Professional Evaluation and Growth Plan

Jordan C Hanson, PhD

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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. I have strived to make adjustments to my classroom practices, and to follow recommendations given to me by my department and FPC. Looking back at my first submitted teaching philosophy, I view it as a good beginning, but something that should evolve to serve the students. In the feedback letter provided by FPC, and in the letter from my department, three general recommendations have emerged.

First, the *pace* of my content should be slowed, in order to maximize student success. Second, I must increase the number of *step-by-step example problems* in my classes, in order to give new and struggling students something concrete to grasp before moving forward. Third, I need to include more *traditional lecture content* in my integrated lecture/laboratory formatted classes. Traditional content is a term used in physics education research (PER) to refer to the classical teaching style in which a new equation is first introduced or derived on the board, then solved in examples and displayed in graphical form. I have strived diligently to put these changes in place, and I have shown promising results in my classes as evidenced by my increased student evaluation numbers (see Secs. 0.2.1 and 0.3.1).

Introductory physics courses at Whittier are taught in an integrated lecture/laboratory format. I describe the format in Sec. 0.1. I learned in my first two years that although our department recommends this format, it does not *preclude* using traditional content. In fact, what works best (we have found) is a healthy mixture. I observe this mixture in the classes of my colleagues. We must begin new concepts traditionally, and then branch into laboratory activities and research-based content when the students are ready. *Researched-based content* is a term in PER that refers to teaching modules that have been shown to boost student learning through controlled research. 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 Sec. 0.1 on these modules' utility.

Teaching physics is about growth. Regardless of the methods chosen, the student should leave class with an improved understanding of physics concepts. Success is measured by the varying degree to which the student can retain, understand, and apply the concepts. The goal of the professor is to formulate the concepts of physics into specific equations, testable by experimentation, and to cause the students to master the equations through problem-solving. The student usually encounters failure, then the ability to solve specific examples. Finally, the professor leads the students to mastery by showing them that the concepts may be applied *in general* to broad classes of problems. Each stage must be accompanied by careful laboratory experiments to validate the equations.

All physics subjects begin by defining a "system," with measurable properties, like displacement, velocity, acceleration, mass, and charge. What follows is the subject of *classical physics*: a description of the motions, forces and energies that govern all systems. With the addition of temperature and heat, *thermodynamics* may be added to classical physics. Students who do not major in physics usually encounter only classical physics. Physics *majors* progress to *modern physics*, which adds the subjects of relativity and quantum mechanics to the toolkit. We often distinguish between *physics majors* and *non-majors*, who encounter different types of material. The bulk of PER is done in the context of serving non-majors, and thus the named modules (PI, JITT, and PhET) are usually applied to introductory courses.

Analogous to learning physics, learning to become a great physics instructor involves learning to impart basic 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 used to solve problems. Upon examining my teaching, 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 increasing the proportion of traditional lecture content.

I have made positive strides in my advanced courses as well as my introductory courses. It was rewarding to see warm reviews for my brand new Digital Signal Processing (COSC390) course. Almost every student in that course wrote in their evaluations that the course should be made into a full-semester length course because they liked it so much. I have submitted a course proposal and this course will now be regularly offered. I am also pleased to see the course changes pay off at the introductory level in PHYS135A/B and PHYS180. Non-majors regularly report that they **do not want to take** the algebra-based physics courses (see Sec. 0.2.1), so to hear the students report that these courses increased their interest in physics was worth the hard work I invested, and a great joy.

Instruction of Students in Introductory Courses

Physics students at Whittier College are 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 using tools from algebra and trigonometry. Thus, *non-major* students usually take PHYS135A/B, and *physics majors* and related majors take PHYS150/180.

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

1. **Curiosity**. Good teaching for non-majors should *entice curiosity*, which begins by having an encounter with students where they are in their knowledge, and asking them to think more quantitatively. 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 instructor. I have continued this practice as a Whittier professor. 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. I continue this practice this year a Family Science Night at Granada Middle School in Spring 2020. Within this teaching focus, I have three measurable goals:

    - Measurably increase student interest in physics as measured by questions 15 and 18 on the evaluations
    - Teach the students to satisfy curiosity through self-designed experiments and pre-designed lab activities
    - Coach the public speaking skills of the students to empower them to present results to peers

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 PER modules in introductory courses to train students, while providing a healthy mixture of traditional lecture content and step-by-step examples. This involves calculations as simple as converting between units (i.e. kilograms to pounds) to plotting the trajectory of a particle in a vector field. Within this teaching focus, I seek to achieve two specific goals:

    - Measurably increase the ability of the students to obtain the correct answer in word problems (questions 12, 14, 19, and 20 on the evalutations)
    - Teach the students to measure with precision the correct result in laboratory settings

3. **Applications to Society**. Whittier College students advance in their technical careers if they can qualitatively explain phenomenon using physics. In recent years, our open-source textbooks [4] [5] have included material relevant to medicine and kinesiology. I have incorporated special units centered on these applications, including human muscle motion (in PHYS135A) and nerve systems (in PHYS135B and PHYS180). I also help the students design experiments which can relate to their field. One example included KNS majors in 135B who measured bicep muscle voltages for varying amounts of lifted weight. Another tool within this learning focus is the inclusion of student-led summaries of scientific articles, which encourage class discussions about the broader implications for society. Within this teaching focus, I seek to achieve two measurable goals:

    - Empower the students to present and discuss articles they find relevant or interesting due to the societal impact (see Supplemental Material)
    - Manage and aid in student-designed experiments that are presented to the class, relevant to society (see Supplemental Material)

Instruction of Students in Advanced Courses

Physics majors are the second category of students we encounter, and I broaden the category to computer science because I also teach advanced COSC courses. 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]. The syllabi for these courses are included in the Supplemental Material.

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 mental discipline. The professor must foster this value in the students in two ways. First, the students need a professional curriculum that requires them to think *analytically* and *creatively*. Second, the professor should demonstrate *expertise* and the ability to lead students by example. For example, in COSC390 (Digital Signal Processing) I wrote example code in MATLAB to demonstrate concepts from class, and the students downloaded and modified it to suit their purposes for individual projects. I summarize mental discipline into two goals:

    - Challenge the students with course content that requires both analytic and creative thinking (questions 11 and 20 from the evaluation)
    - Provide the students with technical expertise and guidance (questions 12 and 19 from the evaluation)

2. **Strength in all Phases of Science**. Advanced course curriculum in physics, math, and computer science must include the following *phases* of scientific activity: abstract problem solving, numerical modeling/prediction, experimental design and execution, and data analysis. I therefore have four specific goals in this area, corresponding to the four areas:

    - Measurably strengthen the abstract problem solving of the students (question 14 from evaluation)
    - Expose students to numerical modeling with computer code
    - Assist the students with the design and execution of technical projects

- Strengthen the data analysis abilities of the students

3. **Communication**. A critical skill in technical fields is 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 peers. Clear communication in engineering and scientific research contexts prevents design flaws and misconceptions. I require the students to submit a longer paper and/or presentation in each advanced course, with the goal of improvement of their technical communication. To this end, I set two goals:
    - Require the students to submit at least one major written or oral assignment
    - Provide students the opportunity to refine the work in office hours before submission

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.

0.2 Introductory Course Descriptions

Algebra-based physics (135A/B). Algebra-based physics, PHYS135A/B, is a two-semester integrated lecture/laboratory sequence covering Newton's Laws to electromagnetism[1]. PHYS135 is a requirement for majors such as KNS and CHEM. Students practice problem-solving with algebra, trigonometry, and vectors. I employ a mixture of traditional and PER methods to satisfy **departmental goals 1, 4, and 6**. The PER methods are *Peer Instruction (PI)* and *Physics Education Technology (PhET)*. I no longer use JITT modules (see Sec. 0.2.1). I have modified them in alignment with department and FPC recommendations. My total teaching credits and number of students for this course is listed in Tab. 1.

The first learning focus for non-majors is **curiosity**, with the measureable goals stated in Sec. 0.1. To satisfy the goal of increasing physics interest, students may present at the outset of class a recent science journal article pertaining to physics. I incentivise the students to present with extra credit, and I help them to practice oral communication of scientific ideas (**Departmental goal 7**)[2]. Once the students overcome nerves and try speaking in front of peers, I find that they begin to choose content that connects to their major. It is fulfilling to see the students shine as they teach their peers.

[1] See supplemental material for example syllabi.
[2] Examples of such articles presented by students are included in the supplemental materials.

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
Fall 2019	PHYS135A-01	4.0	24	Intro
Fall 2019	PHYS150-02/03	4.0	26	Intro/COM1
Fall 2019	INTD255	3.0	23	CON2
–	Total	50.0	–	–

Table 1: This table is a summary of my courses since Fall 2017. The introductory courses are 135A, 135B, 150, and 180. The first advanced course PHYS306 is cross-listed as COSC330. The second advanced course, COSC390, is now listed as an official computer science course and counts towards the ICS major, as does COSC330. I am currently teaching my first CON2 style course, INTD255 (see Sec. xx for details). Not included are my PHYS396 (physics research) courses. This course helps to satisfy **departmental goals 2, 7, and 8.**

A second method I use to increase student curiosity is to require the students to design a physics experiment in small groups. The OpenStax textbooks contain many workable examples they can build. Each group must first submit a proposal in the middle of the semester. I then help them refine it and ensure they have proper equipment. After data collection, I invite them to office hours to coach them on the presentation[3]. Allowing the students to choose the topic and design is meant to give them an avenue for their curiosity. Making this assignment an oral presentation also goes toward **Departmental goal 7**. The data in Sec. 0.2.1 show that the students *are reporting an increase in their curiosity for physics*, and this trend is increasing over time.

The second introductory focus is **improvement of analysis skill**. I use PI modules and PheT simulations strategically. PI (Peer Instruction) modules were first developed by Eric Mazur [1], and have better measured performance than traditional content. 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 modules are my main PER tools for boosting student problem-solving. Following department and FPC recommendations, I have balanced the use of these modules with the inclusion of more traditional content. Finally, I have cut JITT modules [2] in favor of more example problems. The students related that they did not gain much from JITT, but expressed a desire for more step-by-step examples instead.

To structure class, I prepare my whiteboard in the pattern shown in Fig. 1. After explaining the agenda and homework, class begins with a reading assessment or the bonus article disussion mentioned above. This is followed by warm-up examples from the memory bank (see Fig. 1). Next, I introduce new concepts on the projector screen, followed by several examples in traditional form on the whiteboard. Third, I engage the students with a PI module pertaining to the concept just presented in traditional form. PI modules begin with an exercise on the screen, with A-D multiple choice. Our classrooms have a system that records student answers anonymously, and the students first answer individually. I display the answer distribution (see Fig. 2 below), and if fewer than 70% of the class answers correctly I initiate **table discussions** (see Sec. 0.2).

PER shows that students learn efficiently from peers explaining their reasoning. Table discussions encourage this type of learning and give me the chance to find the struggling students. Spending time with struggling students helps me build a relationship of trust, and relaxes their anxieties. After short table discussions, students submit their answers again. We observe the answer distribution shift toward the correct one (see Fig. 2). Further, if 70% of students answer correctly, we move forward. Thus, we accelerate the pace if the students understand. This

[3]Included in the supplemental materials are examples of the students' final presentations.

Agenda
0) Reading assessment
1) Review vectors
a) (x,y) notation to magnitude and angle
b) magnitude and angle to (x,y) notation
2) Displacement and average velocity
3) Motion sensor activity

Memory

$$\vec{v}=v_x\hat{i}+v_y\hat{j}$$
$$|\vec{v}|=\sqrt{v_x^2+v_y^2}$$
$$v_x=|\vec{v}|\cos(\theta)$$
$$v_y=|\vec{v}|\sin(\theta)$$
$$\theta=\tan^{-1}\left(\frac{v_y}{v_x}\right)$$

Homework
Reading: ch. 2.1-2.4
(by next class)

Homework1
(ExpertTA) - Sept. 16

Figure 1: (Left) The class agenda presented on the white board is always concise and based on student progress. It is presented to the students before each class period. (Middle) The memory bank is a list of equations on the whiteboard used during class, and is a practice that I began using in 2017. (Right) The homework box on the whiteboard now includes specific reading assignments, in addition to placing them on the syllabus. This practice follows the suggestion of a student from a 2018 section of algebra-based physics (135A).

creates the possibility of a few students being left behind, so I have added the concept of WAT[4]. WAT corresponds to answer E. If I observe a WAT, I provide additional example work. *This strategy ensures inclusivity*, in that we strive to leave no one behind in class.

The second-half of the lecture/laboratory format moves on to the lab activity or PheT module. An example of the interplay between labs and PhET occurs in PHYS135B and PHYS180 (electromagnetism). As part of these courses, we build DC electric circuits. If the circuit is constructable in our lab, we perform a traditional experiment to measure voltages and electric current to verify Ohm's Law[5]. 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 simulation and experiment. 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 the student evaluation questions pertaining to this learning focus.*

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. After reflecting on recent semesters, I have noticed that learning what interests the students and including content specifically pertaining to their majors is highly beneficial to keep them engaged. Dropping the JITT module also frees more class-preparation time to add material I know particular students will enjoy[6].

Two final methods for my third learning focus are the article discussions and term-papers. An example of the former occured during the past year when an environmental science major in PHYS135A/B regularly tied physics to climate change by presenting geophysics articles. These presentations empower the students to choose topics they know to have an impact on our community. Occasionally I suggest high-impact articles and offer extra credit, and these prompts encourage shy students to prepare one. I also offer extra-credit for 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 measurement of the distance to the Sun[7]. The students use course concepts to understand scientific breakthroughs, and it provides them a venue to practice technical writing (**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[8]. The format of these courses is similar to algebra-based physics, mixing PER and traditional content **departmental goals 1, 4, and 6**. I employ PI modules [1] and PhET modules [3]. In addition, these

[4] e.g. "What?" A meme indicating confusion.
[5] Ohm's law states that the current observed is proportional to the voltage in the circuit.
[6] See supplemental material for an example of such a unit.
[7] Included in the supplemental material.
[8] See supplemental material for example syllabi.

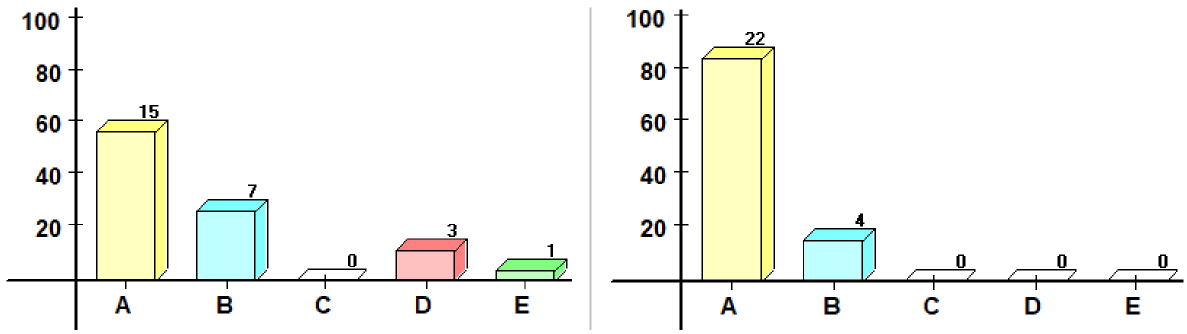

Figure 2: (Left) An answer distribution of my 25-student PHYS135A class (A was correct). This distribution triggered a table discussion. One student pressed E (indicating confusion) and I took appropriate action. (Right) After table discussions, the students responded and the fraction of correct answers was 22/25 = 0.88.

courses require tools from calculus[9]. Students new to calculus benefit from PhET, which help visualize calculus concepts[10]. My total teaching credits and number of students for this course is listed in Tab. 1.

My PHYS150/180 classes are taught in the same fashion as PHYS135A/B, but include the calculus intrinsic to introductory physics. Calculus and Newton's Laws were developed concurrently, often by the same people, making them interconnected. I occasionally pose a calculus problem during the warm-up or reading assessment phase of class, because I need to familiarize the students with a technique that helps solve physics problems in the current chapter. Occasionally the physics requires concepts that the students will first encounter in Calculus III, or MATH241 (which covers electromagnetic fields). I gauge the comfort level of the students, and typically restrict my calculus content to traditional examples or an occasional PI module. *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 helped, 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 PI and PheT modules are outlined below for more detail and clarity, since it is likely that they are familiar mostly to physics instructors.

<u>PI Modules</u> - An active learning strategy involving group problem solving and discussion [1] [8] [9]. Figure 2 contains data relevant to the following example.

- PI-based modules contain multiple-choice questions about a physical system. Suppose we ask the students the following question:

  If the slope on a graph of $x(t)$ vs. t is positive before t_0, zero at t_0, and negative after t_0,

  A) the acceleration of the object was negative before and after t_0.
  B) the acceleration of the object was positive before t_0, then negative.
  C) the acceleration of the object was positive before and after t_0.
  D) the object had no acceleration.

- Each student responds *anonymously* with a device, and their answers appear on-screen (see Fig. 2).

- Students know to press E if they are confused. As described in the text, this maintains inclusivity in class.

[9]MATH141/142 may be taken concurrently.
[10]This is especially important in PHYS180 when PhET helps to visualize electromagnetic fields, a concept from MATH241.

- One of two actions is taken next:
  1. If the fraction of correct answers is > 0.7, we proceed to the next exercise or new material[11].
  2. If the fraction is < 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 and helping the struggling students. After 3-5 minutes, the discussion ends.
- A second poll of the class is taken after table discussions. The *shift* in the distribution towards the correct answer indicates improved understanding. The professor takes appropriate action if there is not a shift. If there are WATs (answer E), the material is re-addressed.
- The procedure is repeated for several exercises, and table discussions take place when necessary. After several exercises, the class proceeds to new material. See Fig. 2 for example PI data.

PhET Modules - These are interactive simulation tools published by The University of Colorado, Boulder [3]. They are based on proven PER and written such that any student can operate them.

- The OpenStax textbooks for our courses have built-in links to PhET tools, allowing students to illustrate concepts by visually.
- Several HTML5-based examples are here:
  1. Electric charge and electric field: `https://phet.colorado.edu/en/simulation/charges-and-fields`
  2. DC circuits: `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 tool re-creates a laboratory measurement, it is useful and informative to first simulate the expected results.
  2. PhET tools are used when an experiment cannot be constructed in the lab, such as altering gravity or changing the friction between surfaces. Students benefit by being able to fine-tune a system in order to understand it.
  3. PhET tools are used to *visualize* systems which are invisible. 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 useful PhET tools from biology, chemistry, and medicine earth science that to engage the curiosity of students.

0.2.1 Analysis of Student Evaluations, Introductory Courses

I have reflected on student evaluations from the 2018-2019 introductory courses. I have implemented recommendations from my department and FPC, and the results appear to be positive. I have gained insight from interactions with the students and from their written responses. I also include reflection focused on qualitative evidence from class that explain my efforts to meet the specific goals within the learning focuses defined in Sec. 0.1. I also reflect on areas in which I hope to improve.

0.2.2 Analysis of Algebra-Based Physics Student Evaluations

The data from 2018-2019 for the *algebra-based* courses demonstrates significant teaching improvement. Tables 2 and 3 contain data from PHYS135A/B for 2018-2019. In Tab. 4, the most *recent* PHYS135 data and the *first* PHYS135 course I taught are compared. Professor Zorba was on sabbatical in Fall 2018, so I taught both sections of PHYS135A and Professor Lagan taught both sections of PHYS150. The mean values and errors in the mean are shown for questions 10-25 on student evaluation. Questions 10-16 pertain to the course (Tab. 2), and questions 17-25 pertain to the professor (Tab. 3). A large majority of the results are statistically consistent with 4.5 out of 5.0. I reflect on the exceptions below.

[11] The number 0.7 was the recommended fraction at the AAPT conference I attended in 2017.

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*.

The data in Tab. 2 regarding questions 15-16 merits further discussion[12]. One huge challenge in teaching PHYS135A/B is that students are *required* to take them, but they do not *want* to take them. Students arrive with varying degrees of math skill, and **responded to Question 9**[13] with an average of 3.13 ± 0.24, 3.92 ± 0.22, and 3.83 ± 0.26. These responses reflect student anxiety when *forced* to do physics. I have strived to address these concerns by including modules which show the students exactly how 135A/B relates to *their major.* Figure 3 contains the data for these questions over time.

Approximately 40% of PHYS135A/B students are KNS majors, and another 30% are biology majors. I have created modules focused on medical applications, and the article discussions also tie in content from their major. The results for questions 15-16 are shown in Figure 3. **The mean values over time show an unmistakable and significant improvement**. Further, the data in Tab. 4 show that *every student evaluation measurement has increased*, with the exception of the question pertaining to course difficulty, Question 11[14]. This was partially by design, because the recommendations were to slow the pace. However, the decrease is not statistically significant.

In following FPC and department recommendations, I have made three modifications to 135. First, the pace has been decreased. Second, I have included more step-by-step examples. Third, I have included more traditional lecture content. This was achieved without a decrease in difficulty: the most recent value for Question 11 was still 4.46 ± 0.159. When I introduced these changes, some students expressed such relief that they told me in office hours. One student joked that "You could be an online professor for Chegg.com!" He was complimenting my style by referencing an online resource where instructors demonstrate solutions to homework problems.

[12]Question 15: "This course increased my interest in the subject matter." Question 16: "Overall, I would recommend this course to others."
[13]"I had a strong desire to take this course."
[14]"This course was academically challenging."

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 4: 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.

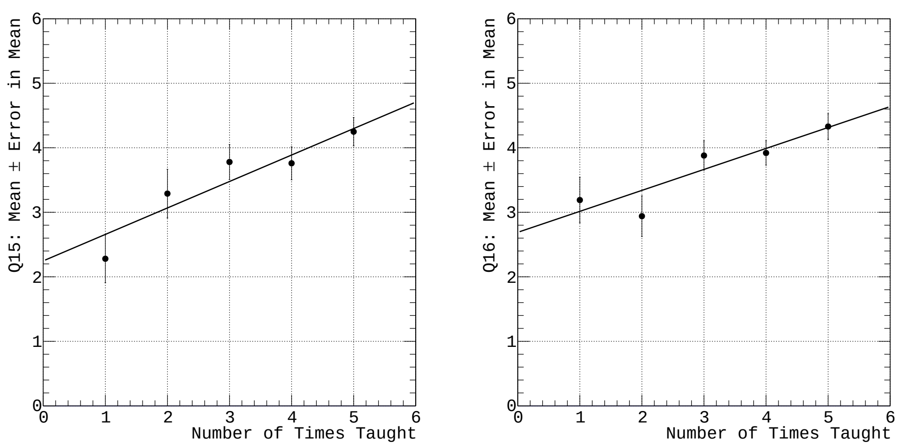

Figure 3: (Left) Responses to Question 15 in algebra-based physics versus number of times taught. (Right) Responses to Question 16 in algebra-based physics versus number of times taught. The y-axis of the data points are the mean values, and the errors are the error in the mean. The solid black lines are best-fit linear trend lines that minimize the χ^2 value.

I have learned recently that this structure is especially helpful to foster **inclusive classrooms** [10]. Figure 3 demonstrates measurable improvement for the first introductory course learning focus (curiosity) by *measurably increasing the interest of the students in physics.* The simple classroom pattern of 1) traditional content introducing concept 2) slow step-by-step example 3) PI module 4) laboratory activity/PhET seems to stimulate engagement and interest in the material. Examples of student-designed experiments and presentations are included in the Supplemental Material, which also serve the first learning goal.

Three additional improvements came from Ch. 4 of Eric Mazur's work on PI modules [11]. I simplified the *agenda* created just before class, ensuring it contains only 4-5 items. I present the agenda to the students before lecture. First, I base the agenda on the students' progress, thereby helping to find the correct pace. Second, the simple agenda also helps to create structure and primes students for class. As part of the agenda, I provide a list of equations used that day in the *memory bank.* Third, I remind them of current homework and reading to complete before the next class, thereby keeping them organized. I now follow a 2018 student suggestion that I break the reading into smaller sections. This prompts the students to focus on the 10-20 pages relevant for the next class. An example agenda is shown in Fig. 1 in Sec. 0.2.

Two additional comments are relevant regarding course pace. First, the number of textbook chapters covered in PHYS135 was not reduced. By attending the classes taught by Profs. Zorba and Lagan, I obtained a better sense of *how much* content within each chapter is covered. Drs. Zorba and Lagan have been very helpful in demonstrating how to best set the course pace. Professor Piner has also attended lectures in my recent classes and offered useful feedback. Second, we removed the topics of physical oscillations from PHYS150 and thermodynamics from PHYS180. In the past, PHYS180 was a 5.0 credit course. We have created a new course, PHYS185, which now contains thermodynamics, oscillations, and optics. The number of chapters for PHYS180 is now reduced by 30%. Thus, my department and I are working together to establish proper course pace.

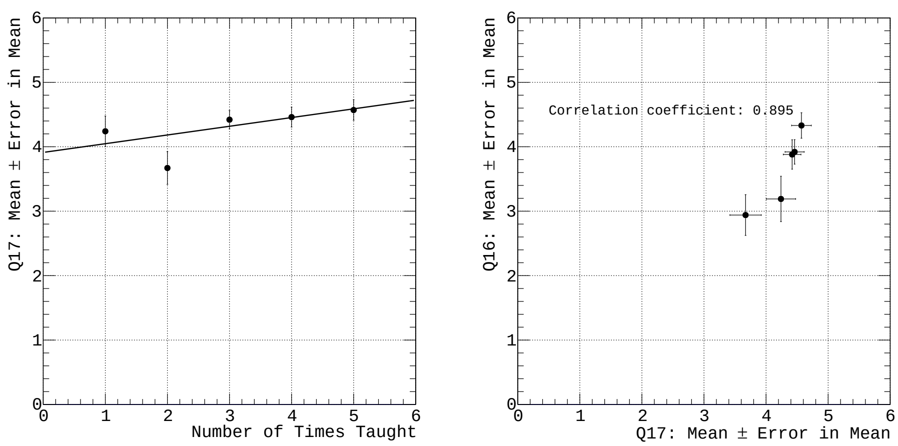

Figure 4: (Left) Student responses (mean values and errors in the mean) to Question 17 in algebra-based physics versus number of times taught. (Right) Student responses to Question 16 in algebra-based physics versus responses to Question 17. The x and y-axis values of the data points are the mean values, and the errors are the errors in the mean.

My department also recommended I focus on Question 17[15]. Question 17 results are shown in Fig. 4. My department a correlation with Question 17 with other key numbers like Question 16. Figure 4 (right) shows that they are correlated. PER modules called JITT modules I used in Spring 2018 contributed to the lower Question 17 numbers (x-value of 2 in Fig. 4, left, and x-value of 2 in Fig. 5). JITT involves analyzing student responses to questions assigned before class, and modifying course content accordingly. However, it was common for students to not respond rather than risk being wrong. I reassured them that their responses are useful and that they were not being graded, but the response rates hovered around 50-60%. It was therefore difficult to modify content, and the students expressed strong preference for more example problems. I have since dropped the JITT module.

[15] "The professor used class time effectively and demonstrated preparation for class".

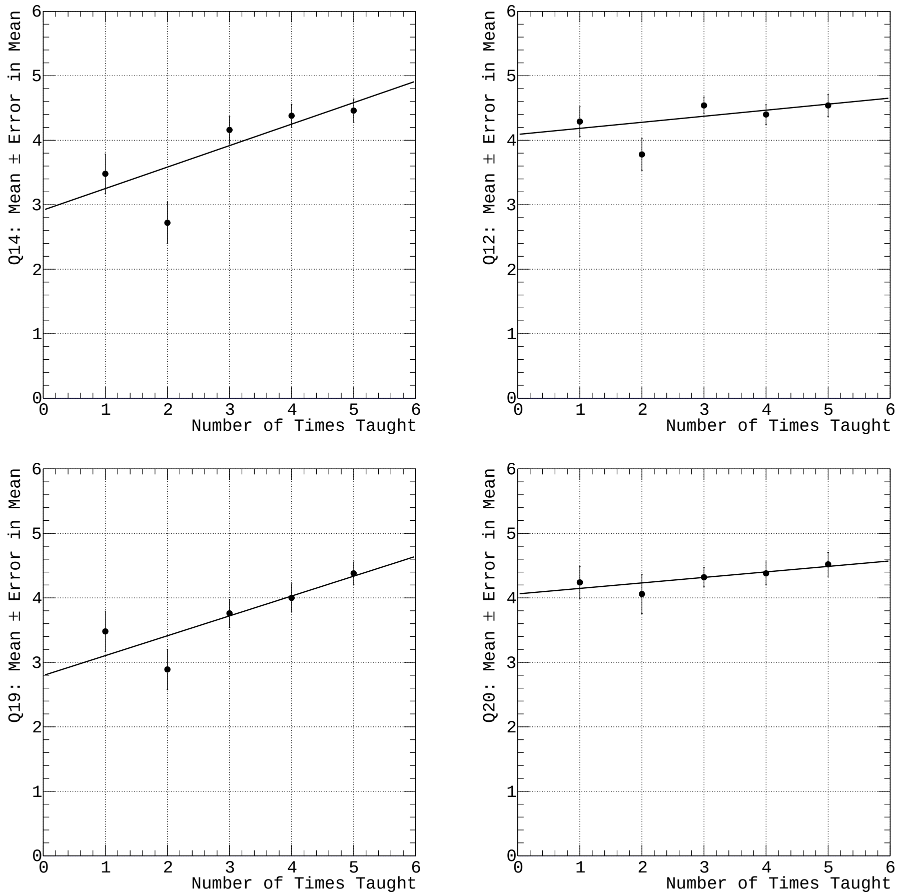

Figure 5: (Top left) Student responses (mean values and errors in the mean) to question 14 in algebra-based physics versus number of times taught. (Top right) Question 12. (Bottom left) Question 19. (Bottom right) Question 20. The solid black lines are best-fit linear trend lines that minimize the χ^2 value.

The second focus for introductory physics courses is to *improve the analysis skill* of the students. Our strategy appears to be working. Figure 5 contains student response data to questions 12, 14, 19, and 20[16]. The data corresponding to the second time I taught PHYS135 ($x = 2$) corresponds to the section with JITT modules, and the data falls below the trend. I removed JITT and implemented the department and FPC-recommended changes. **The student response data shows that their understanding of the material is improving substantially.** One further technique I added in Fall 2019 is to give the students short, conceptual reading quizzes at the beginning of each class-period. These ensure that the students are both primed for class and studying examples in the text.

The third focus is *applications to society*, with measurable goals of requiring the students to present articles they find relevant due to societal impact and to manage and aid in student-designed experiments presented in class. I have included examples of my students' wonderful work in this area in the Supplemental Material. Student groups have correctly predicted rocket flight times, measured the speed of sound, and extracted DC current and voltage. The articles the students chose were often thought-provoking, and related to their major. My questions during their discussions steer them back to the physics involved, and the class therefore learns about the utility of physics in situations beyond the classroom. Perhaps my favorite article example was an inspiring case study in which a University of Texas undergraduate used machine learning to help find extra-solar planets.

[16]Q14: "This course improved my understanding of the material." Q12: "This course offered useful learning tools (such as lectures, discussions, readings, assignments and/or examinations)." Q19: "The professor was able to explain complicated ideas." Q20: "The professor challenged students to think critically and/or imaginatively about the course material."

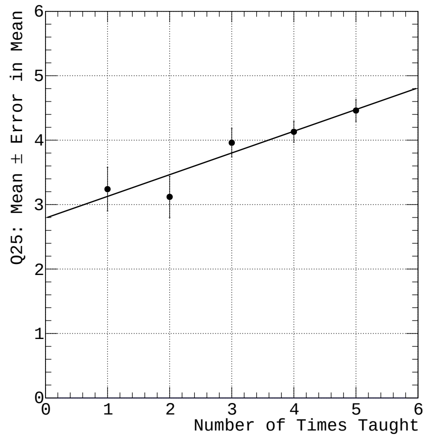

Figure 6: Student responses (mean values and errors in the mean) to Question 25 in algebra-based physics versus number of times taught. The solid black lines are best-fit linear trend lines that minimize the χ^2 value.

Finally, I am thrilled to report an increase in student responses to Question 25[17]. **Figure 6 contains Question 25 mean values over time, and the data show an unmistakable and significant improvement.** It turns out there has been similar improvement in the calculus-based versions of the introductory physics courses I teach. By thoughtfully implementing the changes recommended to me by my department and FPC, I see in the data that the students are endorsing me as their professor at increasing mean values over time. I have found upon reflecting on algebra-based physics methods, that the final piece of the puzzle was to *build relationships* with the students. What follows are anecdotal stories from class that illustrate what I was able to accomplish by building relationships with students who needed help with a difficult subject.

My first story involves a senior KNS major. She approached me with a question during a midterm. The exercise required the students to write an equation and solve for x. It appeared that she was on the right track, and I asked her to think conceptually about which equation is appropriate. Eventually she chose the correct one. I assumed she'd be able to finish, given that the problem was now reduced to solving for x. I will never forget her next words: "How do I move x to get it by itself, without plugging in numbers?" I was completely shocked: she was *unfamiliar with the concept of algebra.* Of course I did not blame her, but the question in my mind was: "Who allowed this to happen?" Knowing that this was a college senior, I resolved to get the job done. I made it my mission to ensure that she passed my class. Her midterm grades improved, and by the end of the course we were both pleased. I devoted more time for her during PI discussions, and it appears to have worked.

My second story involves a senior WSP major who was my student in PHYS135A/B. She is an example of an excellent student who intends to apply to medical school. As part of the new pace control I would include more group discussion time in PI modules, and I would focus my attention on tables of students I knew were struggling. The student and her friends formed a table that almost never struggled. I worried that my new tactics would leave students like these feeling ignored. However, by the end of the course, she told me they had a wonderful experience! Apparently I was able to balance my focus enough such that no one student felt left out. She gave me a thank you card at the end of the year along with a gift card, and I was touched.

My third story involves a senior Biology major. I identified him as someone struggling with the material during my PI discussion rounds during PHYS135A and PHYS135B (2018-2019). During our PI discussion rounds, I got the sense that he was close to get the right answers but was just short of making the vital connections necessary for word-problem solving. I made a concerted effort to spend more time at his table, and worked quick examples for their table during discussion time. Not only did it benefit him but it benefit the three other students because I later observed him teaching them! After the final exam he wrote me this note:

Thank you for a fun year! Physics is hard, but I definitely learned more than I thought I would.

[17] "Overall, I would recommend this professor to others."

0.2.3 Analysis of Calculus-Based Introductory Physics Student Evaluations

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

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: (Left) 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*. (Right) 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	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 6: 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.

As with the algebra-based courses, the data from the 2018-2019 academic year for the *calculus-based* courses demonstrates significant improvement in my teaching. Table 5 contains evaluation data from PHYS180 for 2019. In Tab. 6 the student evaluation data from the *first* time I taught calculus-based physics is compared to the most *recent* time. The mean values and errors in the mean are shown for evaluation questions 10-25 for both tables. Questions 10-16 pertain to the course (Tab. 5, left), and questions 17-25 pertain to the professor (Tab. 5, right). The data reflect high quality teaching and a substantial improvement compared to the first time I taught calculus-based physics.

The PHYS180 section from which the data in Tab. 5 is derived shows almost perfect scores. This is partly a credit to the changes I've put in place, and the reflecting I have done this past year. However, it is also due to two other factors. First, the aforementioned rearrangement of the thermodynamics curriculum made our lives easier in PHYS180. Second, I had the chance to get acquainted with these students as advisees in the prior Fall 2018 semester before teaching them in Spring 2019. Thus, reducing the pace of content and building relationships before class also made the course go much more smoothly.

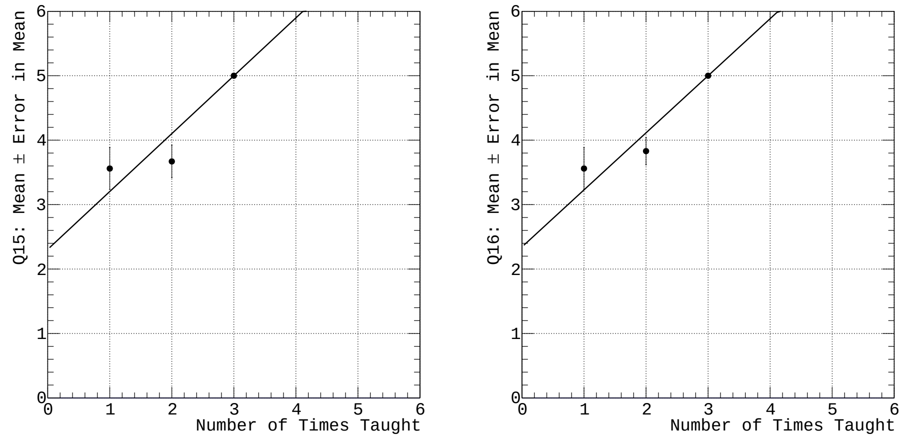

Figure 7: (Left) Student responses to question 15 in calculus-based physics versus number of times taught. (Right) Student responses to question 16 in calculus-based physics versus number of times taught. The y-axis of the data points are the mean values, and the errors are the standard error in the mean. The x-axis of the data points correspond to each time I've taught these courses. The solid black lines are best-fit linear trend lines that minimize the χ^2 value.

The students in the PHYS180 course from 2019 were a combination of physics majors, 3-2 engineering program majors, and computer science. I knew this particular set of students from Fall 2018, when I shadowed Dr. Lagan as he mentored them during Freshman Orientation. By forming a relationship with them early on, I think they trusted that the class activities and methods I chose for them were for the best. I performed my three usual changes to the course style (slower pace, more examples, and traditional content). I followed with PI modules and laboratory activities/PhET activities. They dived in to the PI modules with fervor, and we had many interesting discussions.

The PI module process involved just two students per table rather than 4-5 as in PHYS135. Thus, each time I addressed a table when they hadn't gotten the answer, I was speaking with half the usual number of students. This seemed to reduce complications and make my life easier. When speaking with 4-5 students in algebra-based physics, I sometimes notice that the lightbulb activates in three students' minds, but one stays quiet. Although I try to reach everyone, it is awkward when I have eight tables to approach in a limited time. In PHYS180 (2019) I was able to target struggling students with speed and accuracy. There were originally nine students in my section of PHYS180, but one dropped the course because he was struggling to balance varsity sports and studying. I welcomed him to office hours to discuss his priorities, but ultimately he had to rearrange his schedule and postpone PHYS180.

Figure 7 shows the evolution of student responses to questions 15-16 over time[18]. The data show that I am perfecting my ability to boost **student curiosity** over time, in satisfaction of my first learning focus for introductory courses. The final data point drives the trend line since it has no error. Needless to say, I look forward to teaching PHYS150 this Fall 2019 with my new advisees. This upcoming semester will be the first time I've been a freshman mentor and adviser to my own students.

Similar to algebra-based physics, my department asked me study Question 17[19]. Data regarding Question 17 is shown in Fig. 8. My department suggested that this measurement is correlated with Question 16. Figure 8 (right) contains data showing this correlation. What I predict for Fall 2019 is that the data points questions 16-17 will be between 4 and 5, and that the numbers will remain correlated. The PHYS150 section upcoming in Fall 2019 will have my advisees in it, but also it is filled to capacity (26). To further boost responses to questions 16 and 17, I have introduced pre-lecture material in the form of reading quizzes to ensure the students begin the class on the same page.

[18] Question 15: "This course increased my interest in the subject matter," Question 16: "Overall, I would recommend this course to others."

[19] "The professor used class time effectively and demonstrated preparation for class".

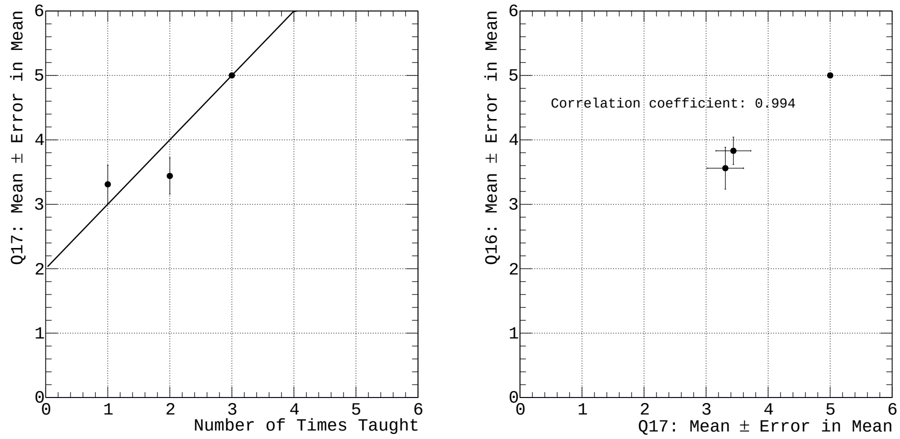

Figure 8: (Left) Student responses (mean values and errors in the mean) to question 17 in calculus-based physics versus number of times taught. (Right) Student responses to question 16 in calculus-based physics versus responses to question 17. The x and y-axis values of the data points are the mean values, and the errors are the errors in the mean. The Pearson correlation coefficient is 0.994.

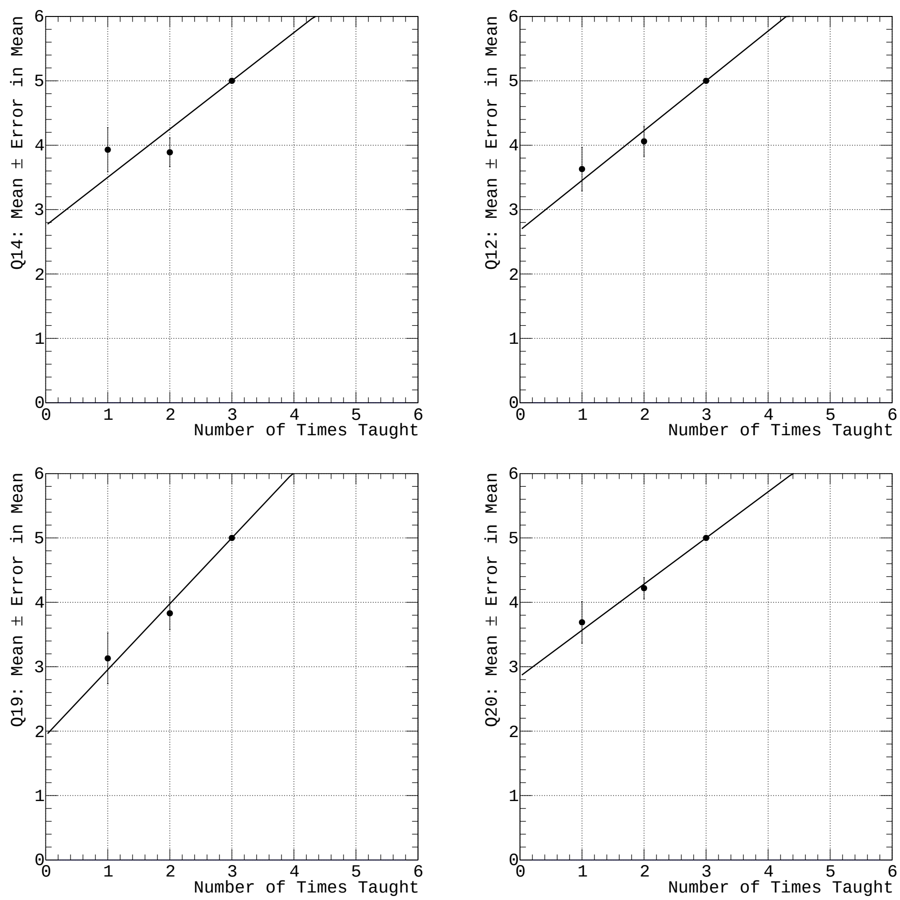

Figure 9: (Top left) Student responses (mean values and errors in the mean) to question 14 in calculus-based physics versus number of times taught. (Top right) Question 12. (Bottom left) Question 19. (Bottom right) Question 20. The solid black lines are best-fit linear trend lines that minimize the χ^2 value. I have now dropped ineffective JITT modules that I used in Semester 2 ($x = 2$).

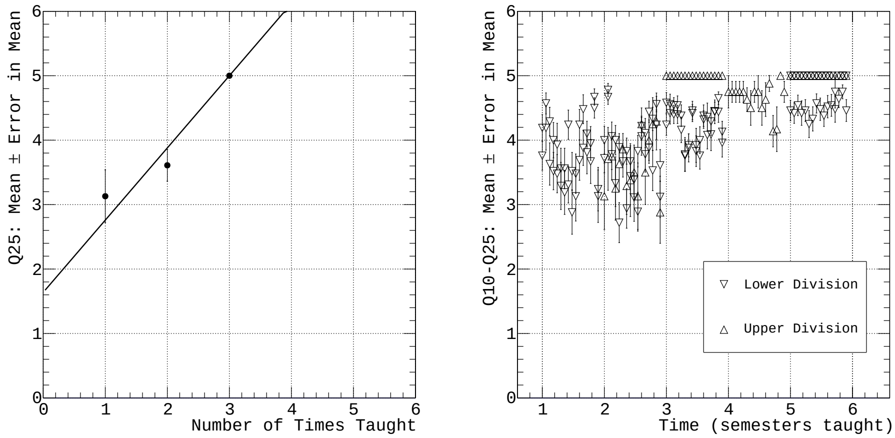

Figure 10: (Left) Student responses (mean values and errors in the mean) to Question 25 in calculus-based physics versus number of times taught. The solid black lines are best-fit linear trend lines that minimize the χ^2 value. (Right) Student responses (mean values and errors in the mean) to Questions 10-25 in all courses versus semesters taught at Whittier. The data points from a given semester are spaced out evenly so they are individually visible.

The second of my three learning focuses for introductory physics courses is to improve the analysis skill of the students. My strategy of combined traditional and PER based content appears to be working as I improve it over time. Figure 9 contains student response data to questions 14, 12, 19 and 20. **The student response data shows that their understanding of the material is improving substantially.** This was in part due to the aforementioned smaller class size and advisee relationships, but also due to the changes recommended by FPC and my department.

The third of my introductory learning focuses is *applications to society*, and we served this goal in calculus-based physics in similar ways to algebra-based physics. The main difference between algebra-based and calculus-based was the sophistication of the student-designed experiments. Students designed electromagnetic lifting devices (similar to cranes that lift metal objects), and presented elloquently and in quantitative detail (see Supplemental Materials). Students also chose articles for daily class presentation that they felt had interesting applications to business and engineering. One student even included an example on how metallurgy is done after learning how to forge metal tools for a project outside of PHYS180.

Figure 10 (left) contains student response data to Question 25, from calculus-based physics versus time[20]. **The data show an unmistakable and significant improvement.** The trend line is driven by the final data point, and as with the other measurements, will likely fall somewhere between 4-5 for Fall 2019 PHYS150 if I continue to refine my approach to the three learning focuses for introductory physics. To make the point of continuous improvement more clearly, I have graphed the mean value responses to *all* questions on the student evaluation form versus semesters taught at Whittier College in Fig. 10 (right). The data points for each question within each semester (within $x = 1, 2, ...$) are spread out so each is visible on the x-axis. The general trend upwards is clear, and some courses show straight 5.0 scores. Downward-pointing triangles represent introductory courses, and upward-pointing triangles represent 200 and 300 level courses. The $x = 3$ semester was the semester when I received and implemented FPC feedback.

As I was learning how to serve the diverse student population at Whittier College, the results were mixed. As time progressed, however, a general trend upwards is observed in all student response data. There are several courses where the students gave me straight 5.0 scores. PHYS180 (2019) was one of them, and the other two are two instances of PHYS396 (physics research for credit). PHYS396 is a course for which we do not receive teaching credit, but is reserved for students who want to do a research project with a physics professor. The January term of 2019 I denote as the fourth semester, in which I taught COSC390, which was a huge success (see Sec. 0.3.1). I am also currently advising a student in PHYS499, our senior seminar that satisfies the paper in the major requirement. Overall, the data show that the students recognize that their learning my top priority.

[20] "Overall, I would recommend this professor to others."

0.3 Advanced Course Descriptions

Computer Logic and Digital Circuit Design. Computer Logic and Digital Circuit Design is cross-listed as PHYS306/COSC330. I have to be prudent about content selection in covering such a broad topic in an undergraduate setting. 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**. 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, non-decimal base systems, and boolean logic
2. Basic digital components, clocks and gates
3. Implementation of boolean algebra with digital components
4. Complex digital components

Coverage the topics above with challenging and thought-provoking course content is how I reach my first advanced course learning focus of *mental discipline.* Additionally, any good digital design course must evenly cover the following phases of the field: *mathematics, computer programming and modeling, hardware design and testing, and digital data analysis.* Thus in implementing this course I must reach my second learning focus of *strength in all phases of science.* The Supplemental Materials contain an example syllabus for this course. The final learning focus is *communication*, and we reached this learning goal through final group-projects coupled with a presentation at the end of the course. My student groups were required to submit a project proposal to me before beginning work, and were given the chance to polish their presentations with me in office hours in advance of the class presentation.

We began by diving into number systems and boolean logic, and the students engaged with the material. I required them to solve problems in pairs, in a lecture/laboratory format similar to calculus-based physics. I assigned homeworks that had both quick math problems, and extended thought-provoking design questions. This style was meant to reach my first learning focus of *mental discipline*, and the first goal of my second learning focus[21]. Group projects focused on computational modeling of digital circuits with LogicWorks software, in order to reach the second goal of my second advanced course learning focus: to expose the students to numerical modeling. I had planned on the construction of digital circuits in the lab to meet the third goal of the second learning focus for advanced courses. Unfortunately, although I ordered the digital components for these experiments six weeks in advance, the purchase orders were not followed by the vendor.

The parts arrived midway through the course, and it disrupted my curriculum. We had to focus on the first two goals of the second learning focus, theoretical problem solving and numerical modeling. Once the parts arrived, we began to push forward with the final two learning goals: design and execution of technical experiments, and data analysis. We completed our transistor radios while waiting for the other parts, but the students felt that the radio project took too long. We have re-stocked for Spring 2020 by ordering two semesters in advance. I have worked with our staff to streamline procurement[22]. A second improvement to better reach these goals in the second learning focus would be to incorporate more traditional content, with examples. I made this change with COSC390, Digital Signal Processing that yielded excellent results (see below).

The final learning focus for my advanced courses is *communication*, with specific goals being that the students must submit one major written or oral assignment. I provide them with the opportunity to refine and clarify their work in office hours. In the advanced course setting, the latter goal takes on more significance than it does for introductory courses. I have helped students debug faulty code, refine presentations, and troubleshoot broken digital circuits. Devoting this extra time is important for the students to achieve success in the results. I further

[21] "Strength in all phases of science."

[22] Large electronics vendors do much beter with credit-card orders rather than traditional purchase orders. Our department now has a department credit card and we can use it to acquire class components more efficiently.

refined this process in Digital Signal Processing by requiring the students to submit their proposals much earlier in the semester. The students have more time to refine their idea with me before beginning the project. This strategy yielded some sharp and interesting final presentations in COSC390 (see Supplemental Materials).

Digital Signal Processing. Digital Signal Processing was listed as COSC390, and I taught it for the first time in the January term of 2019. Similar to PHYS306/COSC330, Digital Signal Processing requires prudent selection of course material in a subject that can be very broad. COSC390 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. I also keep in mind **Physics Department goals 4-7** when implementing this course, even though it is technically not a physics course.

My first goal for the students was to reach my advanced learning focus of *mental discipline* by requiring analytic and creative thinking in class and in the problem sets. Because this was a January term course, we met for three hours each morning for three weeks. Homework sets were assigned each day, and kept *short*, but challenging. This is the first time I tried such a style, and was more or less forced to do it due to the format of the schedule. The students really liked it, and performed well on the assignments. The style ensured that the problems I assigned came straight from the lecture of that day (or occasionally one day prior). The course content touched upon the following key areas:

1. Statistics and probability, complex numbers, and noise in digital systems
2. Linear time-invariant (LTI) systems and filtering
3. Various DSP applications
    - Audio systems
    - Digital images
    - Digital circuits
    - Fourier and Laplace techniques

The second learning focus for advanced courses is *strength in all phases of science.* COSC390 follows COSC330 conceptually, and therefore contains less hardware and more data analysis. One can think of Computer Logic and Digital Circuit Design as learning the logical building blocks of digital components, and some of those components lead to the ability of a scientific instrument to *sample and digitize* analog data. Digital Signal Processing (DSP) is the subject of what follows *after* the sampling and digitization. The idea that COSC390 continued from COSC330 allowed me to focus on the data analysis and software phases, and to broaden the analysis to sub-topics like financial data analysis. Indeed, one of the student-designed projects in COSC390 was an analysis of Federal Reserve interest rate data over many decades using DSP. Other presentations included image processing within the context of criminal justice (facial identification), and audio processing of a student's guitar music.

The overall trajectory of COSC390 is to become the completion of COSC330. That is, after taking COSC330, students could proceed to COSC390 and thus have a "coast-to-coast" or A-to-Z understanding of the collection, transfer, and analysis of digital data. The pedagogy and style of the courses are similar. However, with COSC390 I had the benefit of FPC and physics department feedback. The three main themes of this feedback were pace control, step-by-step examples, and traditional lecture content. The results were encouraging, and I reflect on them in Sec. 0.3.1. In Sec. 0.3.1 I compare the results from COSC330 to those of COSC390, and demonstrate the improvement statistically. This is fair for two reasons: the types of material taught in COSC330 and COSC390 are similar, and the types of students that subscribe to these classes are similar. The academic majors of students in both courses follow a similar profile: physics, math, and ICS are common. Less common but present are 3-2 engineering, business, and economics majors. It is my hope to attract music and design students in the future through audio DSP applications.

0.3.1 Analysis of Student Evaluations, Advanced Courses

What follows is a analysis of student evaluations and reflections on my teaching in the 2018-2019 academic year for the advanced courses. Similar to the introductory course patterns, the analysis reflects the modifications and

Question	COSC390 N	COSC390 result
10	8	4.75 ± 0.71
11	8	4.75 ± 0.46
12	8	4.75 ± 0.46
13	8	4.75 ± 0.46
14	8	4.75 ± 0.46
15	8	4.63 ± 0.52
16	8	4.50 ± 0.76

Question	COSC390 N	COSC390 result
17	8	4.75 ± 0.46
18	8	4.75 ± 0.71
19	8	4.50 ± 0.76
20	8	4.63 ± 0.74
21	8	4.88 ± 0.35
22	8	4.14 ± 0.69
23	8	4.17 ± 0.98
24	8	5.00 ± 0.00
25	8	4.75 ± 0.46

Table 7: (Left) Mean and standard deviation for Questions 10-16 on the student evaluation form, for COSC390, taught in January 2019. These questions pertain to the *course*. (Right) Mean and standard deviation for questions 17-25 on the student evaluation form, for COSC390, taught in January 2019. These questions pertain to the *professor*.

improvements made following recommendations from my department and FPC. I also strived to improve COSC390 based on my experience in COSC330 by focusing on building productive relationships with the students. The reflections focus on qualitative experiences from class that show I am reaching the specific goals within the learning focuses defined in Sec. 0.1.

Table 7 contains the student evaluation responses to Questions 10-16 (left) and Questions 17-25 (right). **The data shows that the students were very pleased with this course**, and I am particularly proud of two specific results. Question 16[23] reflects the fact that the students approved of the course. This was the first time I have taught DSP, and the first time it has been taught *ever* at Whittier College. This is especially interesting considering that the accelerated January term schedule carried the potential for the students to feel lost with the onrush of a lot of material. Apparently this was not the case, and their answers to Question 14 indicate that their understanding of the material *increased.*

Table 7 also shows that **the students approved of my teaching**. Question 25[24] indicates they were pleased with my style, and Question 19[25] shows that even though the DSP material can be challenging, the students understood. I would have liked to score higher on Question 22[26], but time for this was limited in January term. Question 23 I consider linked to 22, since it pertains to differing viewpoints[27], but DSP is a technical topic not always ammenable to open-ended discussions in the same manner we might encounter in other courses. I should think more carefully about connecting the DSP topics covered in COSC390 to real-world applications, and include discussion time to brainstorm how the topics might be applied in new ways.

I have reflected on the written responses from student evaluations from COSC390, and there are two common threads. The most common thread is that they want this course to be made into a semester-long course, in order to cover the topics they liked in more detail. They would have liked more deep dives into the later chapters, when we began to reach the image and audio processing in detail. I encouraged students to take these deeper looks at those topics for their final presentations, but ultimately time constraints limited what we could do. The second thread is that people liked the course, but wanted to slow the pace and focus more on the applications over the basics of DSP. I agree that we should do this, and making the course a full semester would help a lot.

Table 8 compares the student evaluation results from Computer Logic and Digital Circuit Design (COSC330) to Digital Signal Processing (COSC390). This is a fair comparison for the reasons given in Sec. 0.3. **The data show significant increases in student evaluation scores when comparing the two courses.** Like the introductory courses, each measurement shows an increase of 2-3 standard deviations. The only exception is Question 23, pertaining to being receptive to differing views. It is difficult to have opinion-based discussions in both DSP and Computer Logic, because these topics are not as ammenable to such discussions as other courses. That being said, I think there is a venue for sharing differing viewpoints regarding the *applications* of the

[23] "Overall, I would recommend this course to others."
[24] "Overall, I would recommend this professor to others."
[25] "The professor was able to explain complicated ideas."
[26] "The professor encouraged meaningful class discussions."
[27] "The professor was receptive to differing views."

Question	First Time	Most Recent Time	Raw change	Standard deviations
10	3.13 $\pm$ 0.516	4.75 $\pm$ 0.251	1.62 $\pm$ 0.574	2.82
11	3.71 $\pm$ 0.488	4.75 $\pm$ 0.163	1.04 $\pm$ 0.514	2.02
12	3.75 $\pm$ 0.368	4.75 $\pm$ 0.163	1 $\pm$ 0.402	2.49
13	3.25 $\pm$ 0.491	4.75 $\pm$ 0.163	1.5 $\pm$ 0.518	2.9
14	3.63 $\pm$ 0.421	4.75 $\pm$ 0.163	1.12 $\pm$ 0.451	2.48
15	3.86 $\pm$ 0.244	4.63 $\pm$ 0.184	0.77 $\pm$ 0.305	2.52
16	3.29 $\pm$ 0.442	4.5 $\pm$ 0.269	1.21 $\pm$ 0.517	2.34
17	3.38 $\pm$ 0.566	4.75 $\pm$ 0.163	1.37 $\pm$ 0.589	2.33
18	3.5 $\pm$ 0.424	4.75 $\pm$ 0.251	1.25 $\pm$ 0.493	2.54
19	3.13 $\pm$ 0.516	4.5 $\pm$ 0.269	1.37 $\pm$ 0.582	2.35
20	4.25 $\pm$ 0.251	4.63 $\pm$ 0.262	0.38 $\pm$ 0.363	1.05
21	3.5 $\pm$ 0.499	4.88 $\pm$ 0.124	1.38 $\pm$ 0.514	2.69
22	4 $\pm$ 0.315	4.14 $\pm$ 0.244	0.14 $\pm$ 0.398	0.352
23	4.25 $\pm$ 0.41	4.17 $\pm$ 0.346	-0.08 $\pm$ 0.537	-0.149
24	4.29 $\pm$ 0.442	5 $\pm$ 0	0.71 $\pm$ 0.442	1.61
25	2.88 $\pm$ 0.481	4.75 $\pm$ 0.163	1.87 $\pm$ 0.508	3.68

Table 8: Comparison of COSC330 results (mean and error in the mean) for the first time taught (first column) to the first time teaching COSC390. The raw change is given in the third column, and the change divided by the standard deviation is given in the fourth column.

technologies we create. I was relieved and excited to see that the increase in the mean value to Question 25 regarding recommending me as a professor has increased *by almost four standard deviations*.

Below I include a letter my student John-Paul Gómez-Reed sent to myself and the chair of the Department of Mathematics at the conclusion of the course:

Hello Dr. Kronholm,

I have recently completed the January term COSC390 and would like to say that it was an excellent course. It was incredibly informative and related many concepts that were foreign to me with concrete examples, like the math behind image processing. Furthermore, it also provided with exposure with a new programming language: OctaveMatlab. I am emailing you to say that I feel that the course should be promoted from a January term course to a full semester course. I enjoyed my time learning during Jan term, but I feel that making COSC390 a full semester course would allow the course to reach it's full potential; time constraints led to less topics being covered, like the Laplace transform. In any case, I enjoyed my time in the course and hope that COSC390 does become a full semester course.

Thank you for your time and have a good afternoon,
John Paul Gómez-Reed

0.4 Outlook

After reflecting on my teaching, I am optimistic in my outlook. Teaching students with diverse skill levels is challenging, but many people have helped me to improve as an instructor. I want to thank Drs. Lagan, Piner, and Zorba for their constructive comments and encouragement. Each member of my department has shared experience and attended my lectures. I have also enjoyed giving colloquia for my department, and I'm grateful for their interest in my research. I'm also grateful for my wonderful research assistants John-Paul Gómez-Reed, Nicolas Clarizio, Cassady Smith, and Nicolas Bakken-French. Their enthusiasm and energy inspire me, and it has been my privilege to shepherd them through Keck and Ondrasik-Groce fellowships. I am also especially grateful to FPC for motivating me and sharing with candor ideas for improving my teaching. I have taken these suggestions to heart and will always remain open to suggestions.

My teaching is now informed by new mentoring and committee experience. In the Fall 2019 semester, I have become a freshman adviser, and so far it has been a joyful experience to welcome new students to our community.

I am learning how to guide them outside the classroom in their future plans. I teach them in both my new CON2 liberal arts course and in physics, and they have already begun to see the connections. Further, for the 2018-2019 academic year I served the Enrollment and Student Affairs committee and served the sub-committee on student admissions data analysis. I was (possibly) the first person to discover the bi-modal nature of our aid gap distribution, and revealed how the vast majority of students who leave Whittier before their second year come from the side of the aid gap distribution representing *debt* rather than *surplus* tuition. Now I can understand the financial struggle some students undertake just to keep pace in college, and have gained insight into the preparation with which our students arrive.

Another form of service I undertook in the 2018-2019 year was with the Artemis Program, in conjunction with the Center for Engagement with Communities. The Artemis Program is a community-based program designed to bring young ladies from local high-schools to perform a research project with professors at Whittier. During the 2018-2019 academic year, a Whittier student named Samantha Ruiz helped me to organize a research project and recruit four young ladies from high schools in our community. I taught them how to write code in python, and together we ran a research project that used python code to gather data on how quickly and efficiently people solve physics problems. Finally, once we had gathered data, we revealed that some of their high-school peers solved certain types of problems faster than others. These bright young students are now off to present their poster of our work at the Southern California Conferences for Undergraduate Research (`https://www.sccur.org/`).

Looking forward, I will continue to help develop the STEM and liberal arts curriculum. Since arriving, I have created three new courses: *Computer Logic and Digital Circuit Design* (COSC330/PHYS306), *Digital Signal Processing* (COSC390), and *Safe Return Doubtful: History and Current Status of Modern Science in Antarctica* (INTD255, a CON2). INTD255 is my first liberal arts contribution, and it explores polar exploration from a scientific and historical standpoint. The centerpiece is the discovery of the South Pole, and the subtext of the course is that the students must undergo a journey of *self*-discovery in order to plan their futures. Additionally, Prof. Michelle Chihara was kind enough to suggest books that encapsulate the fascinating tradition of polar literature, which has enhanced the course. The students, which include my advisees, seem to be enjoying the course.

Regarding new courses, Digital Signal Processing was so well received that the students all asked for me to morph it into a semester-long course. This is to enable further presentation of applications of DSP relevant to music and image processing, analytics, machine learning, and economics. I have already had discussions with the chair of the Math Department, who has given me the green light. Our department planning includes a semester that is open periodically for me to teach such a course, and the demand seems to be large. This course will therefore connect in interesting ways to subjects within other fields, such as music and economics. Finally, I do want to reassure the FPC that I am still interested in offering another liberal arts course: History of Science in Latin America. I have given myself time for my Spanish to improve, and am in the process of developing the course content for the future.

Once again, I am grateful to my department and to the Faculty Personnel Committee for the feedback and guidance. I look forward to sharing all the exciting developments in my recent scholarship with the committee in my full report in Fall 2020.

Respectfully submitted,
Dr. Jordan Hanson
Assistant Professor of Physics
Department of Physics and Astronomy
Whittier College

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