



# Developing Modeling Skills and Science Identity in Physics Freshmen

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## Overview of Compass

The Compass Project is an APS award-winning, student-founded and student-run organization in the physical sciences at UC Berkeley.

Our goals are to improve undergraduate physics education, provide our participants with professional development opportunities, and increase retention of students, especially those typically underrepresented in the physical sciences. We achieve this by creating an environment that blends teaching, learning, mentoring, leading, and community building.

Among Compass undergrads, 45% are women, 30% are URM, and 20% are first-generation college students. 90% have graduated with or declared a STEM major.

### Compass Courses & Programs

- Freshman course sequence:
  - Summer Program
  - Intro to Modeling** (Fall)
  - Intro to Measurement (Spring)
- Transitioning to Physical Science
- Frontiers of Physics
- Mentoring Program
- Research Lecture Series
- Office Hours
- Organizational Leadership

### Course Structure

- One 2-hour class per week for 14 weeks
- 16-20 freshmen
- 2 graduate student instructors
- Worth 2 units of credit
- First run in Fall 2009

## Overview of "Introduction to Modeling"

week	1 <sup>st</sup> hour	2 <sup>nd</sup> hour
1		
2		
3		
4		
5		
6		
7		
8		
9		Discussions about growth
10		
11		
12		
13		
14		

+ weekly self-evaluations

### Course Goals

Remove barriers to persisting in STEM & build research skills by developing:

- an understanding of the **nature of science**
- a **science identity** as a member of a community of practice
- a **growth mindset**

## Nature of Science

### Ray Model of Light

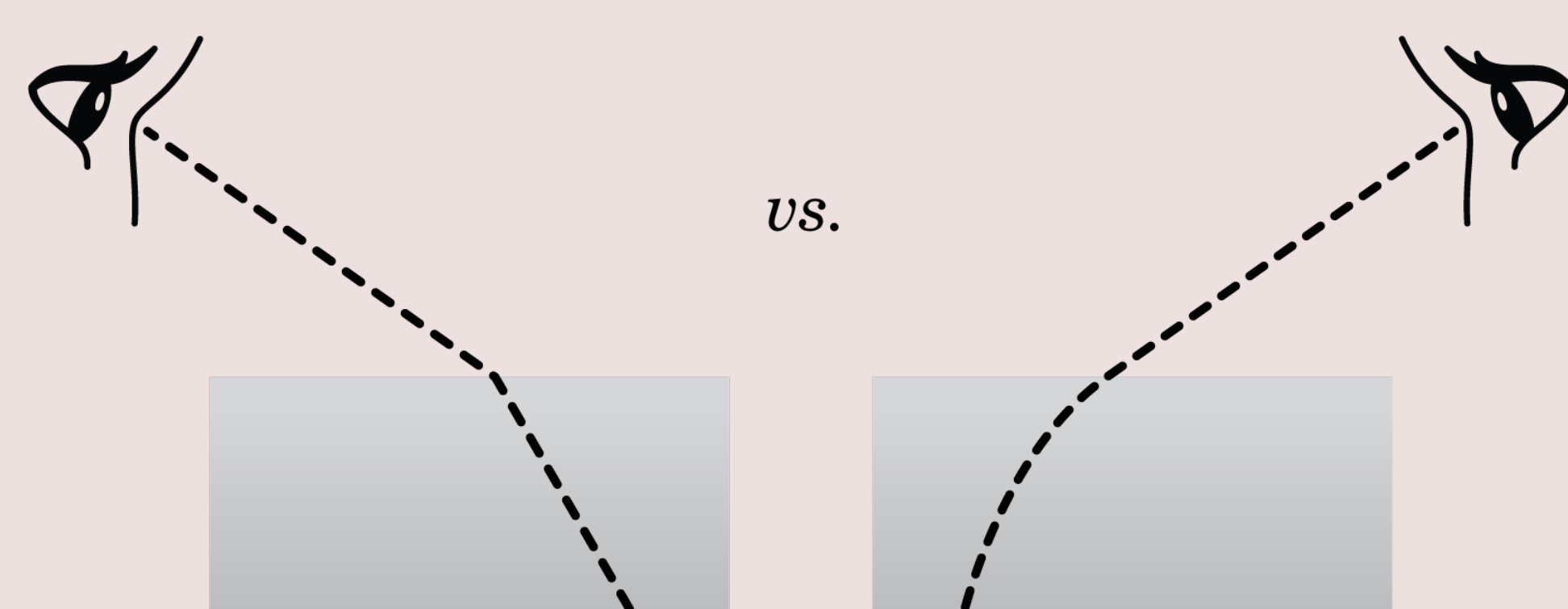
- Students engage in the process of constructing a model for the propagation of light in various circumstances via small-group discussion and experimentation and class-wide consensus-building.
- Students reformulate their own ideas about the "scientific method" by generating new representations of this process based on their experiences studying light.

### Outcome

Students deepen their understanding of the nature of science by creating their own representation of the scientific method and engaging in the process of scientific modeling.

## Example Activity

"Consider two different models for the interaction of light and a piece of plastic: one where the light bends all at once at the interface and one where it bends continuously in the plastic. Using plastic of different, but known, thicknesses, devise and conduct an experiment to determine which model is correct."



## Identity as a Scientist

### Independent Research Project

- Teams of 2-3 students choose a question about a physical phenomenon of interest.
- To answer the question, the team develops models by talking with peers, consulting the literature, and conducting experiments. Graduate student research advisors help guide this process.
- Teams present their work through papers and a poster presentation.

### Outcome

Students gain experience practicing the methods that professional scientists use to conduct and communicate their work, which helps them to identify with the scientific community.

## Example Project

The Physics of Chalk Skipping  
Undergraduates, UC Berkeley

**Abstract**  
The motion of a piece of chalk skipping over a blackboard surface is considered and a simplified description of such collisional process is proposed. The frequency of bounces is estimated by considering dynamics of the chalk.

**Assumption**  
Consider a cylindrical piece of chalk, with length  $L$  and mass  $m$ , held at pivot point  $P$  with a distance  $D$  from its bottom. The angle between the piece of chalk and the vertical direction is  $\theta(t)$  and that  $\theta(0) = \theta_0$ . An external force  $F$  applied at  $P$  drags the chalk across the blackboard surface. Here we make a reasonable assumption that  $F$  is applied to keep the translation velocity  $V$  a constant, and also create a restoring torque on the piece of chalk.

**Methods**  
To describe the chalk skipping motion quantitatively, we introduce the frequency of bounces,  $\nu$ , which is defined to be the number of bounces per second. We want to find a function  $\nu$  such that:

$$\nu = \nu(V, N, D)$$

An apparatus as shown in Fig. 2 is designed to conduct experiments. Data retrieved from repeated experiments are analyzed to build an approximate model. During each trial, we record the bouncing sounds made by the chalk and by inspecting the sound wave diagrams we obtain the average time from its equilibrium position. At time  $t$ , the chalk has rotated to angle  $\theta(t)$ , and hence the restoring force  $F$  has been increased to  $F \sin \theta$ . The chalk then suddenly slips and swings up above the surface of blackboard. Once the tip of the chalk leaves the board, the motion of the chalk is mostly governed by the gravity and the restoring force applied around  $P$ . The chalk rotates around  $P$  back to its balance position in a short instant and fall freely in vertical direction. At time  $t + \tau$ , the tip of chalk falls back to the surface of the blackboard.

**Result**  
The model described in Assumption yields out the following equation:  
$$\ddot{\theta} + \frac{g}{D} \sin \theta = \frac{V^2}{D^2} \cos \theta$$
  
Where  $C$  is given by  $C = \frac{1}{D} \left[ \frac{m g D \sin \theta_0}{2} + \frac{m V^2 \cos \theta_0}{2} \right]$ . And the frequency is  $\nu = \frac{1}{T}$ . Unfortunately, due to the nature of our apparatus, it is unrealistic for us to make precise comparison between the mathematical outcomes and the collected data. However, we can at least match the increasing/decreasing tendency for  $\nu$  in relation to  $V$ ,  $N$  and  $D$ . By taking partial derivatives, we can show that:  
Fig. 4 shows a decreasing relation between the velocity and frequency, which asserts with derived equation,  $\frac{\partial \nu}{\partial V} < 0$ .  
Fig. 5 shows a increasing pattern between the  $N$  and frequency, which asserts with derived equation,  $\frac{\partial \nu}{\partial N} > 0$ .  
Fig. 6 shows a decreasing pattern between the  $D$  and frequency, which asserts with derived equation,  $\frac{\partial \nu}{\partial D} < 0$ .

## Growth Mindset

### Self-evaluations and Discussions of Growth

- Through readings, reflections, and class discussions, students learn about the nature of intelligence and how our reactions to both failure and success can impact how we grow as learners.
- Students conduct weekly, written self-evaluations of their performance in a STEM class of their choice based on a rubric of skills. The course instructors provide weekly, personalized feedback.

### Outcome

Students develop a growth mindset—the belief that abilities can be developed through hard work and dedication—by evaluating their own progress and critically discussing the growth with their peers.

## Example Rubric

Skill	Questions to ask yourself	Beginning	Developing	Succeeding
<b>Persistence</b>	<ul style="list-style-type: none"> <li>What do you do when you're frustrated?</li> <li>Do you independently pursue understanding?</li> </ul>	I tend to try one or two things. I give up more easily than I should.	I try to stick with things, but I sometimes feel unsuccessful. Sometimes I seek new approaches to help.	I look for new ways to think about the problem. I find a way to persist when appropriate.
<b>Organization</b>	<ul style="list-style-type: none"> <li>Do you keep accurate, thorough, and consistent records of work?</li> <li>Do you submit materials in a timely manner?</li> <li>Do you refer to your records to support conclusions?</li> </ul>	There are significant gaps in my records, and/or I consistently forget to complete assignments on time.	I don't complete all assignments on time or I have no record of some of my work/activities. When I neglect to do something, I forget about it because it's too late.	I am timely and thorough with work and record-keeping. When I've neglected something, I correct my oversight quickly. My records are a valuable resource.
<b>Connections</b>	<ul style="list-style-type: none"> <li>Do you try to make connections with new people who might be able to help you in the future?</li> <li>Do you make use of your connections when you need help?</li> </ul>	I tend to go it alone.	I sometimes get help from other people, but only when I really need it. My network of supporters could be better developed.	I have a strong network of people who I go to regularly for help and support.
<b>Self-compassion</b>	<ul style="list-style-type: none"> <li>When you're having difficulty with something, how do you feel about yourself?</li> <li>Do you make productive use of failure?</li> </ul>	I have trouble with feeling like a failure, and these feelings often make me feel like giving up. I'm my own worst critic.	I am sometimes overly critical of myself. I tend to ignore feelings of failure rather than using them to improve.	I acknowledge my difficulty, but I don't let it define how I feel about myself. I act kindly towards myself and view failure as an opportunity for self-improvement.

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