Chapter 2

Teaching

I have reflected on my teaching experiences, and analyzed the results of course evaluations. I continue from my last report, starting in January 2019 through the present. In Sec. 2.1, I have followed the FPC recommendation to reflect upon the role of physics within liberal arts. I felt called to reflect in Sec. 2.2 on ways I put the values of equity and inclusion into practice.

In my report submitted in Fall 2019, I discussed physics teaching modules based in Physics Education Research (PER) and traditional teaching (TT). In Sec. 7, I review the PER and TT methods I use, and I also discuss laboratory activities and online modules. In Secs. 2.3 and 2.4, I describe my introductory courses and evaluations. In Secs. 2.5 and 2.6, I reflect in the same way for advanced courses. Sections 2.7 and 2.8 contain the same for my *CON2* and *CUL3* courses. Sections 2.9 and 2.10 contain descriptions and analysis for my section of college writing seminar.

2.1 Teaching Philosophy: Growth, Order, and Shared Meaning

The pandemic has tested all of us, and I reflected on these experiences in Sec. 1.2. However, after reflecting on *just the teaching*, I realized something startling. My students experienced *greater success* in the period from January 2019 through Spring 2021, compared to Fall 2017 through Fall 2018. I have several explanations for why this is the case.

FPC always suggests adjustments, and I am grateful for the professional candor. There have been three basic suggestions. First, the pace of my content needs to be controlled. Second, I needed to increase the number of example problems to give students a starting point. Third, I needed to include more traditional lecture content. Traditional content is a term used in physics education research (PER) to refer to the style in which a new equation is first introduced or derived on the board, then solved in examples and displayed in graphical form. I impemented these suggestions, and the course evaluations showed clear, positive results.

Another reason my courses went more smoothly during the pandemic is related to the way physics is taught in our department. First, introductory courses are taught using PER modules that work well online. For example, if we build a lesson around a physics simulation integrated within our textbook, the students experience it the same way at home or in person. Second, introductory courses in our department are taught in an integrated lecture/laboratory format. We selected a service called Pivot Interactives that provided interactive, online versions of in-person laboratory activities. For most of our advanced courses, these same strategies worked as long as we created asynchronous videos of TT modules. The exception was advanced *laboratory* courses, and I share how I responded in Sec. 2.5.

Finally, our department was well-positioned because we use open educational resources (OER). *Using OER fosters equity and inclusion, flexibility, and is a strategy that should adopted whenever practical.* The textbook is free and open-access on any platform in all of my courses, with few exceptions. I helped give three OER workshops through Wardman Library. We explained that $\approx 20\%$ of students struggle to buy textbooks[1]. Further, our department uses online homework software. The students have access to all content via Moodle, the open-access book, and online homework at all times. I use free appointment-booking software that automatically syncs with my schedule. The students responded positively, knowing I could accommodate their schedule. Teaching physics, however, goes far beyond issues of problem solving, access, or the pandemic. In the next section, I reflect on the deeper place physics holds within the liberal arts.

[1]This study was done on students at another school before the pandemic. According to Wardman Library research, students in focus groups at Whittier College say the same thing qualitatively.

Physics within the Liberal Arts: Order and Shared Meaning

Philosophical reflection confuses many physicists. It's *subjective* ... is what we hear. When we must engage in philosophy, even the philosophy of teaching, physicists turn to an old friend: plagiarism[2]. Although I have been reflecting on the values of *order and shared meaning*, the words of my former supervisor Prof. John Beacom (The Ohio State University) already encapsulate them nicely:

Lost in Space, by John Beacom, TEDx @ The Ohio State University: `https://youtu.be/d6eMdixkoRI`

It is customary to locate physics within the liberal arts tradition by stating that the oldest questions of humanity are questions of physics. How old is the Universe? How large is it? Of what is it made? **This custom does not serve the moment**. It does not address the sense of division, tribalism, and the increase in anti-scientific rhetoric. One of the reasons physics holds a place within the liberal arts worldview is that it provides *order, and shared meaning.*

Physicists use the word *order* in several ways. The sense in which I use it here is illustrated by a simple experiment. Take out your keys, raise them a short distance, and drop them. How long does it take them to fall? Is it the same time duration if you repeat it[3]? The point is not to understand gravity. The point is you are having a personal encounter with physics, and it is meaningful to you. Imagine the entire faculty was together in the Shannon Center to repeat the experiment with two rules. We hold the keys at the height of the chair in front of us, and we let go simultaneously. Without these rules, we hear a cacophony. With the rules, we here a uniform burst of sound.

Studying physics creates *order* from our individual experiences. We are a diverse group of people, and yet the experiment allows us to reveal order within the Universe. Gravity does not know who is dropping, and the mass of the keys does not matter. Our collective experience forms a pattern, and as soon as we admit one law of physics, there could be more. The Universe is ordered, and the order carries deep meaning. We can explain the past, control the present, and predict the future together.

Notice another facet of physics: order gives rise to *shared* meaning. When we learn about gravity by dropping our keys at our desk, and later find out others have the same experience, we develop a shared understanding of the world that bridges divisions. Physics simply *is*, apart from us. Moreover, physics is consistent everywhere and over time. The consistency means that joining the cross-cultural traditions of scientists extending back to the Enlightenment and beyond allows us to build on the shared meaning of our ancestors. Attending even one national meeting of the American Physical Society (APS) shows us that physics is a discipline that attracts people of all faiths, races, cultures, and ethnicities.

FPC asked me to answer a basic question: *Are there things your physics courses offer a major in business, history, or music that other disciplines cannot?* The answers are order and shared meaning. A business major understands how microeconomics drives customer behavior in a sector dealing with scarcity. Microeconomics predicts optimal prices given simple precepts. Human beings can be irrational, however, so what *forces* people to behave predictably? The forces of physics. Human beings live within an *ordered* Universe that forces us to act if we wish to thrive. Order arises within the economy just as it does in physical systems: many sub-systems obeying shared rules.

Physics offers a music major shared meaning. Imagine a student of music trying to understand melodic styles cross-culturally, and she finds that music from one side of a continent sounds different from the other side. The laws of physics confer shared meaning to the styles, in the sense all humans detect *sound* in the same way. If a melody contains more than one note, sound waves of different frequencies combine to form *harmony.* Though people from two different cultures might identify different frequencies as harmonious, people from all cultures perceive *the existence of harmony* via the laws of physics. Shared meaning arises because physics explains human perception of harmony. I heard a whale researcher remark in a documentary that "singing is older than humans," because whales evolved before us and they sing. Since song is made of sound waves, I would add that singing is older than most *animals.*

Physics offers both order and shared meaning to a major in history. The example I share here is taken directly from my course regarding the history of science in Antarctica. The leader who created the expedition that led the first humans to the South Pole in 1911 was also the man who led the first complete expedition through The Northwest Passage above Canada: Roald Amundsen. Amundsen was a Norwegian captain reknowned for his tenacity and curiosity. The Northwest Passage required more than one year, because the sea would freeze. The ship had to be anchored before the sea froze. Once the ship was frozen, the sailors explored the area before the Spring thaw.

During that time, they encountered the *Netsilik* tribe, who greeted them like old friends despite the fact that they had never seen white men before. The Norwegians realized the Netsilik were partners in survival against the harsh terrain. Amundsen paid attention to how the Netsilik used physics: by melting snow and pouring the hot water onto the bottom of their dogsled runners, the water would freeze to become a layer of ice. Due to the reduced friction, the

[2] Relax, the jokes are just to keep you awake. Thanks for doing all this reading.

[3] Seriously, try it! You're stuck reading this anyways, right? Might as well learn some #%!*.

Netsilik sleds took less work to pull. By understanding this physics together, the Norwegians and Netsilik developed shared meaning. Amundsen later used this trick to upgrade his sleds in Antarctica, and his dogs pulled sleds faster. His group won the "race" to the South Pole, beating their English competitors by several weeks. This example of shared meaning is one of many I share with my students.

Concluding Remarks about Teaching Philosophy

If physics provides a sense of order and shared meaning, *teaching physics* is about the growth of the students towards mastering and applying the order and the shared meaning. The goal of the professor is to formulate the order of physics into specific equations, testing them through experimentation, and to cause the students to master the equations through problem-solving. The student usually encounters confusion, followed by an ability to solve specific examples. Finally, the professor leads the students to shared meaning by showing them how the concepts apply *in general* to other disciplines.

Teaching physics begins by defining the "system" under study, with measurable properties like displacement, velocity, acceleration, mass, and charge. *Classical physics* is 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. The bulk of PER is done in the context of serving non-majors, and thus the named modules (PI, TT, JITT, and PhET) are usually applied to introductory courses.

A good instructor builds the system of classical physics in students' minds, and leads students to more advanced applications. At each phase, the instructor also guides laboratory experimentation to provide students proof that the concepts work. Upon examining my teaching, I have found the correct "solution" to build order for the students in our introductory courses is to control the pace of the modules, including many concrete examples, and increasing the proportion of traditional lecture content. I will discuss how the module system affected this plan in Secs. 2.3 and 2.5.

A similar approach has led to good results in my advanced courses. I have taught an advanced theoretical physics course, a cross-listed physics and computer science course, and a course on digital signal processing (DSP). I employ the same strategies in these courses as I do in introductory courses, but emphasize TT modules over PER. The pandemic restricted my ability to provide laboratory activities in advanced courses, but I responded by utilizing a mixture of technology and teamwork with the students. In my cross-listed computer science and physics course, the students' success and enthusiasm greatly improved relative to the first course version. I will offer DSP again this January term, and students are already asking how to register.

Finally, the students appear to have learned and grown in my *CON2*, *CUL3*, and College Writing Seminar courses. In my INTD100 section, the students practiced and improved their technical writing. The history of science in Antarctica course (*CON2*) was about exploration, self-exploration, and shared-meaning. The history of science in Latin America course (*CUL3* and *CON2*) was about the history of the discovery of natural order across cultures. The students also encountered shared meaning by studying people from mesoamerican cultures *doing science and math in their own way.* Humans from all regions and times in history feel the call to explore the Universe.

2.2 Addressing Equity and Inclusion

Whittier College prides itself on doing the right thing. In Sec. 2.1, I shared my thoughts on physics and the liberal arts. However, STEM courses are not known for being diverse, nor for fostering equity and inclusion[4]. What might come as a surprise is that many STEM professors work diligently to foster equity and inclusion in their classes. In Sec. 2.2.1, I reflect on open educational resources (OER). In Sec. 2.2.2, I reflect on my flexibility with students. Finally, in Sec. 2.2.3, I reflect on our experience with the Artemis program under the Center for Engagement with Communities (CEC).

2.2.1 Open Educational Resources (OER)

I have helped give three OER workshops with Sonia Chaidez and Azeem Khan on the topic of OER[5]. About 1 in 5 students have difficulty buying books. Students cannot justify spending precious dollars on books when the professor only covers half the content. Assigning homework from the book forces the students to make hard choices, and we would spend 15-20 hours per week grading. To address these problems, we use OpenStax resources in all courses for which that is possible[6]. We have used a homework service called TheExpertTA that administers and grades homework

[4]This is particularly pronounced for the topic of gender, although explaining the situation is beyond the current scope.
[5]I have included my slides for those lectures in the supplemental material.
[6]There is a growing library of texts in areas beyond STEM. See `https://openstax.org` for more information.

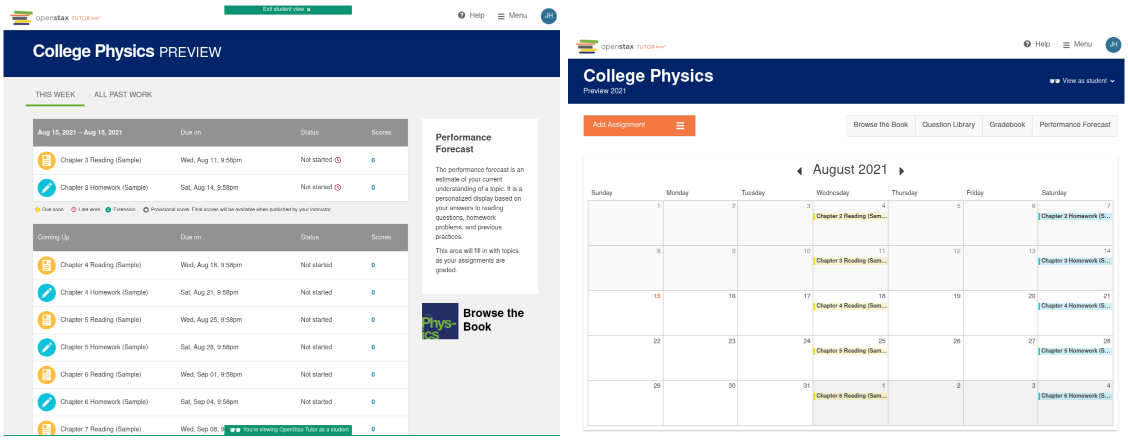

Figure 2.1: (Left) Student view of OpenStax Tutor. (Right) Professor view. In both pictures, reading assignments are in yellow and homework assignments are in blue.

while charging the student \$32.50. During Spring 2021, my students and I learned to use OpenStax Tutor, the homework system fully integrated with OpenStax textbooks that costs just \$10.00.

OpenStax Tutor is cheap, and the books are free. Tutor adds several key features beyond TheExpertTA. First, *reading assignments* can be created to incentivize finishing the reading before class. Second, the homework problems can be multiple choice, conceptual, or require a longer calculation. That adds flexibility for our students who may learn differently year to year. Third, the OpenStax Tutor system uses machine learning to determine the concepts that cause an individual student to struggle. The system assigns them customized practice problems, and I receive statistical reports on the results. I use the insights to focus on concepts with which students struggled. In Fig. 2.1, the student view of the Tutor assignment planner is shown. In summary, the system is more adaptable, more feature-rich, and more cost-effective for our students. Table 2.1 contains a list of all courses I have taught, and includes the use of OER.

I also use OER in my advanced and liberal arts courses. In Computer Logic and Digital Circuit Design (COSC330/PHYS306), students design digital electronics on an integrated circuit board called the PYNQ-Z1 by Agilent (`https://www.pynq.io`). Example and project code is all open-source, and our department purchased the boards, so there is zero cost to the student. In Digital Signal Processing (DSP, now COSC360), the text is open-access. I write the course software in octave, an open-source language. In INTD255, the course about Antarctic science, students use the Open Polar Server (OPS) to access data about ice sheets and ice shelves around the world. In INTD290, the course about Latin American science, students use WeVideo to create digital storytelling projects. Whittier College has a site license for WeVideo, at no cost to the students.

2.2.2 Making Arrangements for a Diverse Group of Students

I have noticed how introductory students struggle to manage time during midterms. The grading data reveals that most students do well on homework but midterms cause headaches because the students cannot work in groups. Typically three-fourths of my students are KNS or Biology majors, who are *required* to take algebra-based physics (PHYS135A/B). They are also required to take courses like organic chemistry. When midterms in these courses align, students' studying is divided. I now poll the students regarding the optimal midterm date to maximize study time, and I write take-home exam versions in case a student has to travel on the day the class selects. The students really appreciate the flexibility.

The flexibility techniques I was learning in 2019-2020 had to be turbo-charged for the module system. I learned about the Calendly booking service from a workshop. This taught me what a booking service is, and I located a free version: `https://10to8.com`. The software syncs with my calendar and provides a booking page for the students. I ensure that my students can grab 30 minutes of my time when they are free. Sometimes I meet with students when they are on break at work. Because we use OER, everything is accessible in that moment.

My courses usually involve a student-designed final project. I have noticed some students create sophisticated projects using our lab equipment, and some create them at home with household items. I could have jettisoned that part of my syllabus during remote instruction, given that the students had no lab access. However, the students really shine when designing and executing their own ideas, so I decided it would boost inclusivity by allowing the students to demonstrate DIY projects for each other via Zoom. Once again, our students rose to the occasion and we all learned.

Semester	Course	Credits	Students	Curriculum feature	OER Usage
Fall 2017	PHYS135A-01	4.0	24	Intro	OpenStax
Fall 2017	PHYS150-01	4.0	17	COM1/Intro	OpenStax
Spring 2018	PHYS135B-01	4.0	18	Intro	OpenStax
Spring 2018	PHYS180-02	5.0	19	COM1/Intro	OpenStax
Spring 2018	COSC330/PHYS306	3.0	6	Advanced	PYNQ-Z1
Fall 2018	PHYS135A-01	4.0	24	Intro	OpenStax
Fall 2018	PHYS135A-02	4.0	26	Intro	OpenStax
Jan 2019	COSC390	3.0	8	Advanced	open-access text
Spring 2019	PHYS135B-01	4.0	25	Intro	OpenStax
Spring 2019	PHYS180-02	4.0	9	Intro/COM1	OpenStax
Fall 2019	PHYS135A-01	4.0	24	Intro	OpenStax
Fall 2019	PHYS150-02/03	4.0	26	COM1/Intro	OpenStax
Fall 2019	INTD255	3.0	23	CON2	OPS
Spring 2020	COSC330/PHYS306	3.0	13	Advanced	PYNQ-Z1
Spring 2020	PHYS135B-01	4.0	23	Intro	OpenStax
Spring 2020	PHYS180-02	4.0	24	COM1/Intro	OpenStax
Fall 2020 (Module 1)	INTD100-21	3.0	14	Intro	–
Fall 2020 (Module 2)	PHYS330	3.0	11	Advanced	–
Spring 2021 (Module 1)	INTD290	3.0	26	CON2,CUL3	WeVideo
Spring 2021 (Module 2)	PHYS135B-02	4.0	17	Intro	OpenStax/Tutor
Spring 2021 (Module 3)	PHYS135B-01	4.0	25	Intro	OpenStax/Tutor
–	Total	78.0	–	–	–
Summer 2020 (Session II)	MATH080	3.0	11	Intro	OpenStax

Table 2.1: This table is a summary of courses taught in four years, plus Summer sessions. Not included: PHYS396 (Physics Research for Credit), and PHYS499 (Senior Seminar). OpenStax and OpenStax Tutor are examples of OER in STEM. The PYNQ-Z1 is a circuit board integrated with open-source software. WeVideo is a web-based video editing platform. OPS stands for Open Polar Server.

2.2.3 Center for Engagement with Communities: Artemis Program

According to a demographic study done by the American Institute of Physics (AIP), women earned about 20% of bachelor's degrees and doctorates in physics in 2017 [34]. Around 3,000 people in the United States enroll in a physics PhD program each year. Roughly, this means only ≈ 10 women sign up to earn a PhD in physics *per state, per year.* I remarked earlier in a footnote that this is a complex issue with many variables not under my control. However, there are ways in which I can help foster inclusion in STEM.

In Fall 2018, Prof. Serkan Zorba and Samantha Ruiz with the CEC approached me about joining the Artemis Program. The Artemis Program invites young ladies from local high schools to perform research with Whittier College professors, while CEC staff help them with the Whittier College application. I served in Spring 2019, and began designing a Python3-based physics education project. Following my teaching philospհy, I had to establish *order* creatively (Sec. 2.1), and asked the girls to write code together (*shared meaning*). They presented their results at URSCA 2019, after they wrote Python3 code that gathered data about how quickly and accurately their fellow students solved physics problems.

I served the Artemis Program again in Spring 2020. Tthe young ladies were to create small, wearable Arduino circuit boards that would relay the location of a lost loved one. I began with demonstrations and code examples. The girls got their boards to communicate via WiFi. Before we could work on making the boards *wearable*, the pandemic struck and URSCA was cancelled. Nevertheless, the young ladies kept their boards and continued designing at home. I look forward to seeing some of them again this Fall.

2.3 Introductory Course Descriptions

The introductory STEM courses I have taught are now introduced, with connections to departmental goals and learning focuses listed in Sec. 7 (Appendix A).

Algebra-based physics (135A/B). Algebra-based physics, PHYS135A/B, is a two-semester integrated lecture/laboratory sequence covering Newton's Laws to electromagnetism[7]. PHYS135 is a requirement for majors such

[7] See supplemental material for example syllabi.