Grant No. 2044432

Science practices in calculus-based introductory physics laboratory courses

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Introduction

Our research examines introductory laboratory courses, including the calculus-based physics series, to investigate the potential for student engagement in science practices, as defined by the *Framework for K-12 Science Education* and the Next Generation Science Standards (NGSS).

- The collection of these practices represents what it looks like to be *doing* science
- The integration of science practices into lab spaces is important for developing scientifically literate graduates

Methods

We utilize the Three-Dimensional Learning Assessment Protocol (3D-LAP) to elicit evidence of students' potential to engage in science practices in undergraduate lab courses. This requires coding all lab artifacts (pre-labs, post-labs, and lab manuals) to determine what (if any) practices are present. Below is an example of a lab activity that met all of the criteria for P5: Using Math and Computational Thinking.

3D-LAP Criteria for P5: Using Math and Computational Thinking	
1.	Question gives an event, observation, or phenomenon.
2.	Question asks student to perform a calculation or statistical test, generate a mathematical representation, or demonstrate a relationship between parameters.
3.	Question asks student to give a consequence or an interpretation (not a restatement) in words, diagrams, symbols, or graphs of their results in the context of the given event, observation, or phenomenon.

Science Practices as Described in the 3D-LAP

P1: Asking Questions	P6: Constructing Explanations
P2: Developing and Using Models	P7: Engaging in Argument from Evidence
P3: Planning Investigations	P8: Evaluating Information
P4: Analysing and Interpreting Data	P9: Communicating Information
P5: Using Mathematics and Computational Thinking	P10: Defining Problems and Designing Solutions

A. At your lab station, find a diagram showing several cars in accelerated motion. Together with your partners, come up with one number to stand for each car's speeding up. There is no clock to tell how long each car has been moving, but all the cars drip oil once each second. Speedometer readings are also provided. Below are some ground rules as well as space to write your work.

- A company always makes its cars speed up in the same way.
- We will not tell you how many companies there are. You have to decide!
- A larger index value should mean a car is speeding up more.

B. Once you have created your speeding up index, discuss the following with your partners.
1. How many different car companies are there? Explain.
2. For the car company with the smallest value of the speeding up index, give an interpretation of that number. Remember that an interpretation is not the same as the name of the quantity! The interpretation is the specific information the number about that car's motion.

Excerpt from PHYS 1 Lab 2

PHYS 1										
Lab 1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 2	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 3	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 4	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 5	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 6	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 7	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
PHYS 2										
Lab 1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 2	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 3	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 4	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 5	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 6	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 7	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
PHYS 3										
Lab 1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 2	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 3	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 4	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 5	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 6	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Lab 7	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10

Key (# of SPs) –
Not observed
1 instance
2 instances
3 instances
4+ instances

Results

The cumulation of all of the coding is represented in the heat map to the left.

Discussion

- The distribution of science practices is uneven, with strong emphasis being placed on a few practices, whilst others are not present
  - *Developing and Using Models*, *Analyzing and Interpreting Data*, *Using Mathematics and Computational Thinking*, *Constructing Explanations*, and *Engaging in Argument from Evidence* are among the **most highly represented science practices** in the physics curriculum
  - *Asking Questions*, *Communicating Information*, and *Defining Problems and Designing Solutions* are **not observed**
  - There is an emphasis on students verifying theory rather than proposing questions and investigations, as well as evaluating, creating, and sharing solutions
  - The frequency and variety of science practices present in lab materials decrease as a student progresses in the series
- There were some activities that were labeled as "near misses" that were often just missing the criterion related to reasoning
  - Small edits can bridge the gap (such as including a prompt for students to explain their thinking), meaning that increased inclusion of science practices in lab does not necessarily mean a complete overhaul of the curriculum
- Work continues to determine the extent to which there is alignment between the science practices identified in the curricula and video data

References

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