Challenging engineering students to think critically in a new flipped, design-based introductory physics laboratory

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Introduction

In the Spring 2016 semester we piloted a new laboratory format in the introductory calculus-based mechanics course (Physics 211). While the previous (Traditional) laboratory format emphasized providing students with experiences of many physics concepts, the new (IOLab*) format was designed with the following aims:

1. **Improve student attitudes and engagement in the lab**
   STEM students view the confirmatory, "cookbook" style of the traditional format as tedious procedural work.

2. **Train students in critical thinking and scientific skills practices**
   These practices prepare students for future course, research, and career experiences.

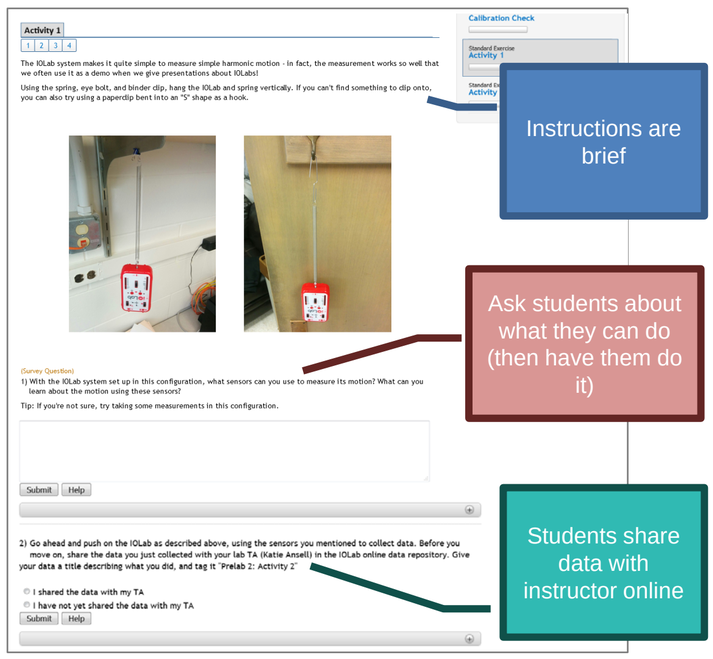
Pilot implementation

Three sections of Physics 211 lab were randomly selected for the IOLab format. Two equivalent sections of traditional lab were administered surveys and a lab practical exam for comparison between the groups.

* In the new format, students used the Interactive Online Laboratory (IOLab) system to collect data in prelab and lab activities.

Online prelab assignments

Before attending lab, students do dorm room experiments to familiarize themselves with the equipment, practice a skill, or develop an experimental technique in preparation for the classroom meeting.



In-Class group assignments

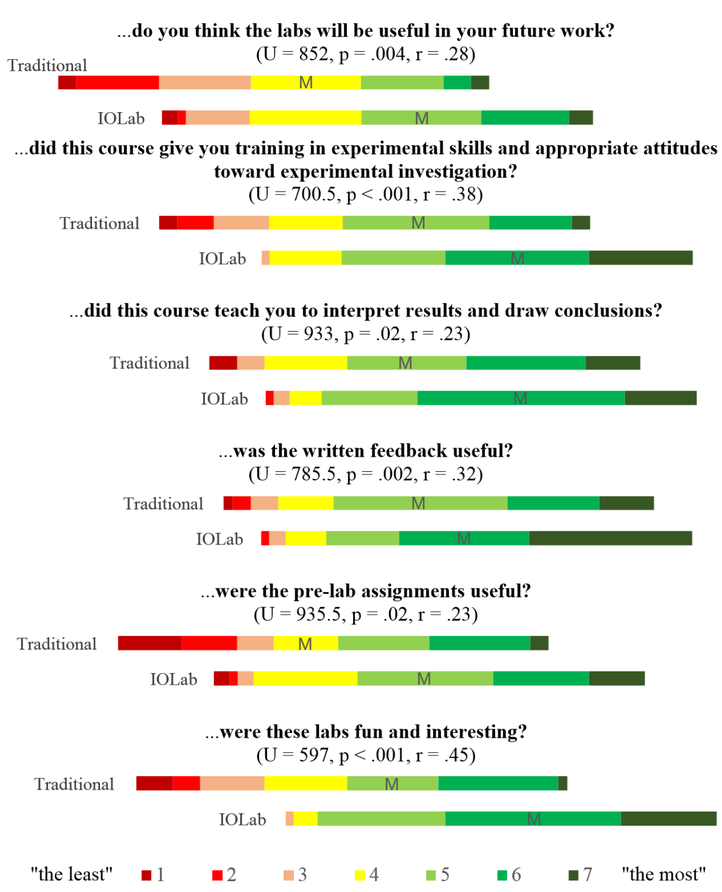
Students are given an objective to achieve in class but the design and implementation is up to them.

Objectives are chosen to not have an immediately obvious solution.

Students record their experimental procedure and data. This work is graded using Investigative Science Learning Environment (ISLE) rubrics.

Outcomes after one semester of instruction

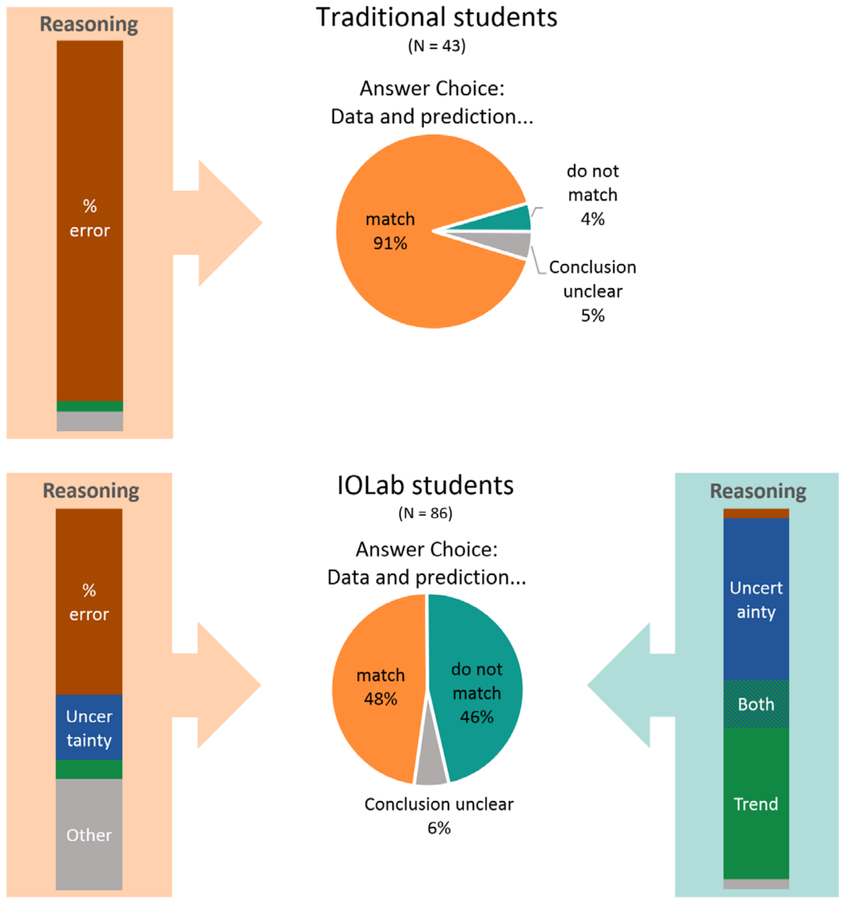
Student Attitudes: End-of-semester survey



End-of-semester survey responses from IOLab (N = 54) and Traditional (N = 47) students. Median response values are indicated with the letter M.

Scientific Skills: Interpreting data in the lab practical

How does [given hypothetical data set] compare to the prediction? Explain how you made your conclusion.



Discussion of Outcomes

Student Attitudes: Significant improvement seen on survey

Students in the IOLab format lab indicated that they felt their experience was fun and useful in the end-of-semester survey and in informal written feedback.

> "This physics labs *[sic]* challenges me to think for myself and be curious. I really appreciate that."
>
> - Written feedback from IOLab student

Scientific Skills: IOLab students are more discerning about data analysis

Data values given to students in the written lab practical were weighted to be close to the predicted value, **but contained a significant systematic error**. Students who received Traditional lab instruction were nearly uniform in using a "small percent error" argument to claim the data and prediction matched. Students who received IOLab instruction were more likely to notice the systematic error, using qualitative and/or quantitative analysis (trend and uncertainty, respectively).

Continuing work

Analysis of data from this pilot semester is ongoing. We expect to learn more about student scientific skills from further analysis of written and video material from the lab practical.

The IOLab format pilot will be repeated in the Fall 2016 semester with the aim of scaling this reform to the entire Physics 211 course in the near future.

More information

For more information on this work or the IOLab equipment, please visit go.illinois.edu/AnsellPER