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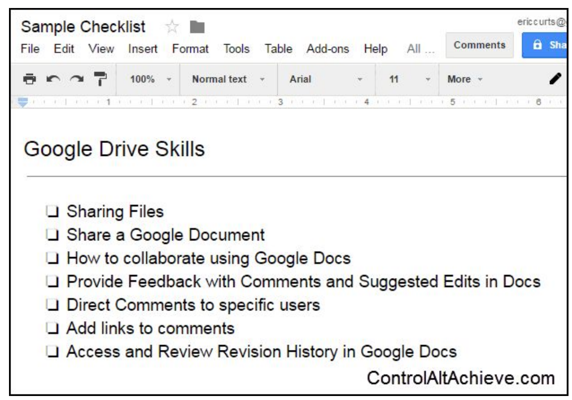


Category

- ❏ Data-Driven Course Design
- ❏ MOOC Success Stories
- ✓ Blended/Hybrid Learning
- ❏ Applications of the Science of Learning (in Online and Blended/Hybrid Learning)
- ❏ Innovative Use of Digital Learning Environments (such as interesting uses of MOOCs, etc.)

Title

Implementation of Design Experiments in a Large-Scale, Blended Learning, Introductory Physics Class at MIT

Author(s)

Pushpaleela Prabakar, Alexander Shvonski, Jacob White, Peter Dourmashkin

University or Organization

Massachusetts Institute of Technology

Abstract

We describe design-based physics experiments that we developed and implemented in a large-scale, introductory physics course at MIT. The residential course, 8.02 Electricity and Magnetism, has >700 students, with 8 sections total (~90 per section), and is built upon an "active learning" structure, where students interact with each other and online materials during class. We introduced 4 new in-class experiments, each having an open-ended, design component, which explored a practical application of electromagnetic concepts. During these experiments, students followed instructions and answered questions on MITx. We also integrated the experiments with pre- and post-experiment assignments to support and reinforce the material covered. We describe how we structured these experiments, some considerations with respect to implementation on a large scale, and also report student feedback.

Introduction

8.02 Electricity and Magnetism is a large, General Institute Requirement (GIR) course at MIT, using the Technology Enhanced Active Learning (TEAL) format of blended learning, where in-class instruction is bolstered with active engagement through group problem solving activities and interactive "student response" questions, which students answer on MITx. Students also engage with other learning materials on MITx, including "pre-class" weekly assignments (prepsets), weekly homework assignments (problem sets), in-class workshop style "Friday Problem Solving" (FPS), and seven in-class experiments. In past student evaluations for 8.01 and 8.02, students commented that the experiments were not well integrated with the course materials, and hence had limited value.

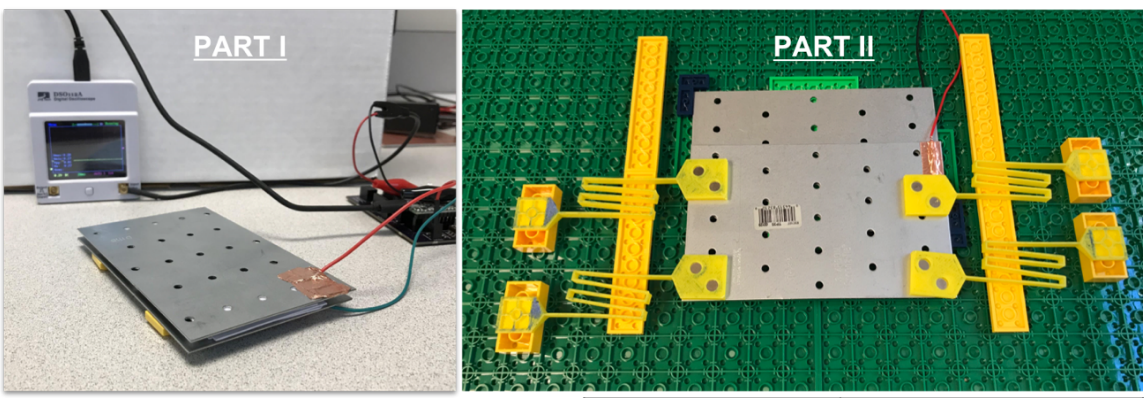
This semester, we sought to increase engagement with in-class experiments in two ways: by integrating experiment concepts on prepsets, problem sets, and FPS problems, where possible; and by introducing four new experiments, each introducing a design challenge. The design challenge represented a pedagogical twist, wherein students were tasked with engineering a solution to a given problem using their knowledge gained in earlier parts of the experiment. We were motivated to add a design component because it has been shown that highly structured, content-focused experiments do not fully engage students in the experimental process, whereas open-ended, student-driven experiments produce better learning outcomes (Holmes & Wieman, 2018).

Results

Here we report on how we structured these experiments, the difficulties that we faced with respect to scaling, and our understanding of the effectiveness of these labs, gleaned from survey responses. Firstly, we structured the experiments in two parts, such that students applied their knowledge from the first, instructional part of each experiment, towards the second, design-focused part. For example, in one lab students explored the geometric properties of a parallel-plate capacitor (plate spacing, area overlap, etc.) and then went on to design an accelerometer which uses these properties (Fig 1-Top). In class they followed procedures and discussion prompts on MITx, and answered questions (Fig 1-Left). For several experiments, we asked that students use their experimental data on a problem set assignment.

Scaling these experiments to accommodate all eight sections was challenging. In particular, we tried to ensure that the design portion could be completed using the same materials from section to section. We used everyday materials (e.g., LEGOs and 3D printed parts) to reduce costs. Our hope is that similar experiments can be undertaken in other settings using these simple materials.

We conducted student surveys (responses for Experiment 1 are reported in Table 1). Here we report general feedback: (i) students understood the purpose of the experiment; (ii) students felt that they had enough time to complete all parts of the experiment in this combined format; (iii) students felt that the problem set questions were relevant/helpful to their understanding of lab content. Generally, we also observed that students enjoyed using common, playful materials in design experiments (many were excited by LEGOs). Moving forward, we hope to quantify students' shifts in attitudes towards experimental physics by examining pre- and post-results from the E-CLASS survey that we administered (Lewandowski, 2014).



Discussion: Discuss the following with your partner, then write a brief response in the field provided.

- How does the capacitance depend on plate separation?
- For what range of separations did you obtain measurements?
- How does your data compare with the expected behavior of an ideal parallel-plate capacitor?

Question: For a non-ideal, parallel-plate capacitor, does the ideal capacitance equation underestimate, overestimate, or equal the measured capacitance?

- a) underestimate ✔
- b) overestimate
- c) equal

Question	Responses
I understood the overall purpose of this experiment.	Strongly Disagree (7%) Somewhat Disagree (11%) Neutral (14%) **Somewhat Agree (50%)** Strongly Agree (17%)
I was able to complete all parts of the experiment without significantly rushing	Strongly Disagree (14%) Somewhat Disagree (22%) Neutral (12%) **Somewhat Agree(30%)** Strongly Agree (22%)
I found the Pset problems relevant to my understanding of the experiment.	Strongly Disagree (5%) Somewhat Disagree (13%) Neutral (34%) **Somewhat Agree (33%)** Strongly Agree (10%)

Figure 1: (Top) Images of Part I & II of Exp 1. (Left) Sample discussion questions and multiple-choice problem for Exp 1. (Right) Table of survey responses, most popular responses are bold-underlined.

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References

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