7-22-2020

A Lab Skills Diagnostic Test

John Zwart
Dordt University, john.zwart@dordt.edu

A Lab Skills Diagnostic Test

Abstract

The American Association of Physics Teachers recommends that physics majors have proficiency in the following lab skills: constructing knowledge, modeling, designing experiments, analyzing and visualizing data, and communicating physics. I have developed a brief multiple-choice questionnaire to assess incoming students' lab skill level in these areas. It was administered as both a pre-test and post-test for the first semester of introductory calculus-based physics. Preliminary results indicate that little improvement on the skills tested occurs without explicit instruction.

Keywords

physics teachers, laboratories, ability, measurement, experiments

Disciplines

Physics | Teacher Education and Professional Development

Comments

Poster presented at the summer meeting of the American Association of Physics Teachers held virtually July 19-22, 2020.

A Lab Skills Diagnostic Test

John Zwart, Professor Emeritus
Dordt University Physics & Astronomy Department
john.zwart@dordt.edu

Introduction

As I have worked to align our physics labs' goals with AAPT's recommendations[1,2] for physics majors' lab skills, we realized that we did not have a clear understanding of the lab skills first semester students brought into that course.

To probe initial lab skills I designed a 20 question multiple choice diagnostic test. These questions probe student understanding of:

- Measurement and significant figures
- Uncertainty
- Graphs – relating data and equations, curve fitting
- Experiment design
- Communication

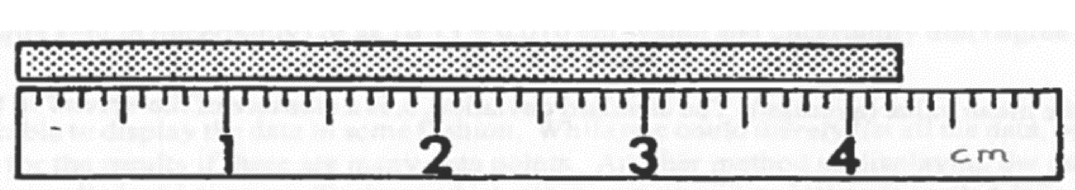
It must be noted that this is a first effort. There is certainly room for improvement on the set of questions.

Methodology

- A 20 point multiple choice diagnostic test was designed to probe knowledge level, NOT misconceptions.
- It was given to our Physics 201 class in Spring 2019. Class size started at 47, ended at 43.
- There was no communication about the contents of the test with either the lecture or laboratory instructor.
- While intended primarily as an initial assessment of incoming students, it was given both as a pre-test (first lab period of the semester) and post-test (last lab period of the semester).
- Students given 30 minutes to take as a closed book test.
- Participation was optional and anonymous.
- >85% participation rate both pre- and post-test.

Sampling of Results

Students scored an average of 38% on the pre-test and 43% on the post-test. What follows is a sampling of some of the questions with comments.



1) The figure above shows a 5 centimeter long ruler which is used to measure the length of a bar. If the length of the bar is measured as part of a physics experiment, what length should be recorded?

a) 4 cm
b) 4.2 cm
c) 4.26 cm
d) 4.3 cm
e) 4.5 cm

The correct answer is C. Students did well with 70% correct on the pre-test and 81% correct on the post-test.

Sampling of Results continued

2) Four students each do a free fall experiment (using the same experimental design) that yields a value for g. Their individual results are: 9.2 m/s^2, 9.6 m/s^2, 9.9 m/s^2, and 10.3 m/s^2. Which of these values is the best experimental result?
a) 9.2 m/s^2
b) 9.6 m/s^2
c) 9.9 m/s^2
d) 10.3 m/s^2
e) not enough information is given to answer the question.

The correct answer is E since the uncertainty is needed to know which is the 'best' answer. <20% had it correct on pre- and post-tests and ~70% chose the value closest to the accepted value of 9.8 m/s^2 on both tests.

1.52 V

3) The figure above shows the display of a digital voltmeter when it is connected to an AA battery. What is the uncertainty in the value of 1.52 V?
a) There is no uncertainty; digital values are exact.
b) 0.005 V
c) 0.01 V
d) 0.05 V
e) You cannot tell from the display; you need to consult the manual.

The correct answer is E since the accuracy depends on the model (for example my home DMM has an uncertainty of 3 in the last digit location). 45% of the students had this correct on the pre-test, but only 5% had it correct on the post-test. On the post-test 76% chose B so it appears students learned 'half the smallest division' for the uncertainty in a digital display during the semester.

7) Trying to find g by having one person drop a golf ball from a height of one meter while another person uses a stopwatch to time how long it falls almost always yields a 'bad' value for g. What is the main reason or reasons for this?
a) It is hard to measure 1 m precisely enough.
b) Air resistance plays a significant role.
c) Human reaction time plays a significant role.
d) Both b) and c) are important.
e) All of a), b) and c) are important.

C is correct. This question was meant to probe students' intuition about relative uncertainty contributions to a calculated quantity. On both tests roughly half the students had it correct, the other half were split between D and E.

10) Suppose you have a set of x-y data and expect them to be related by a power law: $y = Ax^n$, where A and n are fitting parameters to be determined. How could you plot the data so that, if a power law fits, the data fall on a straight line?
a) Plot y vs x.
b) Plot y vs x^n.
c) Plot log y vs x.
d) Plot y vs log x.
e) Plot log y vs log x.

E is the correct answer and chosen by 3% on the pre-test and 11% on the post-test. 30-40% of the students chose B, which would require knowing the fitting parameter n to make the plot.

Sampling of Results continued

20) What does it mean to say that a published paper is peer reviewed?
a) The person who submitted the paper to the journal did a very carefully proof reading before submission.
b) The person who submitted the paper to the journal had someone else do a very careful proof reading before submission.
c) The editor of the journal that published the paper did a very careful proof reading before publishing the paper.
d) The editor of the journal sent copies of the paper to people with expertise in the subject of the paper for advice about whether the paper should be published, revised before publication, or rejected.
e) After the paper is published, others reference it in their publications.

Selection of the correct answer (D) dropped from 58% to 49% while answer B rose from 30% to 51% from pre- to post-test. This is likely due to a step in an abstract writing assignment where student exchanged their work for a proof-reading. The hand-out referred to this as "peer-review."

Discussion and Conclusions

The diagnostic test did provide a snapshot of lab skills that students brought to the course. Results include:

- Little or no understanding of log-log or semi-log plots.
- Understanding what uncertainties mean, but little understanding of how to determine or propagate them.
- Reasonable understanding of the relation between graphed data and their meaning.
- Good understanding of what an abstract is.
- Little understanding of experimental design.

Comparing pre-test results (average of 38% correct) to post-test results (43%) indicates little overall progress was made. Some topics were not addressed in this semester. The biggest concern is the lack of progress in understanding uncertainty since the syllabus course goals include mastery of understanding of both uncertainty and uncertainty propagation.

These conclusions are quite tentative! It is not only the case that there is only one or two questions for a given topic, the questions themselves could use revising. In particular:

- Several graph related question could be removed or replaced since they focus less on lab skills *per se* and more on understanding equations of motion.
- Some need to be revised for clarification.
- At least one of the questions (about the method of least squares) is too esoteric – not only didn't the students get it, none of my colleagues did either!

Note

The entire diagnostic test discussed in this poster along with answer key, comments on each question, and student answer statistics is available in an auxiliary file. If I am unable to post that file where this poster is found, you may e-mail to request that I send it to you. Do feel free to use or adapt this test if you would find it helpful.

References

1."AAPT Recommendations for the Undergraduate Physics Laboratory Curriculum" https://www.aapt.org/resources/upload/labguidlinesdocument_ebendorsed_nov10.pdf
2. "Goals of the Introductory Physics Laboratory" AJP **66** (8) 483-485 (1998).

Acknowledgements
Thanks to the Iowa Section of AAPT for helpful feedback on an early draft of questions, to Luralyn Helming for shepherding the approval process thru Dordt's IRB, and to Kayt Frisch for giving up lab time so I could administer this test.