What's the relevance of Physics Education Research to the Advanced Lab? Transforming the Advanced Lab: Part 1 – Learning goals

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Project Goals

- (1) Create a really spiffy lab.
- (2) Study how students learn in lab courses.
- (3) Provide resources for faculty to develop their own transformed labs.
- (4) Increase student learning.

Existing Advanced Optics and Modern Physics Lab

- 15 students per instructor.
- Mostly seniors.
- Broad content:
 - Nuclear physics (gamma ray spectroscopy)
 - Particle physics (cosmic ray muon lifetime) Condensed matter physics (scanning tunneling
 - microscope, NMR)
 - AMO physics (saturated absorption spectroscopy, magneto-optical trapping)
 - Physical optics (diffraction, interferometry, polarization).
- 4-6 labs in a semester.
- Not linked with any lecture course.
- Associated lecture period not coordinated with lab.
- "Cookbook" lab guides.
- Minimal emphasis on applications of physics.
- 5 week long final project allows for creativity and independence.
- The formal assessments are written lab reports and oral presentations.

Methodology

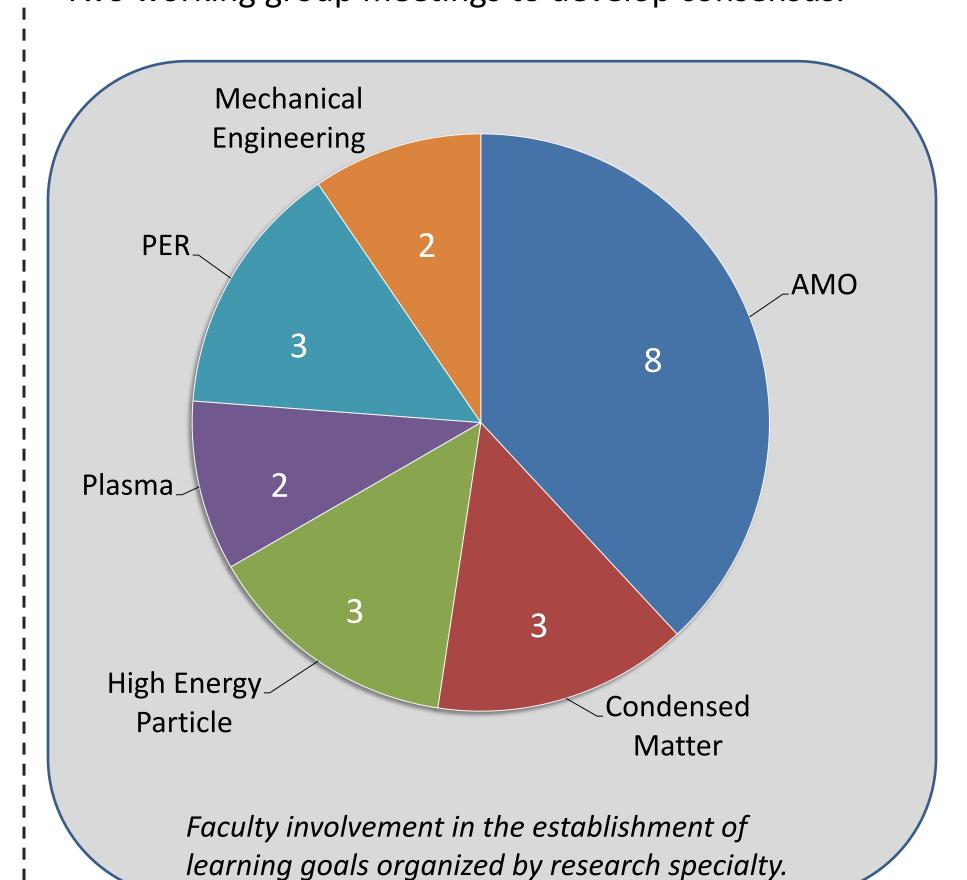
Input from CU Faculty

15 faculty interviews (example questions)

"What is the purpose of a good lab course?" "What is the goal of communication in the lab?" "What abilities do you look for when hiring an new student in your lab?"

A draft set of learning goals was produced

Two working group meetings to develop consensus.



Math-Physics-Data connection

Students should be fluent in translating between their noisy and incomplete data and both the mathematical representation (i.e., theory) and the physical system being

- 1. "Math-Physics connection" is an existing learning goal for
- Faculty believe the best labs are quantitative and rich with physics content, creating a natural opportunity for connecting the mathematical model, data, and the

- our upper-division E&M and mechanics.
- physical systems.

Our current labs were fairly "cookbook", leaving students

unprepared for the open-ended final project.

Experimental Design

Students should be able to design their own experiments and

apparatus for testing hypothesis and models

1. Experimental design is a key part of any scientific

Students should be able to use their understanding of physics to

Engineering design

design a product to meet specified design criteria within practical constraints.

1. Experimental design in physics often involves a significant

amount of engineering.

Students should be able to systematically test their apparatus

Troubleshooting

1. Faculty experience indicates that troubleshooting is a large

and experiments to identify and solve problems.

part of research as a professional physicists. 2. Something in the lab inevitably doesn't work as expected, and we want to teach students something better than

random trial and error approach to troubleshooting.

mastering as a course-wide goal.

Basic test and measurement

equipment

Students should be able to describe the function of basic test

1. Only the most widely used equipment, like oscilloscopes,

waveform generators, lasers and photodiodes are worth

and measurement equipment and use it as part of their course

LEARNING GOALS

Modeling

Communication

Argumentation

Modeling "black boxes"

Students should be able to apply the techniques of modeling

1. Technology creates an increased divide between the

Modeling provides a natural framework for describing

natural systems to engineered devices in the lab.

student and the physical system.

"black boxes."

Statistical error analysis

Students should be able to use the techniques of error analysis

. Statistical error analysis, as one component of process of

Systematic error analysis

sources of systematic error in their measurement devices and

1. Understanding systematic error is regarded by faculty as

Modeling provides a natural framework for discussing

an expert skill, yet it is largely absent from our lab courses.

Students should be able to test and develop models for

in the context of a larger scientific project

developing, testing, and refining models, is valued, but seen

and time-series data analysis as part of comparing data with

mathematical models.

systems under study.

systematic error.

Students should be able to construct convincing scientific arguments, meaning they should be able to evaluate evidence and use reasoning to support a conclusion or an answer to a research question.

- Faculty believe students spend considerable time writing lab reports, but their writing often lacks a coherent and convincing argument.
 - Argumentation is a key practice of professional scientists.

Integration into the physics discourse community

Students should be able to communicate sophisticated physics content using the technical vocabulary and genres standard in the physics community.

- Writing skills taught in the creative writing classes taken by most freshman are difficult to transfer to the physics
- Communication is best learned when claims are being discussed that are of mutual importance to the writer and the reader.

Technical lab skills

Design

LabVIEW

Students should be able to effectively use LabVIEW to automate their measurements and plot data in order to carry out their modeling tasks more effectively.

- 1. Faculty regard measurement automation as an essential skill for the professional physicist which is highly valued in academia and industry.
- 2. LabVIEW can speed up the model development and testing cycle in the advanced lab similar to the way the Microcomputer Based Laboratory does for the ntroductory lab.

Computer-aided data analysis

work in the lab.

Students should be able to use standard mathematical software to complete tasks in data analysis, plotting, and error analysis.

1. These software skills were not being formally taught in our curriculum.

Input from previous goal statements

- AAPT Goals for the introductory physics laboratory.
- Goal statements from the advanced lab community.

Input from STEM education

- Modeling (Modeling instruction)
- Design (Engineering education)
- Argumentation
- Writing instruction

Ongoing work: **Revision of existing labs**

- Incorporating learning goals into labs, while keeping most of the equipment unchanged.
- Converting lecture periods into handson tutorials for LabVIEW and computeraided data analysis.
- Reorganize and restructure the lab

Ongoing work: Resources for instructors

- Guidelines for instructors
- Online tutorials for LabVIEW and Mathematica.
- Rubrics for evaluating assessments.
- Tools for developing new labs.

Ongoing work: Assessments

- Embedding formative assessments into the
- Rubrics for evaluating the assessments.
- Pre-post tests to measure learning gains.