Reflection, evaluation, and participation in undergraduate physics labs

Phys 107/109 &
Science 1
Physics Lab
140 students
Weekly 3-hour lab sessions

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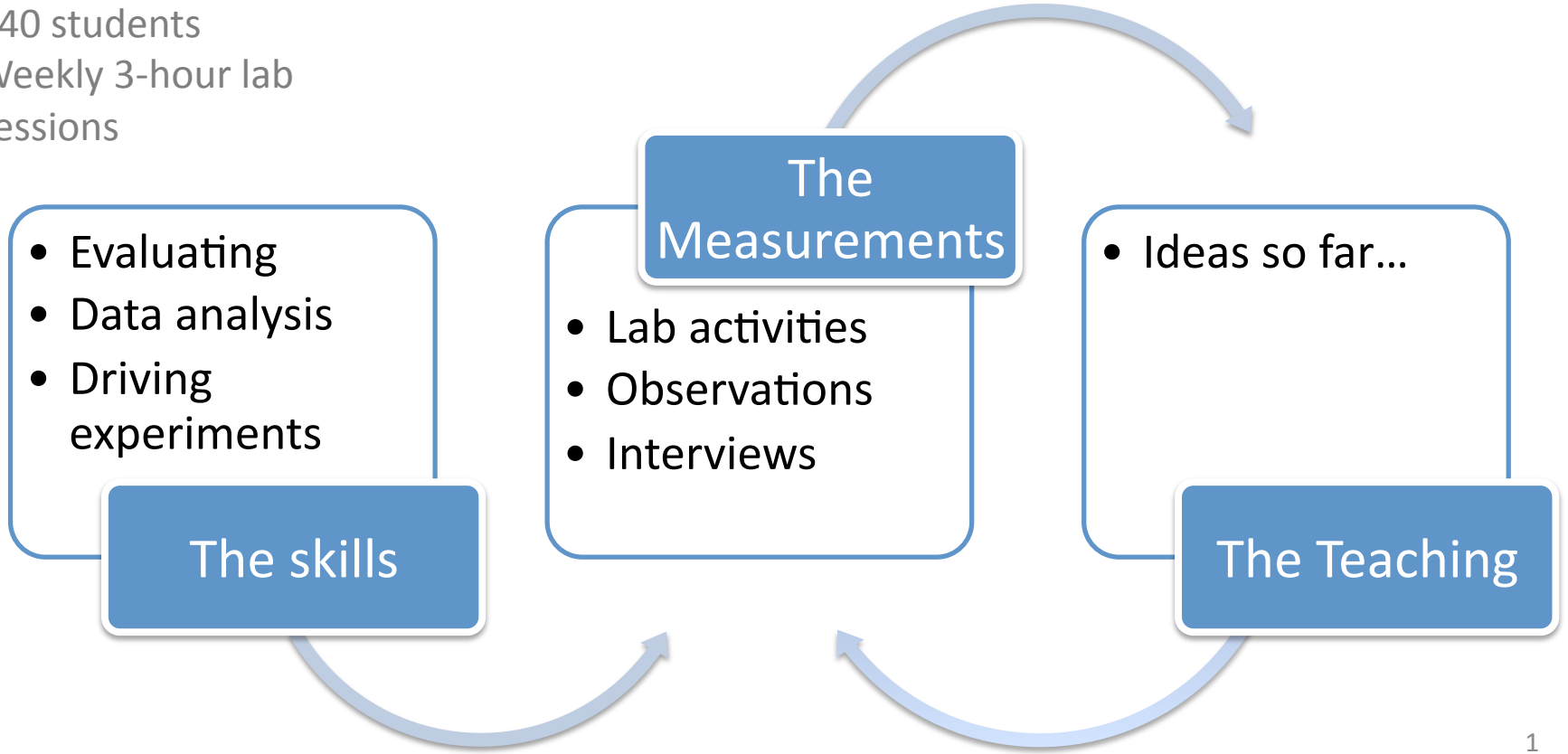
The basic plan…



Identifying the skills

Reflecting

- Can students check their results and compare to things they know as they work?
- When do students trust their data?

Evaluating

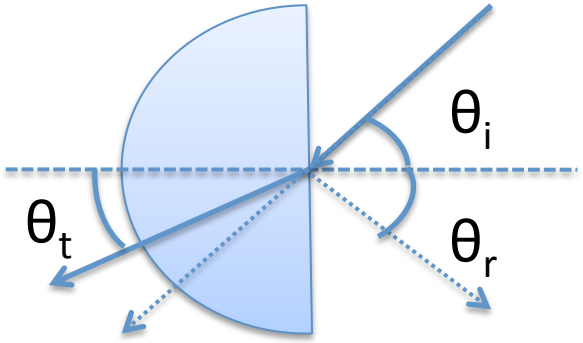
- Will they change models based on their data?
- Will they correct their methods if things don't make sense?

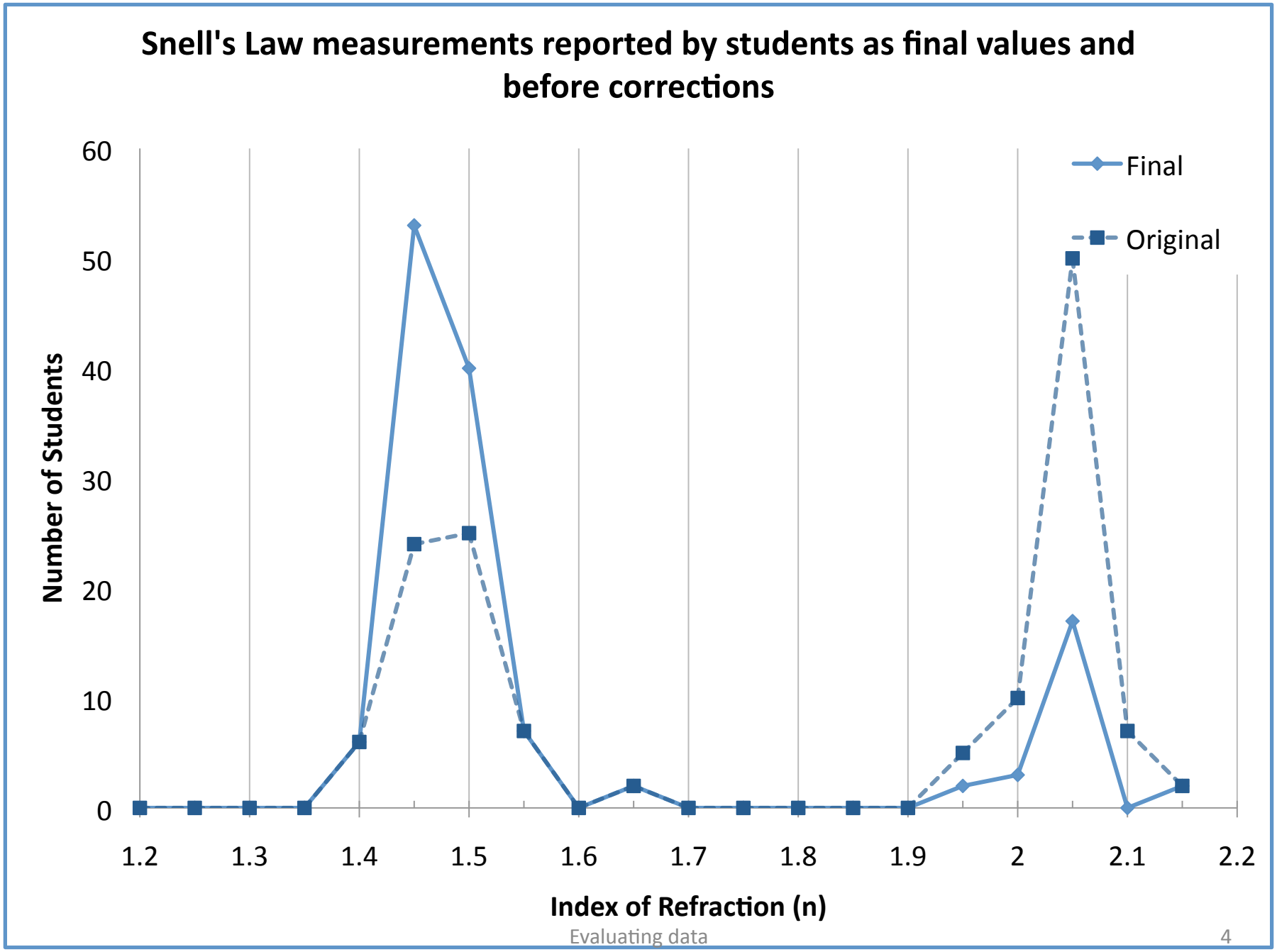
Doing experiments

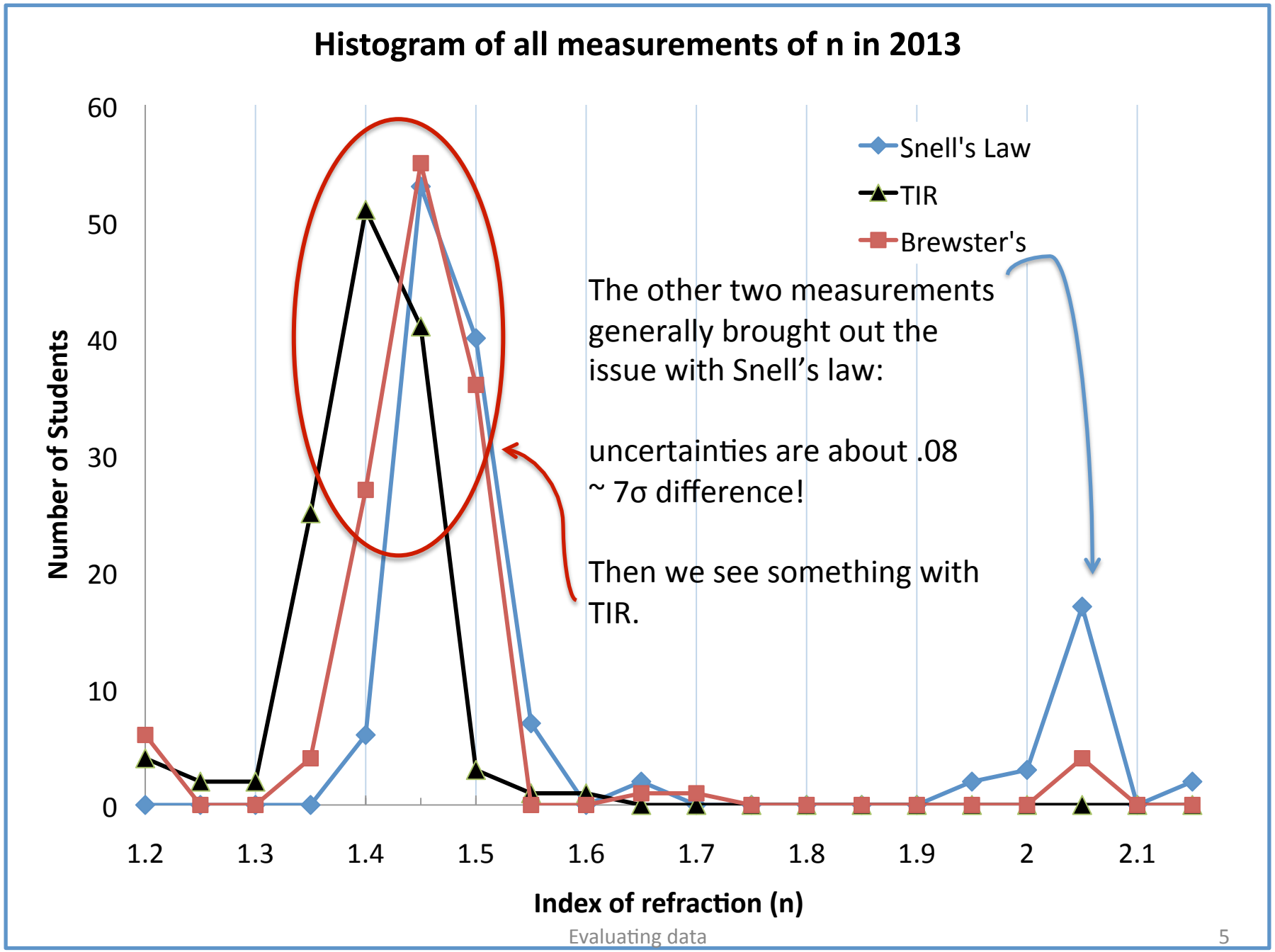
- Can we motivate and empower students to do a good job taking data?
- Can we improve shared responsibility between partners while taking data?

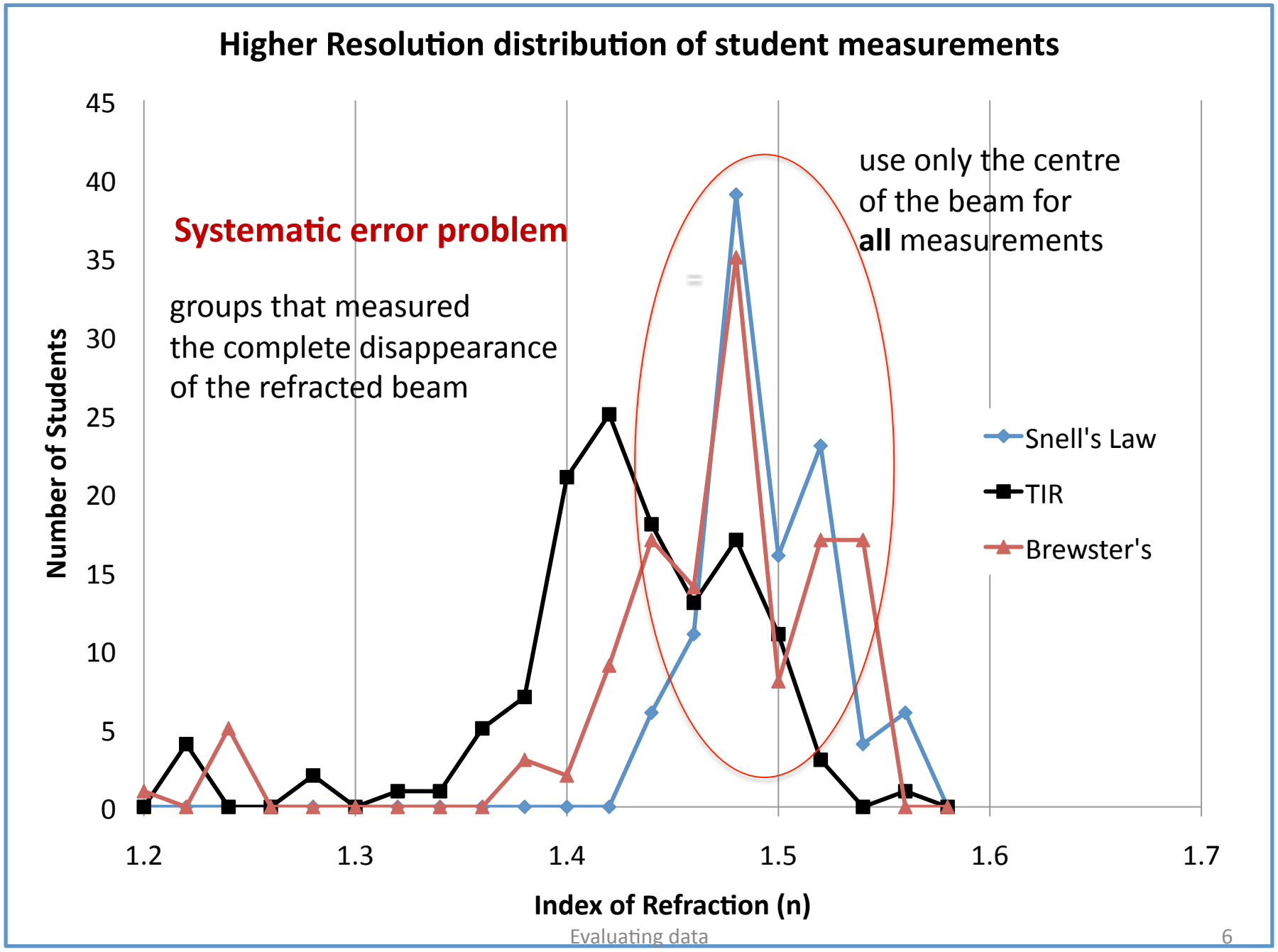
Reflecting and evaluating data: Index of Refraction Lab

- Measure n using 3 methods:
  - Snell's Law
  - Total Internal Reflection
  - Brewster's angle
- Common systematic errors in measurements
  - Did they make the errors?
  - If so, did they fix the errors?
  - What motivated them to fix the errors?




Snell's Law measurements reported by students as final values and before corrections
Number of Students
60
50
40
30
20
10
0
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
2.1
2.2
Index of Refraction (n)
Final
Original


Histogram of all measurements of n in 2013
Number of Students
60
50
40
30
20
10
0
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
2.1
Index of refraction (n)
Snell's Law
TIR
Brewster's
The other two measurements generally brought out the issue with Snell's law:
uncertainties are about .08
~ 7σ difference!
Then we see something with TIR.


Higher Resolution distribution of student measurements
Systematic error problem
groups that measured
the complete disappearance
of the refracted beam
use only the centre
of the beam for
all measurements
Number of Students
Index of Refraction (n)
Snell's Law
TIR
Brewster's
0
5
10
15
20
25
30
35
40
45
1.2
1.3
1.4
1.5
1.6
1.7

What were they missing?

Trust in their ability

- to measure precisely and/or accurately
- In some cases, skepticism that they could have measured inaccurately

Trust in the experiment

- to measure accurately and precisely

Physics definitions

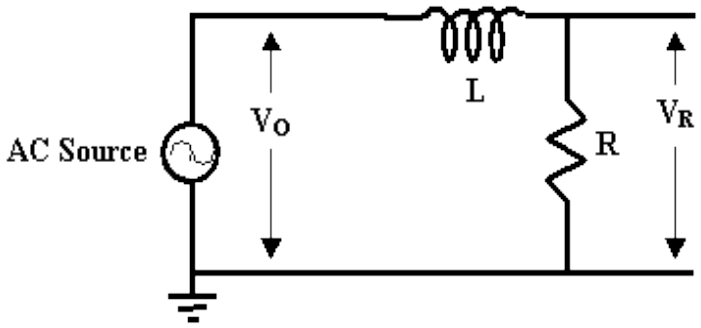
- Is critical angle point at which refracted beam starts to disappear or completely disappeared?

Time

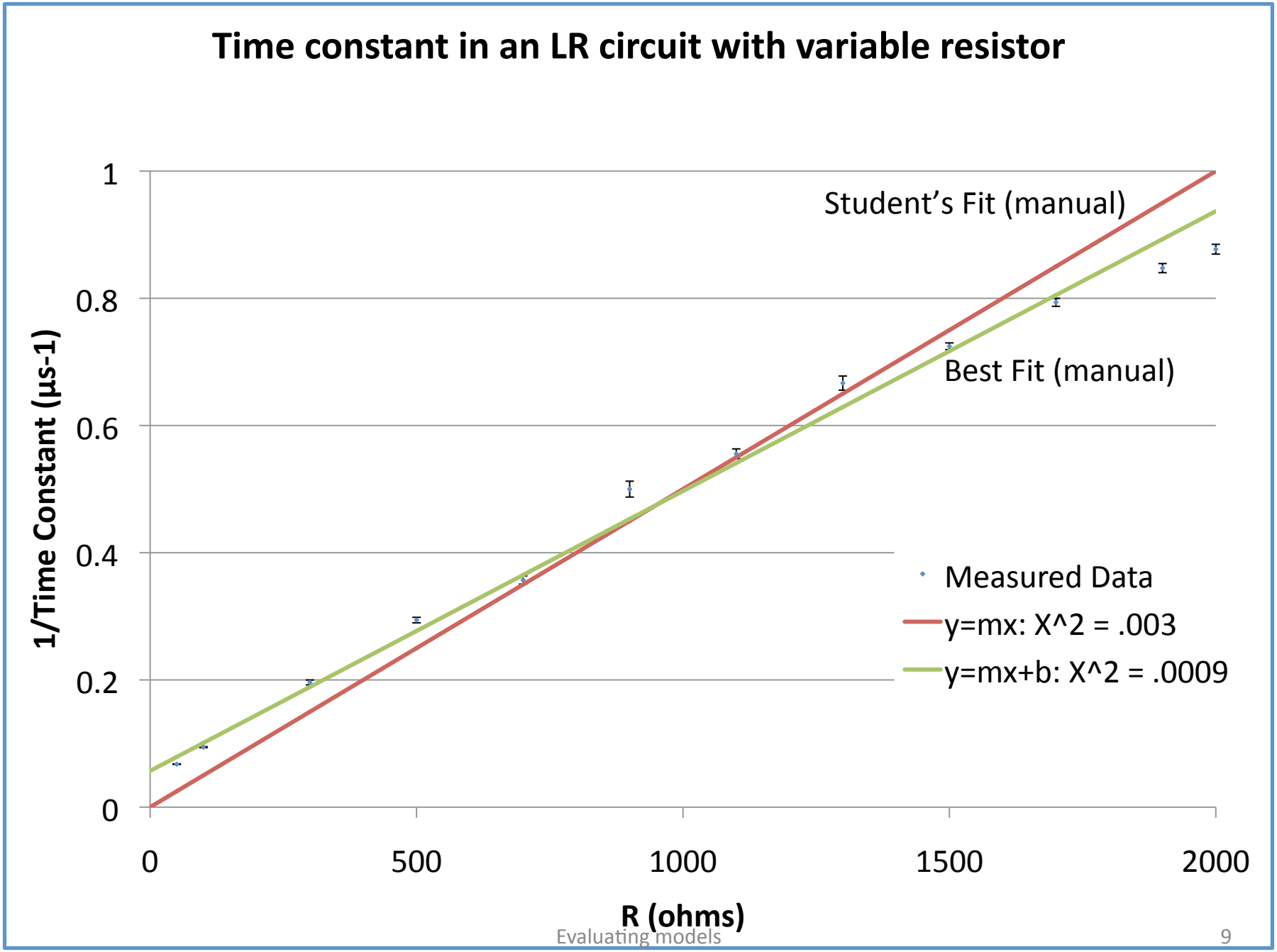
- to reflect on their results
- correct mistakes
- evaluate what they mean physically

Reflecting and evaluating a model: LR Lab

- Measure time constant, τ, as a function of resistance in the resistor



- Accepted model: $\tau = L/R$
- Plot of $1/\tau$ vs. R does not give straight line that goes through the origin


Time constant in an LR circuit with variable resistor
1/Time Constant (µs-1)
1
0.8
0.6
0.4
0.2
0
0
500
1000
1500
2000
R (ohms)
Student's Fit (manual)
Best Fit (manual)
Measured Data
y=mx: X^2 = .003
y=mx+b: X^2 = .0009

Decisions they made…

Intercept fixed at origin

- Because model should have intercept through origin
  - Trust model rather than data
- Goal was to find L

Intercept unfixed

- To minimize χ^2
- Because data obviously had intercept
  - Didn't impact finding L
- Goals was to check relationship

How to teach it?

Support	• Pre-readings • Additional resources
Time	• Shorter labs • 2-week labs
Experience	• Experiment loops where going back improves measurements
Motivation	• Trust in their abilities • Trust in quality of measurements

Challenges

*Cognitive Overload

*Time

*Engagement & Interest

*TA Training

Other things…

Gender roles in the lab

- Who's in charge of the equipment?

Motivation and attitudes

- Achievement Goal Questionnaire (Elliott, 1999)
- E-CLASS (Zwickl, Finkelstein, & Lewandowski, 2012)

Invention Activities

- Problem solving behaviours (e.g. Do they check?)

Cross-discipline measurements

- Compare with measurements of 'checking work' during problem solving in Biol234 (Fundamental of Genetics)