Same data, different conclusions: Comparison of inquiry and validation laboratory instruction on student interpretation of data

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Introduction

As part of ongoing laboratory reforms in an introductory calculus-based mechanics course (Physics 211), we are exploring the effect of the new and old formats of laboratory instruction on student reasoning about data. Important differences between the old ("validation") laboratory format and the new ("inquiry") format are summarized below:

Inquiry instruction

- Train students in scientific skills and decision-making using ISLE framework [1]
- Data analysis used as a decision-making tool
- Students consider systematic and random error

Validation instruction

- Expose students to a large number of concepts
- Experiments confirm predictions; Data analysis is a tool to evaluate the success of the experiment.
- Students consider percent error between data and prediction as a benchmark.

The study

Four sections of inquiry lab and two equivalent sections of validation lab were given a free-response data analysis and interpretation question during a lab practical exam at the end of the Spring 2016 and Fall 2016 semesters.

Data interpretation question

After learning about pendulums in class, a student decides to do two experiments to study the period T of a pendulum. First, the student measures the period of a 1 m long pendulum, being careful to release it from the same position every time. After five trials, she obtains the results shown in the table below.

Trial Number	1	2	3	4	5
Period T (s)	2.06	2.13	2.04	2.13	2.12

Using the equation relating the length of the pendulum to the frequency, she predicted that the period of the pendulum would be 2.01 s. How does her data compare to her prediction? Explain how you made your conclusion.

Coding student responses:

Student written work to this question was coded for reasoning strategy and conclusions.

Student conclusions

For this study, we considered three student conclusion outcomes:

Agree: Conclusions that results agree or discussion that the results are "close" or "accurate"

Disagree: Conclusions of disagreement or discussion that the results are "larger" or "different"

Conclusion unclear: Students did not state any kind of judgement about the data or gave contradictory conclusions

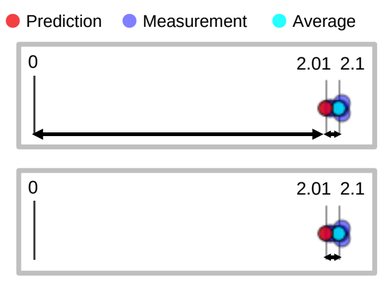
Student reasoning strategies

We identified four major reasoning strategies cited by students in their answers, which we sort into two categories based on the point and set approaches described in Allie & Buffler [2]. Measurements displayed below use the values from the lab practical question.

Point approach emphasizes closeness

Percent error: Compares difference between average and prediction to size of prediction.

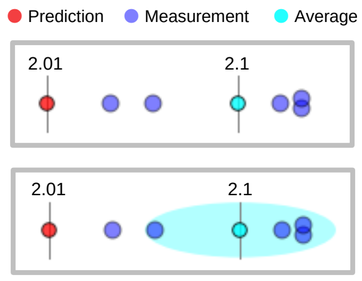
Average: Compares difference between average measurement and prediction.



Set approach emphasizes difference

General Trend: Compares each measurement to the prediction.

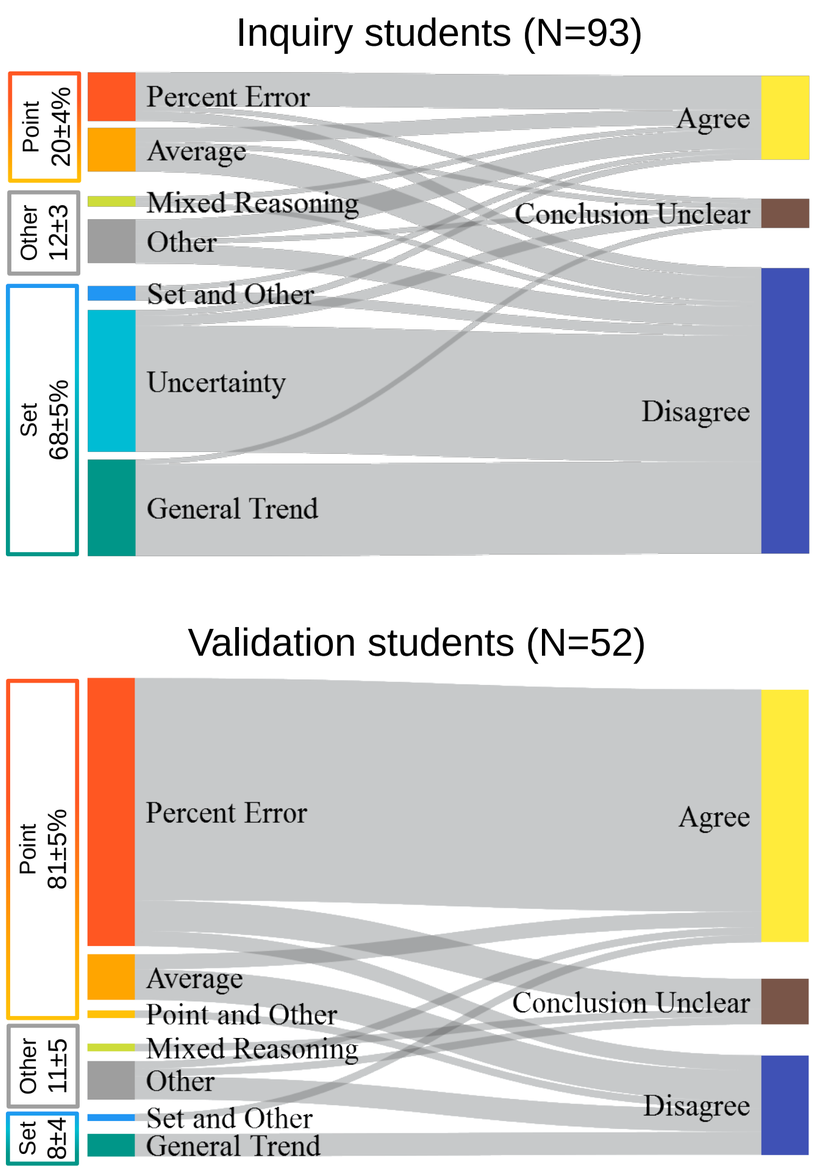
Uncertainty: Uses spread of data to construct a range representing the measurement.



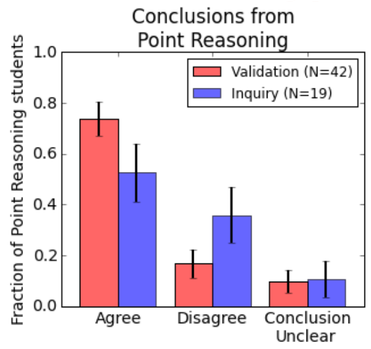
Other categories

Reasoning strategies outside of the four described above were categorized as '**Other**.' Students citing multiple strategies were grouped by their type of reasoning into '**Point and Other**,' '**Set and Other**,' and '**Mixed**' (used both point and set reasoning).

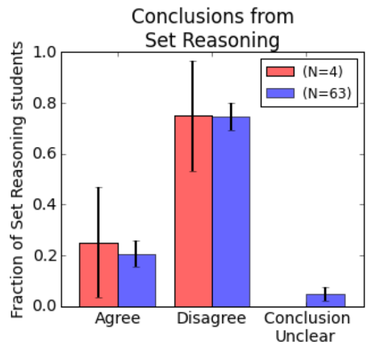
Student responses:
Reasoning, conclusions, and connections from Fall 2016 semester



How well does strategy indicate conclusion type?



Point reasoning: It depends on the instruction format.
Validation students frequently cited 5% as "good enough" Inquiry students did not follow a strict rule.



Set reasoning: Pretty strong connection.
'Agree' conclusions arise from mathematical errors (40%) and from students applying stricter criteria for agreement.

Discussion and Conclusions

Reasoning strategies used by the two groups are very different, leading the groups to generally make opposite conclusions about the data in the question.

In this specific question, student from the validation group who used a point approach were most likely to claim agreement between the prediction and data, based on the reasoning that the percent error was less than 5%.

Students in the inquiry group were much more likely to use a set approach to the data and claim disagreement between the prediction and data.

From these results we conclude that students in the reformed inquiry-style lab are more likely to pay attention to the spread of data and use it as a tool to make decisions about experimental results.

In future work we plan to explore this decision-making process further and to document other ways that the new instruction is changing the students' choices and behavior in the laboratory classroom.

References

[1] E. Etkina, S. Murthy, and X. Zou, Am. J. Phys. **74**, 979 (2006).

[2] S. Allie and A. Buffler, Int. J. Sci. Ed. **20**, 4 (1998).

More information

For more information on this work or other aspects of the lab reforms at Illinois, please visit go.illinois.edu/AnsellPER