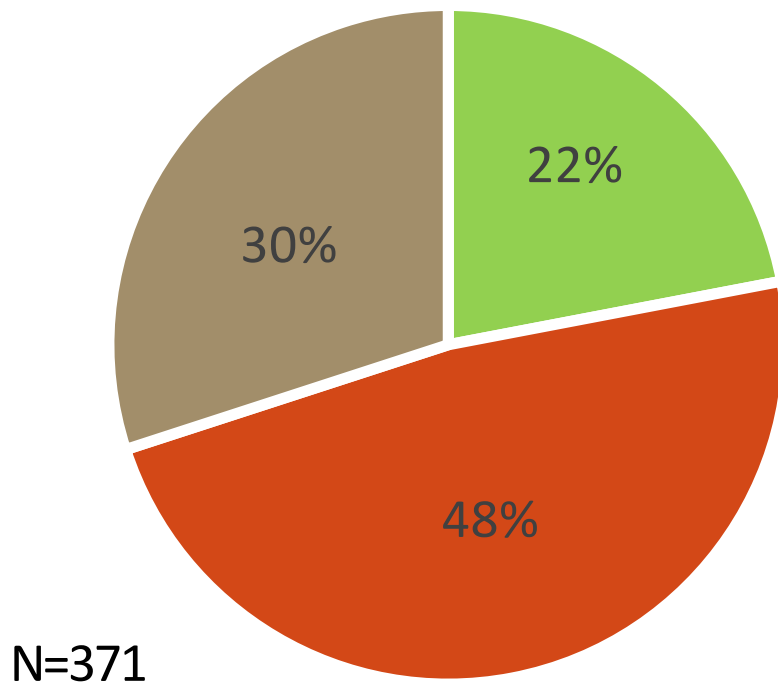
- 12 questions, 5-point Likert scale
 - Strongly Disagree – Disagree – Neutral – Agree – Strongly Agree
- Administered with post-semester conceptual inventories during lab
- “Traditional” = Algebra-based Physics 2
- “Design-based” = Algebra-based Physics 1



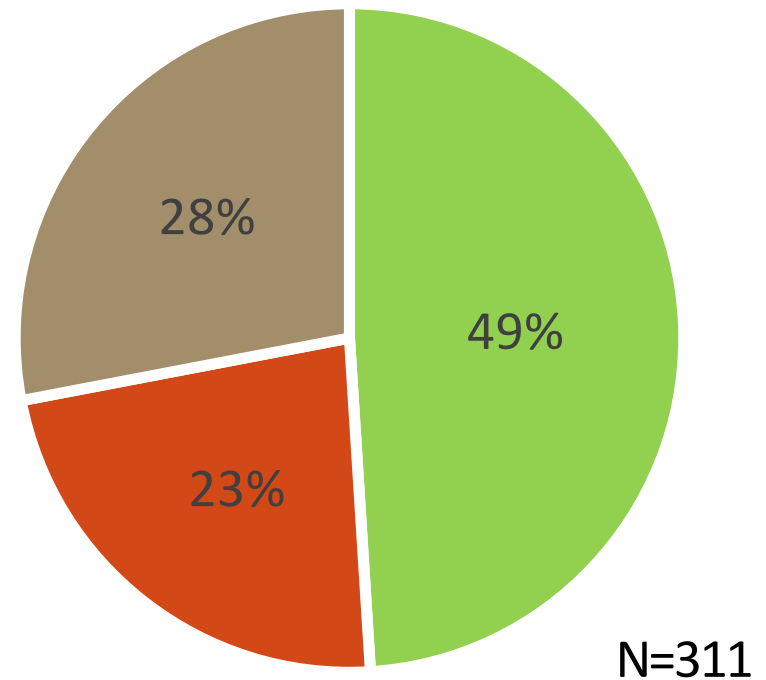
Results: Interest

“Overall, I found the labs interesting.”

■ Agree ■ Disagree ■ Neutral



Traditional



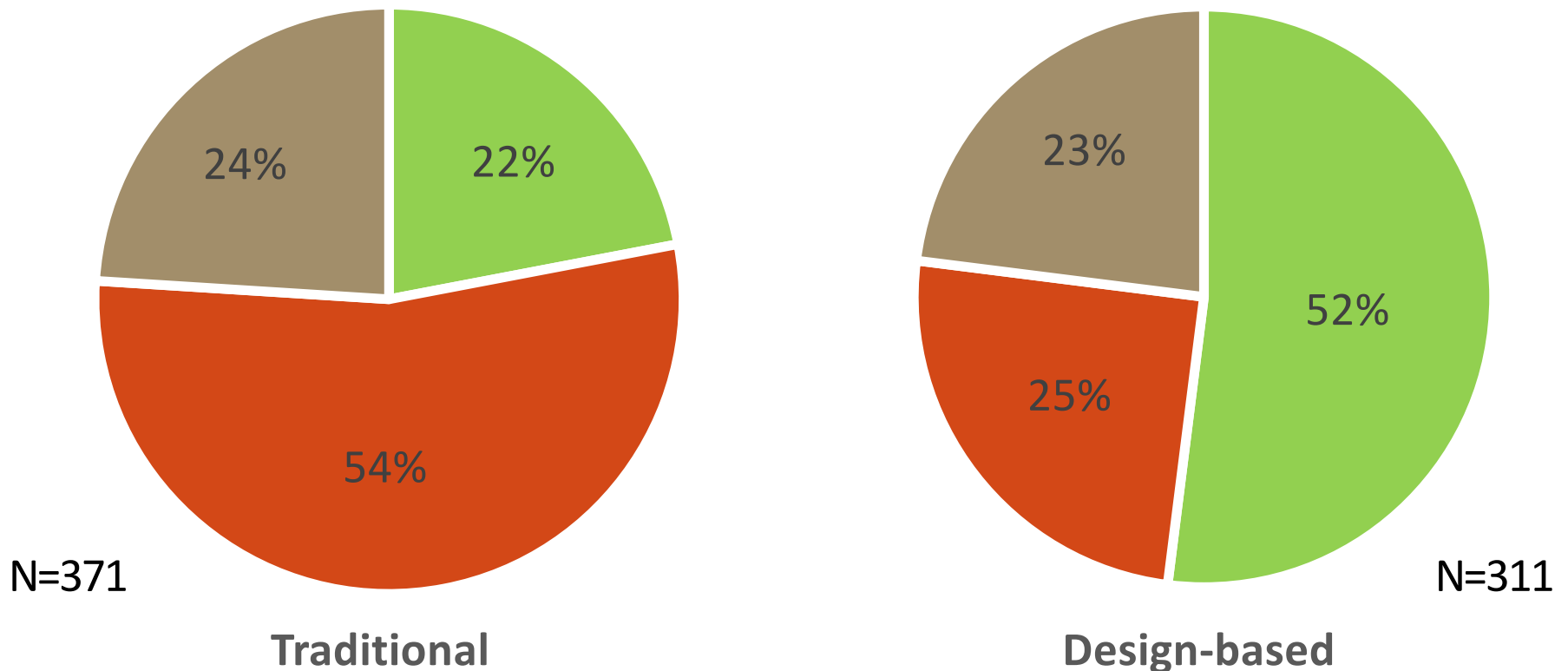
Design-based



Results: Concept development

“The labs improved my understanding of physics concepts.”

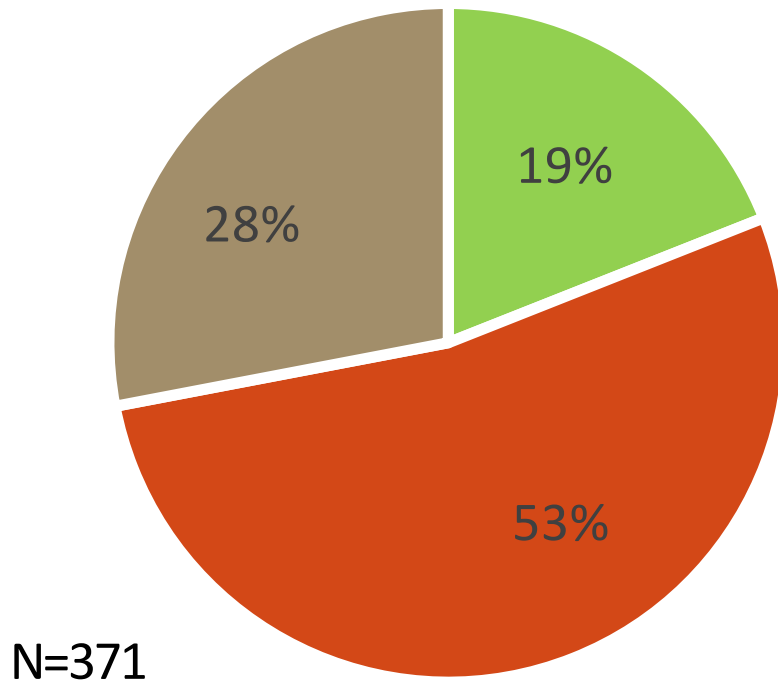
■ Agree ■ Disagree ■ Neutral



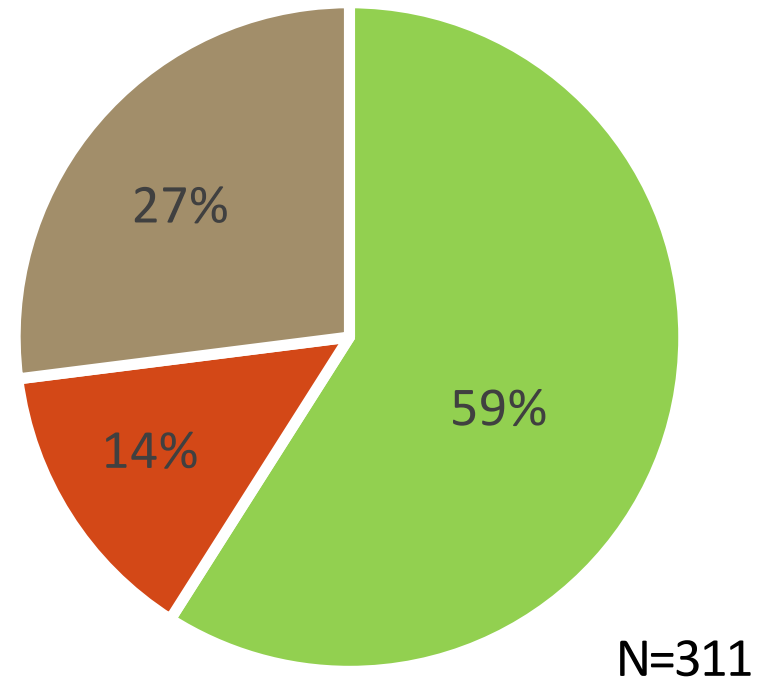
Results: Creativity

“I felt like I had to think creatively in order to be successful at the labs.”

■ Agree ■ Disagree ■ Neutral



Traditional



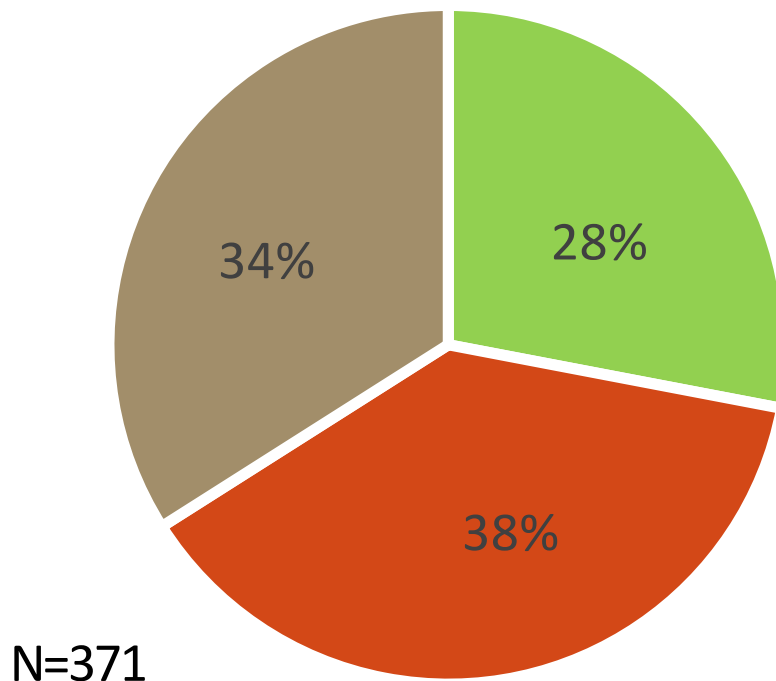
Design-based



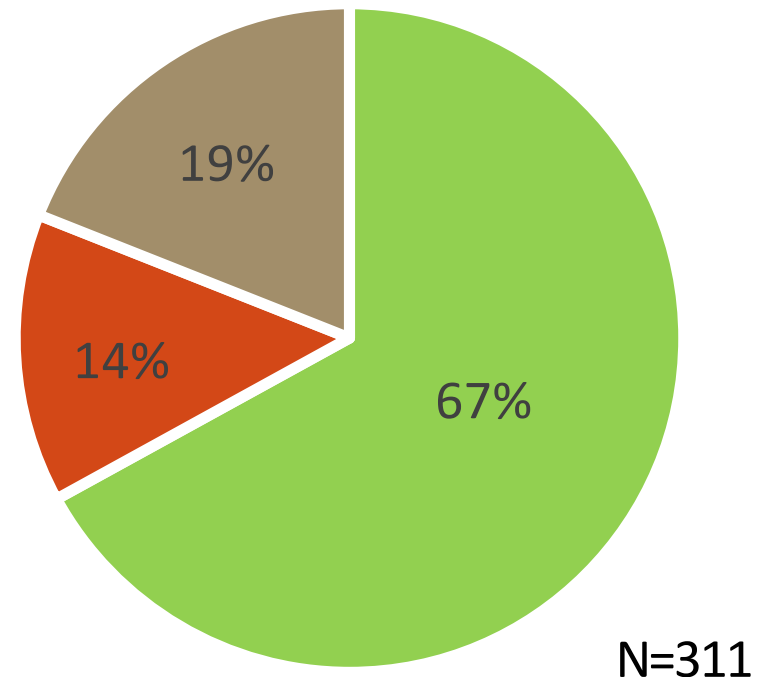
Results: Creativity

“I felt like there was usually more than one correct way to accomplish the lab activities.”

■ Agree ■ Disagree ■ Neutral



Traditional



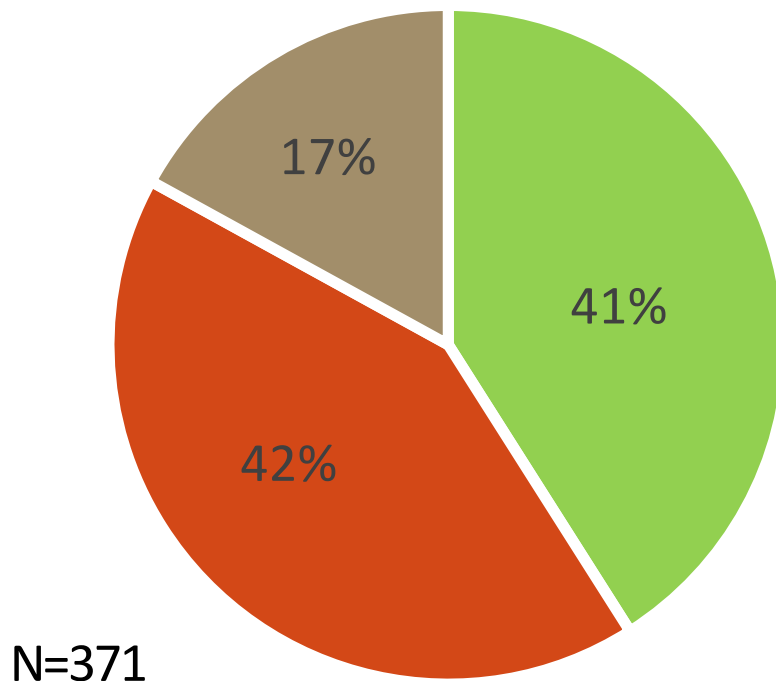
Design-based



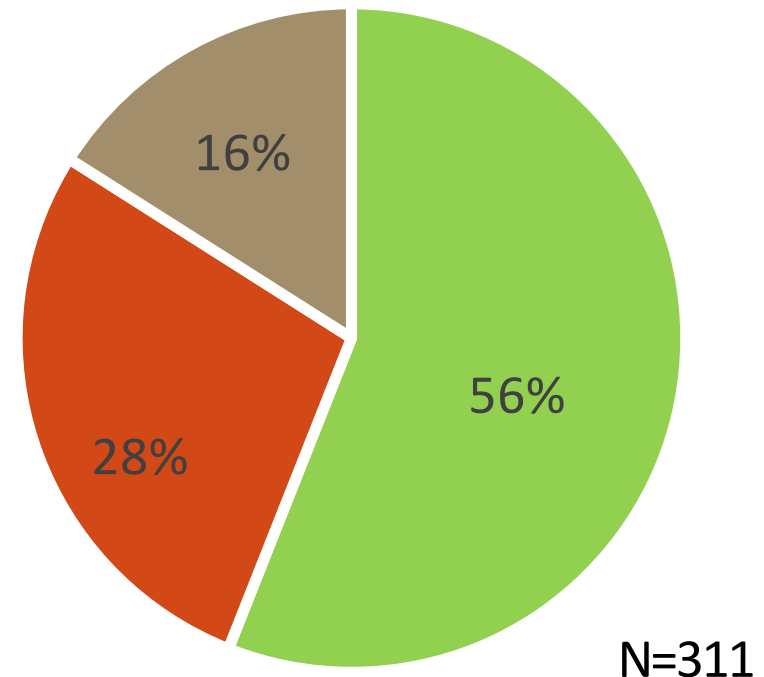
Results: Communication

“In a typical lab this semester, I would discuss my results and/or procedure with another lab group.”

■ Agree ■ Disagree ■ Neutral



Traditional



Design-based



Summary

- We have introduced a new **introductory laboratory model** at UW-Madison
- Preliminary results show positive trends in student **interest, creativity, & conceptual development**
- Room for improvement regarding **symposium** implementation
- **Future Directions**
 - Expand lab model to other courses
 - Conduct classroom observations & interviews



Contributors

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Department of Physics