

STEM Course Enhancement: Physics by Discovery

William Shepherd, shepherd@shsu.edu

Budget:

Total request is \$2000.

STEM Courses involved in the proposal:

This proposal is to contribute to an overhaul of PHYS 1305 and PHYS 1105, the lecture and laboratory sections of physics for non-scientists. A single section of PHYS 1305 enrolls 50 students, and the lab section enrolls ~25 students per section. Multiple sections of both courses are offered every semester. The overhaul supported by this grant will be implemented in Spring 2022; section numbers are not yet assigned.

Project Narrative

Executive Summary

This project supports a planned overhaul of our physics course for non-scientists, which predominantly targets aspiring primary and middle-school educators. The goal of the project is for students to develop more intuition about physical systems and the methods of science generally. The primary objective is to significantly increase active learning elements by incorporating a 'physics by discovery' approach and swapping functionality of lab and lecture sessions. The overhaul will also increase focus on explanatory ability, a key skill these future educators will need to utilize in the classroom, and one which is badly undervalued in the current course structure. This skill will prove useful to students in the other two majors which make up the remaining minority of our students. Kinesiology majors will use this skill to clearly explain diagnosis and treatment plans to their patients, and Agricultural Engineering Technologists will improve their ability to justify their choices of equipment for particular tasks.

This grant will specifically support summer effort toward this goal, which will later be supported by an Engaged Learning Fellowship. The amount of planning needed to establish demonstrations or hands-on systems for student use and discovery of physical principles for lecture sessions is significant, and an early start will be valuable. The grant will also support the purchase of new equipment to aid in achieving our objectives; while most of the activities will be achievable using extant departmental laboratory equipment, some demonstrations will benefit significantly from new equipment.

Project Narrative

Rationale

The course is targeted predominantly at primary educators and has no prerequisites in mathematics. It has an associated lab section, which is separate but also required for the degree plan. Currently, the material covered in this course is taught at a slightly less mathematically rigorous level than in the algebra-based physics courses for scientists (PHYS 1301 and 1302), but still focuses significantly on numerical calculations. Given the audience, this focus seems to be out of place.

The Texas standards for education in science (TEKS) require a number of physics-focused topics and abilities, but important to note is that the level of numerical skill involved in these requirements is significantly below what we are currently demanding of our students. By contrast, the breadth of topics and the intuitive and conceptual grasp required to successfully teach this knowledge is beyond what we are instructing. Therefore, this course would significantly benefit from a re-targeting at the more purely conceptual level. This can be particularly difficult in physics because everyday intuitions about how and why things move and interact are subtly incorrect. Developing this intuition (and overcoming incorrect preconceptions) is a challenging process of unlearning and relearning; doing it without significant mathematical groundwork is best achieved with a highly hands-on, active approach.

Materials and Methods

This overhaul will 'flip' the lab and lecture portions of the course; in the current design students interact with physical systems in the lab section and learn in a more pen-and-paper model for the lecture. The more active structure would instead have a hands-on experiment or interactive demonstration for every lecture meeting, scaffolded to guide students to discoveries like conservation of momentum and energy. Currently, this would simply be asserted as dry mathematical fact during a lecture.

Following completion of the experiment and discoveries, group and/or class-wide discussions will explore the further application of the principles demonstrated in the given experiment to real-world and more extreme experimental settings. The understanding of these discoveries would then be applied in the meetings that used to be lab. In these meetings, students will practice applying the concepts discovered by predicting behavior and solving mathematically simple problems.

These hands-on experiments will simultaneously require and inspire significantly increased student engagement; physically manipulating an experiment and making discoveries firsthand is more exciting than having something explained, and also engages the spirit of scientific exploration in a way that these future educators will hopefully be able to inspire in their students as well. Working through example problems in the longer 'lab' meetings allows for time to enable significant group work, peer education, formative assessment, and community building within the class and with the instructor.

Experiments will be composed primarily of judiciously repurposed pieces of educational lab equipment already owned by the physics department. I anticipate, however, that some physical effects will be difficult to produce with current hardware. New equipment purchases, supported materially by this grant, will significantly broaden the scope of experiments and demonstrations that can be performed.

Expected Results and Dissemination Plan

The overhauled course will be compared against sections instructed more traditionally, mainly by use of the Force Concept Inventory, a standard tool in physics education research. I anticipate that this overhauled approach will significantly improve student performance at the conceptual and intuitive level. I will also ask colleagues to assign explanatory exercises similar to those that I request of my own students, to assess any impact on student educational abilities from the change in course structure.

Presuming that this new structure does indeed improve student performance, I intend to roll it out to multiple sections and instructors in the future. This is a course which is regularly taught by adjunct faculty, so having a more solid framework for their use should significantly reduce unevenness in instruction across the sections and semesters this course is offered in. The expansion of the overhauled course will also benefit from economies of scale, reducing departmental costs per student to achieve our goal. This is achieved by setting up demonstrations only once for multiple sections.

After proof of concept, dissemination beyond SHSU will be accomplished in the form of a physics education research article, where appropriate. A video library of these demonstrations will also be compiled, both for public use and also for use in online sections of this course, which are very popular with students who are in their student-teaching portion of the education degree plan.

Budget Justification

The primary benefit to the project of this grant is summer lead-in time spent on experiment, demonstration, and curriculum design. Thus, the majority of the grant budget is to be used as a \$1500 faculty stipend to support the use of a summer month primarily on this project.

The remainder of the requested amount, \$500, will be spent on upgrades and additions to the current teaching laboratory equipment in the Department of Physics and Astronomy. Many of the lab experiments presented in the overhauled course will be completely new, and while most can be constructed utilizing the equipment already available, there will undoubtedly be needs for additional equipment to demonstrate effects that have thus far only been discussed as lecture material. The specific equipment purchased will be determined during the design period of the course overhaul.