Professional Evaluation and Growth Plan

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0.1 Teaching Philosophy

That people may know wisdom and discipline, may understand intelligent sayings; May receive instruction in wise conduct, in what is right, just and fair; That resourcefulness may be imparted to the inexperienced, knowledge and discretion to the young. - Proverbs 1:2-5

The following is a reflection on the growth and development of my teaching practices as a professor, and is submitted upon recommendation by the Faculty Personnel Committee (FPC). My first two years as an assistant professor of physics were filled with valuable experiences and memories. I have strived to make important adjustments to my classroom practices, and to follow recommendations given to me by both my department and FPC. In putting these changes in place, I have reflected on my teaching philosophy. Looking back at my first submitted teaching philosophy, I view it as a good place to begin, but something that should evolve as I learn to handle the style of student we find specifically at Whittier College. In the letter submitted to FPC by my department, and in the feedback letter provided to us by FPC, three general recommendations have emerged.

First, the *pace* of my content delivery should be slowed, in order maximize student success. Second, I must increase the number of *step-by-step example problems* in my physics classes, in order to give students new to the subject and those who are struggling something concrete to grasp each time a new concept is introduced. Third, I need to include more *traditional lecture content* in my classes, which happen to take the form of an integrated lecture/laboratory format. Traditional lecture content is a term used in physics education research (PER) to refer to the classical teaching style in which the equation corresponding to a new concept is first introduced or derived on the board, then solved in several examples and displayed in graphical form. I'm happy to report that I have strived diligently to put these changes in place, and it has in fact yielded promising results in my classes as evidenced by my increased student evaluation numbers.

All of the introductory physics courses are taught in an integrated lecture/laboratory format. I describe the lecture/laboratory format in Sec. 0.1 below. I have learned in my first two years that although we do use that format by default in our department, it does not *preclude* giving the students traditional content. In fact, what works best (we have found) is a healthy mixture of the two. When I attend the classes of my colleagues in the physics department, this mixture is what I observe. The mixture results in a style of physics course which begins new concepts traditionally, and then branches into laboratory activities and research-based lecture content when the students are ready. *Researched-based content* is a term in PER that refers to non-traditional physics teaching modules subjected to controlled research, and that have been shown to improve student learning beyond traditional content. I described three such modules in my first PEGP: Peer-instruction (PI) [1], Just-in-Time Teaching (JITT) [2], and Physics Education Technology (PhET) [3]. I reflect in detail in Sec. 0.1 on which modules tend to work best, which do not, and why.

Teaching physics is about growth. Regardless of the physics teaching methods chosen, the student should leave the encounter *enlightened*, with an increased understanding of the physics concepts. The success of the encounter is measured by the varying degree to which the student can retain, understand, apply, and reflect upon the concepts. The goal of the physics professor is to serve the students by formulating the concepts of physics into specific equations, testable by experimentation, and to create a problem-solving environment in which the students gain the ability to master the equations through problem-solving. The student usually encounters failure, then the ability to find the correct solutions to specific example problems. Finally, the professor leads the students to mastery by showing them that the concepts they have gained may be applied *in general* to a broad range of problems. Each stage must be accompanied by careful laboratory experiments to verify the equations.

All physics begins with defining the concept of a "system" about which we can make measurements. Beginning at this common place, we define the concepts of the displacement, mass, and electric charge of a system, as well as the passage of or change in time with regard to a system. What follows is the subject of *classical physics*: a description of the motions, forces and energies that govern all systems. With the addition of concepts like temperature and heat, *thermodynamics* may be added to classical physics. Students who do not major in physics usually encounter classical physics and thermodynamics. Physics majors progress to *modern physics*, which adds the subjects of relativity and quantum mechanics to the toolkit[1]. Thus, physics professors often make the distinction between *physics majors* and *non-majors*, who encounter different types of material. The bulk of PER is done in the context of serving students who are non-majors, and thus the named modules (PI, JITT, and PhET) are usually applied to introductory courses. Physics majors usually experience more traditional lecture content once they progress to upper division courses.

Analogous to learning physics, learning to become a great physics instructor involves solving the basic problem of imparting simple concepts to the students and building upon their success. The instructor must be able to generalize the teaching modules to lead students to more advanced topics, building the system of classical physics in their minds. At each phase, the instructor must be able to guide laboratory experimentation, while at the same time demonstrating how the physics formulas are derived and used to solve problems. Upon examining my teaching practices, I have found the correct "solution" for our classical and introductory physics courses to be keeping the pace of the modules under control, including more concrete examples, and providing more traditional lecture content.

I have built upon modifications made in the first semester of introductory physics to the second semesters of two-semester sequences (when the material becomes more challenging), as well as advanced physics and computer science classes. It was rewarding to see positive reviews in all of these courses, but I was especially pleased to see these changes pay off at the introductory course level. Non-majors regularly tell us that they do not want to have to take these courses (see Sec. 0.2.1), so to hear the students report that these courses increased their interest in the subject matter was worth the hard work and sacrifice I have exerted in improving these courses.

Instruction of Students in Introductory Courses

Physics students at Whittier College are first categorized as *non-majors* or *physics majors.* Non-majors encounter physics for two semesters in either *calculus-based* or *algebra-based* courses. Classical physics at the undergraduate introductory level is built upon single-variable calculus, with some multi-variable or vector calculus introduced in the second semester. However, students who have not taken calculus can still learn the portions of the subject based on algebra and trigonometry. Thus, *non-major* students usually take the *algebra-based* versions, and *physics majors* and related technical majors take the *calculus based* versions.

Three focuses are relevant for teaching at the introductory level, especially to non-majors:

1. **Curiosity**. I regularly give colloquia at universities, seminars in physics departments, and public lectures to children, families, and astronomical societies. Experiencing people's curiosity is necessary to become a great physics professor. I have continued this practice as Whittier professor. For example, I have given lectures at Los Nietos Middle School and colloquia here at Whittier College, and invited speakers from UC Irvine to give colloquia as well. Good teaching for non-majors should *entice student curiosity.* My introductory courses include specific activities designed to entice student curiosity. For example, I have students present science articles to the class, and give presentations on home-built experiments. Within this teaching focus, I seek to achieve three specific goals:

    - Measurably increase the interest of the students in physics
    - Teach the students to satisfy their curiosity by doing sucessful self-designed experiments, and through pre-designed lab activities
    - Coach the public speaking skills of the students to empower them to present their findings to each other

2. **Improvement of Analysis Skill**. The scientific method relies on analytical skill. We as physicists best serve Whittier College introductory students, especially non-majors, when we develop their problem-solving abilities. We apply specific modules in introductory courses (for example PI, JITT, PhET) to help train students to think analytically and hone their problem solving. We also realize that students must learn by example, and therefore we provide healthy mixtures of traditional lecture content and step-by-step examples of problem solving. This involves calculations as simple as converting between units of measure (i.e. kilograms to pounds) to plotting the trajectory of a particle in a vector field. Within this teaching focus, I seek to achive three specific goals:

[1]Students satisfying liberal arts requirements via specialty courses do experience non-classical physics qualitatively.

- Measurably increase the ability of the students to obtain the correct answer in word problems
- Measurably increase the ability of the students to measure with precision the correct result in laboratory settings

3. **Applications to Society**. Whittier College students gain potential in technical careers if they can qualitatively explain phenomenon using physics. In recent years, our open-source textbooks [4] [5] have included material relevant to popular majors (e.g medicine and kinesiology). I have incorporated special units centered on these applications, including human nerve systems (in PHYS135B and PHYS180). I use group projects to allow the students to design an experiment which relates to a topic of their field and present it to the class. I aid in the development of these projects as they progress throughout the second half of the semester. Another tool within this learning focus is the inclusion of student-led summaries of a scientific news or journal article, which encourage scientific class discussions about the broader implications for society of the results. Therefore within this teaching focus, I seek to achive two specific goals:
   - Empower the students to present and discuss articles they find relevant or interesting due to the societal impact
   - Manage and aid in student-designed experiments that are presented to the class, relevant to society

Instruction of Students in Advanced Courses

Physics majors are the second category of students we typically encounter. I broaden my discussion to *Mathematics and Computer Science majors*, because I teach advanced computer science courses that typically draw math and computer science majors. In my time at Whittier College, I have created two upper-division computer science courses that are part of every engineering/computer science curriculum in schools similar to Whittier College, but were not being offered here. The first was PHYS306/COSC330, Computer Logic and Digital Circuit Design, and COSC390, Digital Signal Processing. For sample curricula demonstrating the widespread adoption of these courses in schools like Whittier College, see [6] [7].

Three focuses are relevant for teaching physics, mathematics, and computer science majors at the advanced level:

1. **Mental Discipline**. Advanced physics, math and computer science courses require discipline. and there is no substitute for grit. The professor must foster this value in the students in two ways. The first is to deliver a challenging curriculum, with problem sets and exams that require students to think *analytically* and *creatively*. For example, in COSC330, homework sets included both mathematical practice and open-ended design questions. Second, the professor should demonstrate *expertise* in the field, and the ability to lead the students to success by example in difficult modules. For example, in COSC390 I wrote example code in MATLAB to demonstrate concepts to my students, and they in turn took that code and modified it to suit their purposes for individual homework problems and projects. In COSC330 my students and I designed and debugged digital circuits together, before the students constructed them for class presentation. These ideas may be summarized into two specific goals:
   - Assign challenging homework and exams that require analytic and create thinking, and lead the students to success
   - Provide the students with technical expertise, leading by example.
2. **Strength in all Phases of Science**. Good advanced course curriculum must include the following *phases* of scientific activity: theoretical and abstract problem solving, numerical modeling or simulation, experimental design and execution, and data analysis. We may think of these phases as the actions that move the student through the scientific method. Whittier College graduates in physics, mathematics, and computer science should be comfortable working in any of these four areas. I therefore have four specific goals in this area, corresponding to the four areas:
   - Provide engaging curriculum designed to strengthen the theoretical problem solving of the students
   - Provide engaging curriculum designed to expose students to numerical modeling and simulation with computer code and open-source software tools
   - To aid the students with the design and execution of technical experiments and laboratory activities
   - To lead the students in data analysis of experimental results that either confirm or reject hypotheses

3. **Communication**. Two skills that should never go overlooked in technical fields are oral and written communication. Whittier College graduates in the fields of physics, mathematics, and computer science should be able to communicate technical ideas to their colleagues. Clear communication in engineering and scientific research contexts often prevents the introduction of design flaws, misconceptions or ambiguities. In all of my advanced courses, the students are required to write at least one longer lab report or presentation, and submit it to me or present it to the class. I provide activites in which students are solving problems together in small groups to foster communication with each other [2]. Finally, I encourage the students to visit me in office hours in order to refine and clarify their work long before they are due. This gives them an individual space in which they can grow if they do not feel comfortable yet with their communication skills. To this end, I set two concrete goals:
    - Require the students to submit at least one major written or oral assignment
    - Provide students the opportunity to refine the work with me in office hours before it is submitted

Department-Level Goals

The Department of Physics and Astronomy has eight goals, developed as part of our 5-year assessment cycle. In the coming course descriptions, these goals will be referenced.

1. Develop and offer a wide range of physics courses using the most effective pedagogical methods and styles. Such courses shall include appropriate contributions to the Liberal Education Program (currently COM1 and CON2).
2. Create research experiences for physics majors that will engage and inspire them in their discovery of physics.
3. Build a departmental community that is supportive and welcoming and that encourages students in their studies of physics.
4. Keep the physics curriculum current so that students gain the skills necessary for success in todays scientific environment.
5. Teach students how to teach themselves. Give them the intellectual tools necessary for independent thinking and learning.
6. Train students to think “scientifically” i.e. critically, rigorously, quantitatively, and objectively, so that they can analyze problems and generate solutions.
7. Train students to effectively communicate scientific ideas to others.
8. Advise students about various career paths and help them along these paths.

[2] See supplemental materials for examples of student presentations, writing, and activities in which they solve problems together.

Semester	Course	Credits	Students	Curriculum feature
Fall 2017	PHYS135A-01	4.0	24	Intro
Fall 2017	PHYS150-01	4.0	17	COM1/Intro
Spring 2018	PHYS135B-01	4.0	18	Intro
Spring 2018	PHYS180-02	5.0	19	COM1/Intro
Spring 2018	COSC330/PHYS306	3.0	6	Advanced
Fall 2018	PHYS135A-01	4.0	24	Intro
Fall 2018	PHYS135A-02	4.0	26	Intro
Jan 2019	COSC390	3.0	8	Advanced
Spring 2019	PHYS135B-01	4.0	25	Intro
Spring 2019	PHYS180-02	4.0	9	Intro/COM1
–	Total	39.0	–	–

Table 1: This table is a summary of the courses I have taught since Fall 2017. The introductory courses carry the course numbers 135A, 135B, 150, and 180. The advanced course PHYS306 is cross-listed as a computer science course, COSC330. The other advanced course, COSC390, is now listed as an upper division computer science course and counts towards the Integrated Computer Science (ICS) requirements. This table does not include the two times I have taught PHYS396 (Physics Research), which does not count for teaching credit, but is 3.0 credits per student. Physics 396 also goes toward **Departmental goal 2**.

0.2 Introductory Course Descriptions

Algebra-based physics (135A/B). Algebra-based physics, PHYS135 A/B, is a two-semester integrated lecture/laboratory sequence that covers algebra-based physics from kinematics and Newton's Laws to electromagnetism without the mathematics of calculus[3]. Algebra-based physics is a core requirement for many technical majors such as kinesiology (KNS) and chemistry (CHEM). Students learn problem solving in a physics context with algebra, trigonometry, and vectors. I employ a mixture of traditional and PER active learning methods to **satisfy departmental goals 1, 4, and 6**. These methods are *Peer Instruction (PI)* and *Physics Education Technology (PhET)*. I no longer use JITT modules, which I experienced to be ineffective for the students (see Sec. 0.2.1). I attended the American Association of Physics Teachers (AAPT) Workshop in 2017 to practice the implementation of these modules [4], and I have since modified them as per department and FPC recommendations. My total teaching credits and number of students for this course is listed in Tab. 1.

The first learning focus I identify for non-majors is **curiosity**, with the measureable goals stated in Sec. 0.1. To help satisfy the goal of increasing their interest in physics, I encourage an activity at the beginning of each class period in which a student presents a news or science journal article pertaining to physics that was published in the previous week. I incentivise the students to volunteer as presenters by offering extra credit, and through the activity I help them to practice oral communication of scientific ideas (**Departmental goal 7**) and help them recover points lost on midterms [5].

A second method I use to increase student curiosity is to require the students to design and complete a physics experiment. The OpenStax textbooks contain many workable suggestions that the students can construct. Each student group must first collectively agree on an idea, and submit a proposal to me in the middle of the semester. I then edit it with the group and ensure they have the equipment they need. After they have begun to collect data, I invite them to office hours to coach them on the presentation of the results [6]. By allowing the students to choose the topic and design, I provide them the opportunity to satisfy their own curiosity. Making this assignment an oral presentation also goes toward **Departmental goal 7**. With the two activities of article/journal presentations, and group-designed physics labs, I touch upon all three goals for the curiosity learning focus. The data in Sec. 0.2.1 show that the students are reporting an increase in their curiosity for physics at an increasing rate over time.

The second introductory course learning focus is **improvement of analysis skill**. PI (Peer Instruction) modules were first developed by Eric Mazur [1], and tend to yield higher learning gains than traditional lecture content.

[3] See supplemental material for example syllabi.
[4] See supplemental material for details.
[5] Examples of such articles presented by students are included in the supplemental materials.
[6] Included in the supplemental materials are examples of the students' final presentations.

Moreover, it is often helpful to illustrate physics concepts with PheT (Physics Education Technology) simulations, or to perform laboratory activities we cannot consruct (e.g. altering the strength of gravity) [3]. These two activities form the engine by which I seek to improve the analysis skill of introductory students. In alignment physics department and FPC recommendations, I have balanced the use of these two modules with the inclusion of more traditional lecture content in recent semesters. Finally, after reflecting upon the use of JITT modules [2], I have decided to cut them in favor of more example problems. The students express a desire for more concrete, step-by-step examples. Although popular PER methods claim to yield better results than traditional content, we must be receptive to the concerns of the students.

A typical introductory physics class in the lecture/laboratory format begins with 1-2 journal/news article presentations from the students. After a short discussion, we begin with a warm-up example on the white board from the prior class. We then introduce new concepts on the projector screen, followed by several examples worked out in traditional form by me on the whiteboard. Third, I engage the students with a PI module pertaining to the topic at hand. PI modules first pose a problem *conceptually*, with A-D multiple choice answers. Our classrooms are equipped with a system that records student answers anonymously. The students take several minutes to think conceptually *without specific numbers or equations*, and answer on their own. I view the answer distribution, and if fewer than 70% of the class answers correctly, I ask them to discuss at their table how they obtained the answer. The students often learn best from each other, as they explain their reasoning in their own words. I circulate through the classroom at this stage, seeking out the struggling students and helping them. Deliberately focusing on the struggling students helps me to build a relationship of trust with them, and relaxes anxieties they have with word problems.

After 2-3 minutes, I require them to re-submit their answers *as a group* at their table. We observe the distribution of answers (choices A-E) *shift* toward the correct one at the end of PI modules[7]. Further, if the students answer correctly before the group discussion I learn that I can move on without the need for the group discussion. In this way, we only accelerate the pace when most of the students are ready. This leads to the possibility of 1-2 students being left behind (if they are not in the super-majority of the A-D answers), so I have added the concept of WAT[8]. Usually WAT corresponds to answer E, and it allows a student who is lost notify me anonymously. If a WAT occurs, I work another example until it disappears. *This strategy ensures inclusivity in my introductory classes*, in that we leave no struggling student behind. For more difficult or extended examples, I have the student groups work the problem together on the whiteboards in the classroom together[9]. The advantage there is that the students can observe how other groups are solving a problem step-by-step.

The second-half of the lecture/laboratory format moves on to the laboratory activity or PheT module. An example of the difference between traditional labs and PhET modules occurs in PHYS135B and PHYS180, which cover electromagnetism. In these courses, we often build DC electric circuits. If the circuit is constructable in our lab, we perform a traditional experiment in which we measure voltages and electric current to verify a principle such as Ohm's Law. If the circuit cannot be easily built in our lab, we simulate it virtually with PhET software. Whenever possible, we first simulate the circuit in PhET, and then construct it to compare theory and experiment in full detail. The PI modules, PheT modules, and traditional lecture content complete my strategy for improving the students' analysis skill, and go towards **Departmental goals 1, 4, and 6**. *The student evaluation data in Sec. 0.2.1 show great progress in a broad range of measures in this category.*

I employ several methods to reach my third introductory course learning focus, **applications to society**. The obvious routes are the applications in the OpenStax texts [4] regarding kinesiology and medicine. I develop special PI modules and example problems around topics such as motion/work/energy in the human body, nerve cells as DC circuit simulation, and lightning/weather. Which modules I deploy depends on the semester. I have reflected on the fact that in more recent semesters I have been much better about learning what interests the students and including content specifically for the students in my class. Another reason why I have dropped the JITT module is that it frees up time before class for me to add material I know particular students will enjoy[10].

Two final methods for my third learning focus are the student-led article discussions, and term-papers. A nice example of the former occured during the past year occurred when I had an environmental science major

[7] See supplemental material for example PI modules.
[8] e.g. "What?" A meme indicating confusion.
[9] I named this trick "board problems" in my previous PEGP.
[10] See supplemental material for an example of such a unit.

interested in climate change in PHYS135A/B who would find climate science articles that used concepts from class to present to the group. This type of activity empowers the students to choose topics they value, and believe have an impact on our community. Occasionally I give hints at articles which are of high-impact for the *scientific community*, and this prompt is all most timid students need to take the next step of preparing one for class. For extra-credit I offer term-papers asking students to explain the physics of a recent or past historical discovery. Some brilliant examples have emerged, including the history of the first measurements of the distance between the Earth and the Sun[11]. The preparation of these papers requires the students to use concepts learned during the semester to understand scientific breakthroughs, as well as providing them a venue to practice writing about societal impact of physics (**Departmental goal 7**).

Calculus-based physics (150/180). Calculus-based physics, PHYS150/PHYS180, is a two-semester lecture/laboratory formatted sequence that covers calculus-based kinematics, mechanics, work/energy, and electromagnetism[12]. I employ a mixture of traditional and PER active learning methods to **satisfy departmental goals 1, 4, and 6**. As in the algebra-based classes, I implement *Peer Instruction (PI)* [1] and *Physics Education Technology (PhET)* [3] modules when necessary. Because PHYS150 and PHYS180 require tools from single and multi-variable (vector) calculus, students taking those courses concurrently benefit from PhET simulations to help visualize calculus concepts. Examples include operations with scalar and vector fields in electromagnetism, single-variable integrals and derivatives in kinematics, and line integral calculation of work and energy. My total teaching credits and number of students for this course is listed in Tab. 1.

My PHYS150/180 classes are taught with the same methods and format as the algebra-based courses, with the inclusion of the full calculus-based version of introductory physics concepts. Since the subjects of calculus and Newton's Laws were developed concurrently, often by the same scientists, these two subjects are linked. During the warm-up phase of class, I will sometimes pose a calculus problem (when necessary) to familiarize the students with a technique that is required to understand the concepts we will encounter during class. Occasionally (and this is especially true in PHYS180) the physics requires calculus concepts that the students have not encountered yet in their concurrent courses. These cases usually involve vector calculus (Calculus III, or MATH241), which helps to explain electric and magnetic fields. I gauge the comfort level of the students, and typically restrict my vector calculus content via traditional whiteboard content and examples. *As a rule, we do not place calculus concepts on exams that the students have not encountered in pre-requisite or concurrent courses.*

In Sec. 0.2.1, I reflect on the student evaluation data in the same fashion as with the algebra-based courses. Similar to the conclusions for PHYS135A/B, the data in Sec. 0.2.1 show that calculus-based student date shows an increase in their curiosity for physics over time, and *great progress in measures touching upon their problem solving skills.* I received almost perfect scores for data collected from my most recent PHYS180 course. Although the reduced class size made this easier to achieve, I have reflected on the fact that the students place a high value on *building a relationship of trust with them* in order to satisfy their curiosity and increase their analysis abilities.

Descriptions of each Module Type

The following descriptions provide more detail about our PER instructional modules, in list form.
<u>PI Modules</u> - Implementation of an active learning strategy involving group problem solving and discussion. Several good references are found in [1] [8] [9].

- PI-based modules contain conceptual, multiple-choice questions for the class about a physical system.
- Key to the multiple-choice questions given in class are that they minimize the use of equations and specific numbers, and instead are posed conceptually.
- Students respond individually with an electronic device, and the distribution of answers for choices A-D is shown on the class screen.
- (I introduce answer E as a safety valve option so that students who are lost can notify me anonymously).
- One of two actions is taken next:
    1. If the fraction of correct answers to the conceptual question is larger than 0.7, class proceeds.

[11] Included in the supplemental material.
[12] See supplemental material for example syllabi.

2. If the fraction is less than 0.7, the professor initiates **table discussion**.

- **Table discussions** take place between students at the same table. During this time the professor circulates, searching for the struggling students and answering questions. After approximately 5 minutes, the discussion ends.
- A second poll of the class is taken. The *shift* in the distribution towards the correct answer indicates an improved understanding of the concepts. If the shift is not observed, the professor may give another example problem, or take another appropriate action. If more than one person selects E, the material is covered again regardless of the shift.
- The overall procedure is repeated for several rounds, and table discussions take place when necessary. After several rounds, the class proceeds to the next round.

<u>PhET Modules</u> - Simulations written in HTML and JAVA, and published by The University of Colorado, Boulder, with public support from the National Science Foundation and private support from Google and the Moore and Hewlett Foundations [3]. The goals of the simulations are that anyone should be able to operate them, and that they be based on proven PER. The benefits of the simulations are researched and they are only published if the benefits to the students has been proven.

- The OpenStax textbooks for PHYS135 A/B and PHYS150/PHYS180 have built-in links to PhET simulations that allow students to illustrate concepts by visually simulating physics systems.
- Several HTML5-based examples are here:
  1. Electric charge and electric field: `https://phet.colorado.edu/en/simulation/charges-and-fields`
  2. DC circuit construction: `https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc`
- PhET simulations are incorporated into active learning in the classroom in four situations:
  1. When a PhET simulation re-creates a laboratory measurement we are about to perform, it is useful to first simulate the expected results with the HTML or Java code and then perform the measurement to confirm the behavior of the system.
  2. PhET simulations are also used when a desired measurement or experiment cannot be performed or constructed in the lab, such as altering gravity or changing the amount of friction between two surfaces. Students benefit by being able to "fine-tune" a system, in order to expose the behavior of a system in real time.
  3. PhET simulations are used to *visualize* physical objects which are invisible. Obvious examples are magnetic, electric, and gravitational fields, which are real but not (always) visible.
  4. In special units, such as studying the behavior of electrical signals in the human body, there are PhET simulations from other fields (biology, chemistry, earth science, etc.) that prove useful to engage students' curiosity.

Question	135A-01 N	135A-01 result	135A-02 N	135A-02 result	135B-01 N	135B-01 result
10	24	4.58 ± 0.16	25	4.24 ± 0.17	24	4.46 ± 0.16
11	24	4.42 ± 0.17	25	4.56 ± 0.15	24	4.42 ± 0.16
12	24	4.54 ± 0.12	25	4.4 ± 0.14	24	4.54 ± 0.16
13	24	4.54 ± 0.15	25	4.4 ± 0.14	24	4.42 ± 0.19
14	24	4.38 ± 0.17	25	4.16 ± 0.2	24	4.46 ± 0.17
15	24	3.78 ± 0.26	25	3.76 ± 0.25	24	4.25 ± 0.21
16	24	3.92 ± 0.18	25	3.88 ± 0.22	24	4.33 ± 0.19

Table 2: Mean and error in the mean for questions 10-16 on the student evaluation form, for PHYS135A/B taught in Fall 2018 and Spring 2019. These questions pertain to the *course*.

Question	135A-01 N	135A-01 result	135A-02 N	135A-02 result	135B-01 N	135B-01 result
17	24	4.42 ± 0.13	25	4.46 ± 0.14	24	4.57 ± 0.15
18	24	3.83 ± 0.24	25	3.92 ± 0.26	24	4.48 ± 0.17
19	24	4.00 ± 0.21	25	3.76 ± 0.21	24	4.38 ± 0.17
20	24	4.38 ± 0.17	25	4.32 ± 0.14	24	4.52 ± 0.17
21	24	4.08 ± 0.22	25	4.36 ± 0.22	24	4.54 ± 0.17
22	24	4.09 ± 0.25	25	4.29 ± 0.22	24	4.48 ± 0.20
23	24	4.45 ± 0.14	25	4.44 ± 0.18	24	4.64 ± 0.13
24	24	4.65 ± 0.10	25	4.44 ± 0.16	24	4.75 ± 0.11
25	24	4.13 ± 0.16	25	3.96 ± 0.22	24	4.46 ± 0.17

Table 3: Mean and error in the mean for questions 17-25 on the student evaluation form, for PHYS135A/B taught in Fall 2018 and Spring 2019. These questions pertain to the *professor*.

0.2.1 Analysis of Student Evaluations

Tables 2 and 3 show the results of the *algebra-based* introductory physics courses taught in the 2018-2019 academic year. Tables 4 and 5 show the results of the *calculus-based* introductory physics courses taught in the 2017-2018 academic year. The results show an interesting correlation that reveals a potential strategy for continual improvement of my teaching in these courses.

First, there are areas that need improvement. Questions 14-16 and 19 read as follows: "This course improved my understanding of the material," "This course increased my interest in the subject matter," "Overall, I would recommend this course to others," and "The professor was able to explain complicated ideas," respectively. For *algebra-based physics*, there are no prerequisites, but students are required to solve problems involving algebraic equations, graphical analysis, and concepts like vectors and vector fields. It is not surprising that students struggle if they're encountering these concepts for the first time. I have been trained to teach much faster than the students who disapproved expected.

In the students' written responses, the most common remark was that the pace of the course was too fast, and that they desired more traditional lecture time with explicit examples given. Some students remarked that the portions of the lecture on the projector (e.g. PI-modules, JITT-modules) were not as helpful as the traditional

Question	180-02 N	180-02 result
10	8	5.00 ± 0.00
11	8	5.00 ± 0.00
12	8	5.00 ± 0.00
13	8	5.00 ± 0.00
14	8	5.00 ± 0.00
15	8	5.00 ± 0.00
16	8	5.00 ± 0.00

Table 4: Mean and error in the mean for questions 10-16 on the student evaluation form, for PHYS180-02, taught in Spring 2019. These questions pertain to the *course*.

Question	180-02 N	180-02 result
17	8	5.00 ± 0.00
18	8	5.00 ± 0.00
19	8	5.00 ± 0.00
20	8	5.00 ± 0.00
21	8	5.00 ± 0.00
22	8	4.75 ± 0.25
23	8	5.00 ± 0.00
24	8	5.00 ± 0.00
25	8	5.00 ± 0.00

Table 5: Mean and error in the mean for questions 17-25 on the student evaluation form, for PHYS180-02, taught in Spring 2019. These questions pertain to the *professor*.

Question	First Time	Most Recent Time	Raw change	Standard deviations
10	3.76 ± 0.227	4.46 ± 0.159	0.7 ± 0.277	2.53
11	4.57 ± 0.164	4.42 ± 0.159	-0.15 ± 0.228	-0.657
12	4.29 ± 0.22	4.54 ± 0.159	0.25 ± 0.272	0.919
13	3.52 ± 0.29	4.42 ± 0.19	0.9 ± 0.347	2.6
14	3.48 ± 0.297	4.46 ± 0.169	0.98 ± 0.342	2.87
15	3.29 ± 0.367	4.25 ± 0.21	0.96 ± 0.423	2.27
16	3.19 ± 0.343	4.33 ± 0.188	1.14 ± 0.391	2.92
17	4.24 ± 0.227	4.57 ± 0.149	0.33 ± 0.271	1.22
18	3.52 ± 0.29	4.48 ± 0.174	0.96 ± 0.338	2.84
19	3.48 ± 0.306	4.38 ± 0.167	0.9 ± 0.348	2.58
20	4.24 ± 0.238	4.52 ± 0.174	0.28 ± 0.294	0.951
21	4.48 ± 0.225	4.54 ± 0.169	0.06 ± 0.281	0.213
22	4.1 ± 0.194	4.48 ± 0.202	0.38 ± 0.28	1.36
23	3.95 ± 0.262	4.64 ± 0.135	0.69 ± 0.294	2.34
24	4.67 ± 0.127	4.75 ± 0.108	0.08 ± 0.167	0.48
25	3.24 ± 0.338	4.46 ± 0.169	1.22 ± 0.378	3.22

Table 6: Comparison algebra-based numbers for the first time taught (first column) to the most recent time (second column). The raw change is given in the third column, and the change divided by the standard deviation is given in the fourth column.

Question	First Time	Most Recent Time	Raw change	Standard deviations
10	4.19 ± 0.207	5 ± 0	0.81 ± 0.207	3.9
11	4.19 ± 0.345	5 ± 0	0.81 ± 0.345	2.35
12	3.63 ± 0.327	5 ± 0	1.37 ± 0.327	4.18
13	4 ± 0.275	5 ± 0	1 ± 0.275	3.64
14	3.93 ± 0.333	5 ± 0	1.07 ± 0.333	3.22
15	3.56 ± 0.315	5 ± 0	1.44 ± 0.315	4.57
16	3.56 ± 0.315	5 ± 0	1.44 ± 0.315	4.57
17	3.31 ± 0.285	5 ± 0	1.69 ± 0.285	5.93
18	2.88 ± 0.34	5 ± 0	2.12 ± 0.34	6.24
19	3.13 ± 0.385	5 ± 0	1.87 ± 0.385	4.86
20	3.69 ± 0.312	5 ± 0	1.31 ± 0.312	4.19
21	3.88 ± 0.273	5 ± 0	1.12 ± 0.273	4.11
22	3.81 ± 0.333	4.75 ± 0.251	0.94 ± 0.417	2.26
23	3.67 ± 0.343	5 ± 0	1.33 ± 0.343	3.88
24	4.5 ± 0.157	5 ± 0	0.5 ± 0.157	3.17
25	3.13 ± 0.407	5 ± 0	1.87 ± 0.407	4.59

Table 7: Comparison calculus-based numbers for the first time taught (first column) to the most recent time (second column). The raw change is given in the third column, and the change divided by the standard deviation is given in the fourth column.

style with examples. In Fall 2017, Professor Serkan Zorba and I both taught PHYS135A, and in Spring 2018 we both taught PHYS135B, meaning that some students had to switch professors. Students who switched were newly stressed by the increased pace, in addition to the students I had from the Fall. Some students even met with me in office hourse to brainstorm ways in which we could move more slowly, but still cover the necessary book chapters. These meetings were helpful, and I learned that the difference in my expectation of student physics preparation and their actual preparedness was wide. Now that I fully understand the problem, which is more pronounced for 135B, I can begin to solve it.

PHYS135B introduces the concept of vector *fields*, necessary for understanding electromagnetic fields. This new concept further added difficulty for students encountering vectors for the first time[13]. The research-based methods such as PI-modules rely on groups of students teaching each other. If a whole group is struggling, they don't gain the benefit of the one student who understands the problem to show them how to solve it. Thus, the average scores on questions 14, 16 and 19 showed slight decreases (less than one standard deviation). Responses to Question 11, "This course was academically challenging" showed a slight increase, which is evidence that the students found the second semester more difficult than the first. I assess this further in the Appendix. Figure **??** of the Appendix shows that when I score high, there is broad consensus among the students that I am performing well. However, when the *average* scores are lower, there is less consenses (a larger variance in the data).

I did not encounter many written responses in which students expressed strong feelings about question 15, "This course increased my interest in the subject matter." Most students taking PHYS135A/B are fulfilling a requirement for their major (a two-thirds majority are KNS majors), and typically do not express a strong desire to take the course[14]. Nevertheless, I have attempted to add content that appeals to KNS majors. For example, when we reach concepts in PHYS135A pertaining to biomechanics, such as torque, I give specific example problems and final project assignments that relate in some way to torque in the human body. Another example pertains to PHYS135B, which addresses electric current. When we reach the topic of current, the class solves problems specific to the electrical currents in the human nervous system[15]. For more information on KNS-relevant material in PHYS135A/B, see Sec. 0.4.

In *calculus-based physics*, the story was different. There are many areas in which the courses and my teaching scored well. **I am especially proud of the fact that Q25 ("Overall, I would recommend this professor to others") jumped in 2018 relative to 2017 for the calculus-based courses. In fact, my teaching scores improved in almost every category in calculus-based physics in going from Fall 2017 to Spring 2018.** Further, students in both sections believed that the courses were rigorous and challenging, while still giving me increasing marks in all categories. Some students appreciated the PI modules, PhET simulations, and JITT exercises. This is reflected in responses to question 12 on the standard evaluation ("This course offered useful learning tools"), which is a key data point. I focus on this data point because I am being asked by my department to teach in an activities based style with modules like PI-modules, different from the traditional lecture. The purpose of the activities and group exercises is to satisfy the focus on **improvement of analysis skill**. The PI, JITT, and PhET modules are constructed to improve analysis skill through conceptual understanding. However, upon reflecting on the students' constructive comments, it seems that these modules benefit some students but not all.

A vital teaching method emerged in PHYS180, which the students call "board problems" in their written responses to evaluations. It started with an interesting compromise between my desire to move forward in the book faster, and the students' desire to go slowly and have me do examples. Notice that in the PHYS180 written responses, the students still express quite often a desire for worked examples in class. In light of all the research-based teaching methods that encourage students to learn through interactions with each other, I decided to have them *work example problems for each other*. I began by giving an example problem to the class. The problem would be difficult, and I would either design it myself, or draw it from the current chapter. Students would then work the problem in groups of 3-4 on the whiteboards, next to other groups. The class responded positively to this method, and it is reflected in their written responses. Some even state explicitly that my teaching improved! The board-problem method works for two reasons: it allows struggling students to see how harder problems are approached by peers, and struggling groups see other groups' strategies and therefore learn

[13] A single vector describes, for example, the velocity of a single leaf blown in a direction by the wind. A vector field, on the other hand, describes the wind velocity at all points in space.

[14] Question 9: "I had a strong desire to take this course." PHYS135A/B students reported 3.24 ± 1.64 and 3.00 ± 1.71, respectively.

[15] In the supplemental materials I include a student's final presentation on the electrical nerve activity of a bicep under torque.

from the whole class.

The success of the "board problems" technique also reflected the fact that some of the issues PHYS150/PHYS180 students shared were similar to those in PHYS135A/B. Some students wrote that the pace was too fast, while others reminded me that this was the first time they had encountered mathematical concepts like vector fields. Students also wrote that class time should be used more effectively, with fewer PhET simulations and more concrete traditional lecturing with examples. Finally, some students wrote that they didn't benefit from the summarization of scientific articles (meant to practice scientific oral communication). A handful of students seemed to express the opposite opinion, that there should be more of that activity. Going forward, I have learned that inclusion of communication activities should be gauged mid-semester, and I will include them if the students are eager and if time permits.
Having reflected extensively on all of the student feedback, I have decided on **three concrete improvements** to my introductory courses. In consultation with my department chair, and in studying past PEGP documents in my department, the first improvement will be an increase in traditional lecture content. The reason is that if every single concept and number in physics is confusing to a first-time student, then merely updating the teaching style with researched-based modules will not help that student. The traditional lecture style offers the benefit that students see many example problems done in explicit detail, such that they can copy and repeat the technique. I was taught to never expect this as an undergraduate student. My colleagues in my department have reassured me that it is necessary to give inexperienced students an explicit starting point. Thus, going forward in my introductory courses, *a significant fraction of class-time will be spent on concrete examples in the traditional style.*

The second major change I will be making to my introductory course teaching style is to slow the pace. In reading students' remarks, this is the second most common desire on their part. I was taught at the undergraduate and graduate levels at high speed, with intense focus on both content and mathematical detail. Of course I must make adjustments for the environment at Whittier College, and not merely teach to myself. I must *teach to the middle*, as one of my colleagues recommended. The students felt relief when I began assigning them board-problems, precisely because it allowed them to slow down, and check their work with each other and other groups. Thus, the addition of board-problems solved both the problem of pace and example problems at once. The students got a chance to lecture to each other momentarily. In the coming semesters, *I will include the group-board technique regularly.* One minor adjustment to this technique is that the courses are getting larger enrollments, and we may run out of whiteboard space. My plan is to sketch the problem, and then allow student groups to design specific examples meant to be exchanged with another group. This is working in my Fall 2018 PHYS135A sections when it's not feasible to do board-problems.

The third change I'd like to make is to include more applications of calculus in the *calculus-based* introductory sequences. In my view, more applications of calculus should be included in PHYS150/PHYS180. From the feedback from my department, I need to include more laboratory activities in PHYS180. Thus, I propose solving both problems simultaneously. When I teach *calculus-based* introductory courses in the future, I will use the laboratory activities as a venue for demonstrating the difference between results obtained with and without calculus. The inclusion of more lab activities is mandatory (and now possible because I'm fully trained on all the equipment). Thus including calculus concepts in the labs will require little extra effort. Finally, homework problems involving calculus will be selected from the book's less-difficult category, easing the transition from math to physics contexts.

In consultation with my department, I have been focusing on question 17 ("The professor used class time effectively and demonstrated preparation for class."). My colleagues believe that many numbers will rise in correlation with question 17. Struggling students who desired traditional lectures with examples and worksheets likely felt class was not organized because they were unaccustomed to research-based modules like PI or PhET. Of course I prepared for my courses; I have built an interactive, open-source GB-scale database of lecture content [16]. Going forward, I can use the discussion period during PI modules to focus on helping struggling students one-on-one with a mini-lecture at their table. The group board problems also afford me the chance to do this. Finally, providing more traditional lecture content should help the situation. For further analysis of the data in Tab. 2-5, see Appendix A.

[16] see my account on Github.com: `https://github.com/918particle/AlgebraBasedMechanics1` or `https://github.com/918particle/AlgebraBasedMechanics1`.

0.3 Advanced Course Descriptions

Computer Logic and Digital Circuit Design. My premier advanced course was ambitious, and has a well-defined direction for continual improvement. Digital design is as broad a topic as any undergraduate would encounter. To cover it adequately at Whittier College, I had to make hard choices about where to spend class-time. My first goal for the students was to impart my advanced learning focus of **strength in all phases of science**, and to satisfy departmental goals 4-7. Naturally multi-disciplinary, digital design has many sub-topics[17]. COSC330/PHYS306 is a 300-level integrated computer science course that satisfies core requirements in the following majors: ICS/Math, ICS/Physics, ICS/Economics, 3-2 Engineering/Math, and the scientific computing minor. Such a broad course that serves a wide variety of students should touch on at least the following sub-topics:

1. Binary mathematics and non-decimal base systems
2. Boolean algebra and logic
3. Implementing boolean algebra with transistors
4. Digital clock signals and digital component specifications
5. Digital components built from clocks and transistors
6. Complex digital systems (microprocessors, microcontrollers)

Additionally, any good digital design course at a liberal arts college must evenly cover the following phases of the field: *mathematics, computer programming, hardware design and function, and computer modeling.* I attempted to design a course syllabus that incorporated **all phases** of the field.

My first advanced course learning focus is **mental discipline**, and I attempted to reach that goal in three ways. First, the homework assignments were difficult, and assigned in two-week increments, with both mathematical repetition (to facilitate learning to speak with binary and boolean algebra) and open-ended design questions [18]. Second, I chose to combine a traditional lecture component with electronic slides that meshed with my work on the whiteboard, as I've observed with professors of foreign language at Whittier College. Teaching binary to newcomers felt like teaching a new programming or spoken language. Solving problems individually and in pairs helped those struggling during the introduction of Boolean algebra. A language course requires a student *verbally communicate* repeatedly with others to improve grammar and comprehension, so I required my students to practice the same mental discipline. Finally, I assigned design problems in the homework and group projects. The students' project designs had to achieve an agreed-upon task, via a project proposal. Next, they had to be modeled with software, built, tested, and presented to the group. The group projects were designed also as additional oral and written communication practice.

My second advanced course learning focus is **strength in all phases of science**. By design, this course incorporated multiple sub-topics and four phases (as listed above): *mathematics, computer programming, hardware design and function, and computer modeling.* The first month of the course required me to focus on binary math and boolean algebra, finishing with the topic of Karnaugh maps [19]. Unfortunately, although I ordered the digital components for this course over a month in advance, the purchase orders were not followed and we did not received the parts until halfway through the course. This disrupted my curriculum, but the parts are reusable so it cannot happen again. While waiting for components, we focused on simulating the circuits implied by our algebraic derivations with a software package called LogicWorks. LogicWorks gave the students the benefit of seeing how their designs would behave over time, once activated. It also allowed student to locate rare cases for which the algorithm implied by their design would fail. When the hardware arrived, we built everything from super-heterodyne AM transistor radios, to circuits that could add two 8-bit binary numbers. The students enjoyed the tinkering aspect of the course in the lab, but I would have wanted the lab and lecture activities to be more integrated.

[17] See supplemental material for a course syllabus. Although listed as COSC330, this course is also cross-listed as PHYS306, so I felt our departmental goals should apply.
[18] See supplemental material for examples of assignments.
[19] Karnaugh maps are a way of speeding through boolean algebraic derivations efficiently.

Question	COSC330 N	COSC330 Mean	COSC330 Std. dev.
10	8	3.13	1.46
11	8	3.71	1.38
12	8	3.75	1.04
13	8	3.25	1.39
14	8	3.63	1.19
15	8	3.86	0.69
16	8	3.29	1.25

Table 8: Summary of questions 10-16 on the student evaluation form, for COSC330/PHYS306, taught in Spring 2018. These questions pertain to the *course*. N refers to the number of students.

Question	COSC330 N	COSC330 Mean	COSC330 Std. dev.
17	8	3.38	1.60
18	8	3.50	1.20
19	8	3.13	1.46
20	8	4.25	0.71
21	8	3.50	1.41
22	8	4.00	0.89
23	8	4.25	1.16
24	8	4.29	1.25
25	8	2.88	1.36

Table 9: Summary of questions 17-25 on the student evaluation form, for COSC330/PHYS306, taught in Spring 2018. These questions pertain to the *professor*. N refers to the number of students.

My third advanced learning focus is **communication**. I had groups of two and three submit project proposals to me for approval. The project proposal rubric is graded on *attention to detail*, and the students responded with diagrams, sketches, and text explaining their design. Once everyone was on the same page, I required them to simulate the design in LogicWorks, checking it for flaws, and to show me progress. The students used office hours to ask for help "de-bugging" their designs, which is jargon for trouble-shooting. I recall spending a few hours with each group during the semester thinking about their design logic in an attempt to locate algorithm flaws. In these moments I admired the growth in the students' mathematical communication. The final presentations were good, and would have been excellent had I provided more specific guide-rails for the presentation content. What we experienced was two main presentation components: the demonstration and the explanation with data. In the future, I will formalize the requirement of both, and provide a structured schedule for the components of the assignment.

0.3.1 Analysis of Student Evaluations

Tables 8 and 9 show the results of my advanced computer science and physics course. For the lower scores, the fractional error is about 50%, whereas the higher scores have fractional error of about 20%, similar to the introductory courses (see Appendix). The numbers inform the analysis of my teaching of COSC330, and the students' remarks in the evaluations provide more detail.

Some students remarked that the course did not seem adequately structured or prepared. This was in large part caused by the disruption of not having the equipment I needed. Although I did order the textbooks and digital components long before the first day of class, the company shipping the parts refused to accept our department cheque, wanting a credit card. I had chosen a standard electronics textbook and lab companion book written by professors at MIT [10] which assumed we would have the parts. Upon hearing that the parts would be delayed, I was forced to revert to an alternative textbook a colleague provided me [11]. This text was excellent for demonstrations of binary math and boolean algebra, but was lighter on hardware. The students were unhappy that the textbooks they bought would not be used until later in the course.

We now have the reusable digital components stored in the physics labs, so we will be able to integrate the lab and lecture activities and use free instructor desk copies of the MIT text I obtained. Also, this will allow me to do what I originally planned, which was to organize the course by *sub-topic* rather than simply doing all the mathematics first. This should raise the students' assessment of categories like course preparation and effective use of class time. Further, pre-assembly of some of the digital circuits will facilitate learning by freeing up time to probe how the circuit projects work (taking it apart and reassembling, for example).

Having experienced once how long it takes students to assemble circuits, I can better plan future class times. Students remarked that the super heterodyne AM radio took too long to assemble, for example. In the future, those projects could be partially assembled by me in advance. Some students also wrote that they didn't understand how the transistor radio was related to digital circuits. I included the transistor radio so the students could get a hands-on experience working with transistors, which form the basis for other all other digital components. In the next iteration of the course, partial pre-assembly should leave more time to probe how the circuit works using transistors, rather than spending more time just building the project.

Some students remarked that they felt under-prepared for the course material. I did notice that I had two Whittier Scholar Program majors (F. Capraro, and A. Dodds), and while one felt the course was easy and appeared comfortable with the material, the other did not. Nevertheless, I was pleased to have those students and would like to encourage WSP enrollment in the future. To entice the curiosity of the WSP majors, I included some cross-disciplinary examples during the Boolean algebra phase of the course. Nevertheless, the pace will have to be relaxed if I am to continue to accomodate WSP majors in this type of course. Some 3-2 engineering and mathematics majors felt that they did not remember the physics related to sub-topics like resistors and capacitors well enough to relate those concepts to transistors. I had a tough decision regarding the course prerequisites, which are normally introductory-level physics and computer science courses. My department and I felt that in the course's inaugural year that I should waive the prerequisites on a case-by-case basis in order to gain more students. I promoted COSC330 in PHYS150 and PHYS180, and students who felt they could handle it approached me. It turned out to be the mathematics seniors who did not remember the physics and struggled with circuit-based topics, which is taught in PHYS180 (a course they might not have taken). In the future, I plan to review circuit analysis in more detail, before adding digital elements.

0.4 New Course Offerings

Here I propose future courses that will serve the broader liberal arts goals of Whittier College. I have already submitted two proposals for two CON2-style courses which linked aspects of physics and my sub-field of *astroparticle* physics with broader cultural and scientific issues. The first was entitled *Physics of the Five Senses* (see below). The second was a entitled *Safe Return Doubtful: History and Current Status of Modern Science in Antarctica*, which incorporated elements of my sub-field of research with elements of history of science and exploration, environmental science, and climate change. The latter course would be a longer-term project, whereas the former would require a simple remix of content I already teach. I have already offered 9.0 credits of COM1 in my first year, because both *calculus-based* introductory courses, PHYS150 and PHYS180, count as COM1. While this is a start, I plan to do more to help further the liberal arts goals of the College, and the courses below are one set of ideas to meet those goals.

Digital Signal Processing (COSC390) - This special topics in computer science and mathematics is meant to serve 3-2 engineering students, math/computer science majors, and physics/computer science majors, while remaining open to all students interested in interacting with digital data. The applications will include audio and image processing, and "analytics" or Big Data analysis, This course is a brand new course, to be taught for the first time this coming January term, 2019. There are several advantages to this course that add value for Whittier science and engineering students. First, this course is a natural continuation of my COSC330/PHYS306, and students taking both should be able to grasp the entire digital-data ecosystem from transistors to data processing. Second, the course will focus on managing large data sets (Big Data), which prepares students for "analytics" applications. These skills are relevant to a broad range of science courses. Finally, the coding language (octave)[20] and textbook [12] for this course will be open source, and therefore free.

[20] See `https://www.gnu.org/software/octave`.

The History of Science in Latin America - This is a history of science course that I believe would be widely subscribed for several reasons. Given that a) the ethnic composition of Southern California is changing, and b) Latinos are historically under-represented in physics, it might be helpful for all of our students to become familiar with the scientific achievements of pre-Columbian peoples. I do see this as part of the broader effor by the college to be more diligent in the areas of equity and inclusion, but the main focus would be on the history of science. [21] I would center the course on two ideas. First is the idea that those people who make scientific progress have the most accurate data, regardless of where they are on the globe. For example, civilizations in Latin America saw different celestial objects than those in Europe, and likely had more knowledge of them before European astronomers explored the Southern Hemisphere. Another example are pre-Columbian Latin American calendars. These were based on astronomical data, and worked within certain limitations, just as European calendars.

The second idea would be that language matters in science. I am curious what words pre-Columbian peoples used to desribe certain physics effects, and how they later translated them into Spanish. As a start, I decided to take introductory Spanish courses with Prof. Doreen O'Conner-Gómez, who was kind enough to let me audit one of her courses. I would like to eventually cover original documents from Spanish colonials who had the first glimpse of the scientific knowledge of the indigenous people. My hypothesis is that indigenous peoples had significant knowledge of physics and astronomy, but that it didn't translate simply into the contemporary European framework. By understanding both the original Spanish writings, and physical and astronomical effects, I would attempt to show that there was some common understanding of the natural world. This course would probably become a CON2-type course, but I would be open to pairing it as a CON1 if another professor is willing.

Physics of the Five Senses - This is a course I proposed as a liberal education breadth course, which would expose non-STEM majors to the physics and kinesiology of the human senses. Many kinesiology majors take my introductory physics courses to fulfill graduation requirements, and often express an interest in physiological measurements[22]. Why not base an entire course around making physiological measurements, and open it to non-STEM majors who could take it alongside STEM majors? The course would be fun, and activity-based, centering on KNS and physics labs meant to establish that our five senses are not that different from other sensors based on electrical signals, optics, and thermodynamics.

[21] Math professors have already suggested the decoding of the Mayan language, and the accuracy of the Mayan calendar as example topics.

[22] See supplemental material for a final project example on muscle activation

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