Professional Evaluation and Growth Plan

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Contents

Chapter 1

Introduction

Dear Friends,

I have compiled a report on my progress as an instructor, scholar, steward, and advisor for Whittier College during the period of 2021-2022. I reflect on my educational and scholarly practices, and the service I have performed for the College as a mentor, advisor, and committee member. I am pleased to report that my students are learning and growing at Whittier, and achieving success in the professional world. In our last communication, after my second major PEGP report (delayed to the fifth year due to the pandemic), you asked me to reflect on my pedagogical practices. In particular, you posed four questions I could use to discuss my teaching philosophy: (a) describe my interpretation of the learning process, (b) describe how I incorporate tools and practices in my courses, (c) describe how the tenets of my teaching philosophy help us to achieve learning objectives, and (d) focus on the *why* behind specific teaching decisions as opposed to the *how*.

With questions (a)-(d) in mind, I have taken a straightforward and concise approach to the structure of my teaching philosophy in Sec. 2.1. I reflected on what practices I actually use most often in my teaching, and answered questions (a)-(d) for all practices. This exercise has been useful and enlightening. It is my hope that this exercise provides you with useful insight into modern physics instruction. I have also reflected on the *learning focuses*. These ideas were derived originally from my colleagues in my department, and I have modified them and made them my own. I have come to the conclusion that the learning focuses guide my course creation and course content selection, and the *why* behind teaching decisions I make are driven by the tenets of my teaching philosophy. Though my teaching practices continue to generate positive student feedback, I have also identified areas of courses that need to be adjusted.

Turning to my scholarship, I have new and exciting accomplishments to share with you in Sec. xxx. I highlight three recent experiences as examples of my progress. First, I have finally published in *Physical Review D,* the flagship peer-reviewed journal in my field by the American Physical Society (APS)[1]. I am the first professor at Whittier College to achieve this. This publication was the culmination of two years of work with an undergraduate student who has become a dear friend. This result marks the first time a professor from my department has published in one of the *Physical Review* journals in the last 16 years[2]. The piece provides the first fully analytic model of Askaryan radiation. The results represent a significant contribution to my field, and my undergraduate researcher helped me to improve and finish this work (see Sec. xxx, and also Sec. 3.3.2 of my previous PEGP).

The second experience pertains to my radio-frequency (RF) engineering and radar research with the Office of Naval Research (ONR). In 2021, I published a paper involving the computational electromagnetism (CEM) of radar design[3]. This work was ranked Top 10 Most Notable Articles in Electronics Journal for six months, and researchers from four countries contacted me to collaborate. This Summer, I was invited to speak at a CEM conference held at MIT. I gave a 45 minute lecture on RF CEM design alongside colleagues from MIT, Google, Georgia Tech, Stanford, and BYU. It was an incredibly meaningful moment in my career. I took the opportunity to promote the mission and values of Whittier College. Having received an ONR Summer Faculty Research Program (SFRP) grant for the third year in a row, I am eligible for ONR Senior Fellowship in Summer 2024 after a mandatory one-year break. For the past two years, our ONR partners at NSWC Corona Division have granted us money and precision RF equipment to boost the engineering research experiences of our students. Based on this fruitful collaboration, I'm happy to share that NSWC Corona would like to form an Educational Partnership Agreement (EPA) with Whittier College. NSWC Corona forms EPAs to

[1] J.C. Hanson and R. Hartig. "Complex analysis of Askaryan radiation: a fully analytic model in the time domain." Phys. Rev. D **105**, 123019 (2022).

[2] See, for example, S. Zorba *et al.* "Fractal-mound growth of pentacene thin films." Phys. Rev. B **74**, 245410 (2006).

[3] J. C. Hanson. "Broadband RF Phased Array Design with MEEP: Comparisons to Array Theory in Two and Three Dimensions." Electronics Journal **10**, 415 (2021).

strengthen undergraduate engineering research, and to recruit engineering talent. This project would be wonderfully beneficial to our students.

The third experience is related to both my scholarship and teaching. In Fall 2019, I taught INTD255, entitled "Safe Return Doubtful: History and Current Status of Modern Science in Antarctica" (CON2). In Spring 2021, I taught INTD290, entitled "A History of Science in Latin America" (CON2,CUL3). I concluded these courses with material related to the connection between modern scientific endeavors by peoples of diverse cultures and exploration literature. I showed the students how it is possible to travel to Antarctica through the United States Antarctic Program (USAP). As part of my research with the IceCube Gen2 collaboration[4], I have conducted research expeditions to Antarctica through USAP. Thus, there is a deep connection between my teaching and research via the concept of exploring the unknown. A long-time goal of mine has been to inspire my students to begin their own careers in science and in life with the same organization, mental discipline, and curiosity required of explorers. I am thrilled to share that we are finally sending our first Poet to Antarctica. Scout Mucher, who was my student in INTD290, was inspired to go, and we met to go over the application process. Scout was hired as a contractor to help run USAP operations in McMurdo station on Ross Island. Scout has now PQ'd (physically qualified), and is slated to begin the journey when the sun rises this Fall! We are so proud of Scout.

For my service to Whittier College for the 2021-2022 academic year, I joined the Educational Policy Committee (EPC). I had been in discussions with Prof. Rehn about joining the Whittier Scholars Program (WSP) advisory board. Near the end of Spring 2021, I was asked to serve on EPC, and I answered the call. The major task for EPC was to generate consensus around a revised course system proposal to be brought before the full faculty by the end of the year, in light of proposed changes to faculty load. While discussions of the course system and faculty load proposals continued, we also completed a long list of other tasks. These included studying and approving changes to ten major programs and changes to programming within the Center for Engagement with Communities (CEC), raising student per-semester credit limits, revising the definition of a credit hour, revising the new course proposal form, revising handbook language pertaining to syllabi, and to study the use of "tracks" or "emphases" within major programs at Whittier College.

I led a sub-committee dedicated to the study of tracks and emphases, and our goal was to develop a common language for tracks across campus. I framed the task by comparing "tracks" and "options" to *partitions*, as a computer hard drive is partitioned. We examined data from DegreeWorks to accurately determine the number of partitions per program. I found that, on average, major programs at Whittier College have two partitions per major. Rounded to integers, the natural sciences tend to have three partitions, while the social sciences and humanities tend to have two. The variances, however, are large. We used this diverse data set to formulate a survey sent to department chairs. The data set and chair responses will be used to formulate policy for tracks and options within majors. Students should find it useful to have a common language describing options within majors to improve their understanding of the curriculum.

With regards to the course system, I tried my very best to aid in the discussions by thinking through the technical implications of the proposal. One example of how I advanced the discussion was to offer a compromise regarding the maximum number of courses per semester. One one hand, some wanted to limit first-year students to just four courses per semester, and require all students to obtain permission to take five courses in any semester. On the other hand, some objected to any restriction. I describe my compromise idea that we adopted into the final proposal in Sec. xxx. I hope this demonstrates for you that I can help build consensus, even when the task is technically challenging. I give much credit to my colleagues on EPC, and especially co-chairs Profs. Camparo and Householder, for setting such a good example. In Sec. xxx, I describe ways in which I might be of service to Whittier College in the future, given my reflections on my accumulated committee service. I often find ways to add weight to technical policy discussions by writing code and crunching numbers. Thus, I propose to help with institutional research, and provide a few ideas in Sec. xxx. Finally, there is always a special place in my heart for interdisciplinary research, so I have joined the WSP Council and am working with a new WSP advisee.

In Sec. xxx I describe my accomplishments in advising and mentoring. In our last communication, you gave concrete suggestions for my writing and reflection in this area. Specifically, you asked about my philosophical approach to advising and mentoring. You shared a concern that my advising leads students down a rigid path, and that creating digital profiles using services like LinkedIn narrows their path. You also shared that you would prefer a self-reflective approach to the advising and mentorship section. I have responded by reflecting on my advising and mentorship more succinctly than my previous PEGP report. I employ a philosophical perspective that motivates my students to take charge of their future in a way that is useful for them and in alignment with their values and interests. I have also included tangible results of successful student outcomes, such as internships, publications, and fellowships gained by my advisees. In Sec. xxx I discuss how I am managing first-year advisees again this year, and my new section of INTD100.

[4] See, for example, `https://icecube.wisc.edu/`, and Secs. 3.1 - 3.3 of my prior PEGP.

To your point about rigidity, I'm surprised that the counter-examples I provided in my last report did not ameliorate your initial reaction. I do maintain flexibility in my approach to advising, and I gave an example as proof. I had an advisee who initially decided on majoring in physics, but realized in the midst of our discussions that his path lies in a different direction. After appropriate reflection, we decided to change his major to Digital Art and Design (see Sec. 5.2.1 of my previous PEGP). In Sec. xxx, I share how the decision tree I provided (also in Sec. 5.2 of my previous PEGP) actually reflects the thinking of many majors in the physical sciences. I have infused this decision tree with more detail about the diverse paths my students take towards their career goals. I also point out in Sec. xxx that our recent curricular discussions include the creation of digital portfolios and encourage sharing senior theses in Poet Commons. Our advisees will use these to draw connections between projects at Whittier College and their future plans. Tools liked LinkedIn are a widely accepted mechanism to facilitate sharing work. I encourage students to use all these tools to take control of their path forward. Finally, I note that my WSP recruitment and WSP advisory board participation serve as evidence that my advising and mentorship is not rigid, but encourages students to explore interdisciplinary fields. In Sec. xxx, I describe the work of my current WSP student, and my plans with future WSP students.

In Sec. xxx, I describe a project regarding equity and inclusion within the natural sciences at Whittier College. Back in 2017, I had the idea to create an app that would facilitate inclusion in introductory physics courses infused with machine learning to tailor user experience. I named the idea "The Primer," in reference to a sci-fi novel in which a young woman aquires a tool that accelerates her education through a narrative tailored to her background. The visual environment and narrative of the app was to be designed by diverse Whittier College undergraduates to make the experience as inclusive as possible. I finally found time to encapsulate this idea into an internal DEI grant through IDC. The IDC members suggested I attend three workshops on inclusivity in introductory STEM courses given by the Cottrell Scholars Network. In these workshops, we learned about current psychological research within the field of inclusion in introductory STEM courses. One of my advisees in computer science has (in my humble opinion) the right experience and cultural background to help me create and test the code for the app this year. We will recruit digital designers this Fall from within the Whittier community to develop the digital storytelling aspect of the tool. We hope everyone will enjoy the results!

My friends, it is my hope to be granted tenure at Whittier College. I hope that the effort and passion I have given to our institution for the past several years merits this distinction. I have created and taught new courses that students have enjoyed and found useful, including liberal arts courses that fused my research interests in the natural sciences with social issues and history. I have demonstrated tangible successes in the areas of scholarship of discovery and application, and the the future holds several exciting research avenues to explore with our students. I have served on multiple committees that have tackled complex issues ranging from student admissions data to the course system proposal. I have continued to be a resource as a first-year advisor to many new Whittier Poets, and I have a track record of leading majors in the physical science to successful career outcomes. All the while, I have done my best to incorporate your suggestions made with professional candor into my work. I speak for myself and my department when I say that we are grateful for the work that you do, and we trust in your insight and wisdom.

Sincerely,
Jordan C. Hanson
Assistant Professor, Dept. of Physics and Astronomy

Chapter 2

Teaching

I have reflected on my overall teaching practice for the academic year (AY) of 2021-2022. In Sec. 2.1, I respond to your questions in our last communication regarding my teaching philosophy. In Sec. 2.2, I reflect on the introductory physics courses I taught in AY 2021-2022. In Sec. 2.3, I analyze the course evaluation data from these courses and reflect upon the student feedback. In Sec. 2.4, I reflect on the advanced physics courses I taught in AY 2021-2022. In Sec. 2.5, I analyze the course evaluation data from these courses and reflect upon the student feedback. I list several interesting ideas for modifying PHYS306/COSC330: Computer Logic and Digital Circuit Design, including further integration with COSC360: Digital Signal Processing.

2.1 Teaching Philosophy: Six Easy Pieces of Active Learning Technique

The following is a reflection on the six main teaching activities I use in the physical sciences. I also apply them, as appropriate, to my liberal arts courses and college writing seminar sections. Each activity is derived from the over-arching principles of *order* and *shared meaning.* I do not cover those principles in detail, since I have already shared that in Sec. 2.1 of my prior PEGP. For each of my six main teaching activities, I answer the following four questions you posed:

- (a) *For this teaching activity, can you describe your interpretation of the learning process?*
- (b) *For this teaching activity, how do you incorporate teaching tools and practices?*
- (c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?*
- (d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?*

After completing this exercise, I reflect potential changes going forward, and what seems to work well. One interesting shift that has taken place within our department is the use of *online laboratory activities.* I reflect on *why* we have included this practice in recent years. I review the learning focuses mentioned in Sec. 7 (Appendix A) of my prior PEGP, and reflect in Sec. xxx how these drive my course content selection.

2.1.1 General Approach: How I Teach with Six Easy Pieces (1)-(6)

My teaching philosophy may be broken into the six main teaching activities, or ingredients, below. Each of them is an active learning technique, keeping students engaged in the processes of science. As I shared in Sec. 2.1 of my prior PEGP, physicists classify students into *majors* and *non-majors.* The broadest definition of a *major* student is someone who takes physics or engineering courses above the introductory level. Physics education research (PER) usually covers courses designed for *non-majors*, or introductory courses. PER provides evidence for *why* active learning techniques are effective. Most students who take physics and engineering courses at Whittier College are non-majors, so my teaching philosophy is focused on active learning techniques for non-majors. When I teach advanced courses, I remix the ingredients into a different recipe. Advanced physics and engineering courses are built from introductory ones. Students in advanced courses have already experienced ingredients (1)-(6), and they are ready for something new. I combine some of the activities (1)-(6) with writing assignments when I teach liberal arts courses and college writing seminar.

I begin introductory course sessions with (1): traditional lecture format. I start with a warm-up exercise drawn from textbook readings assigned 1-2 days prior. Before giving the solutions, I present the agenda for the session so the students know what to expect. I then solve the warm-ups as on the whiteboard, and build on them with more intricate examples and proofs of theorems. Next, I usually proceed to (2): peer-instruction [1]. I pose conceptual multiple-choice questions to the students, based on content from activity (1). Students record anonymous answers electronically, and we view the answer distribution. We discuss our responses as peers in small groups, and I help stuggling students to stimulate their thinking by re-phrasing the question or giving them clues[1]. The students respond again, and we move forward when a super-majority of the students get it right. Next, we arrive at (3): PhET simulations. The students find it useful to simulate complex systems. Physics education technology, or PhET [2], consists of HTML5 applications designed with PER. I provide written activities the students complete while operating the simulation.

I use the second half of our session to conduct a laboratory activity, ingredient (4). We work as a team in our department to maintain consistent lab pedagogy and equipment. The students complete labs that cover the same content presented in activities (1)-(3). Sometimes activity (5) becomes possible, in which we cover traditional lecture content that is testable in both a PhET and a lab. We align theoretical predictions with simulation and lab experiment[2]. The students perform activity (6) near the end of the semester, when they propose, build, execute, and present experiments as small groups to the class. Though teaching activities (1)-(6) represent the *average* recipe for my sessions, I do not repeat the exact same routine each day. As a cookbook contains a diverse collection of healthy recipes using common ingredients, I mix these ingredients in new and interesting ways to maintain student engagement.

2.1.2 (1) Traditional Lecture Format

Having reflected on activity (1), I find three facets **(i)-(iii)** that make it useful for students. **(i)** Solving problems on the whiteboard **displays the components of physics** in step-by-step fashion. These include variables, estimation, units, functions, algebra/calculus, solutions and graphs, and checking results by examining units, limiting cases, and symmetry. Facet (i) is derived from the principle of *order* because scientific statements about nature must be ordered using consistent terminology and mathematics. **(ii)** Traditional lecture gives the students **memorizable examples** that serve as concrete anchor points, a form of *shared meaning*. Anchor points assure our mutual understanding of a system, and students use them to solve new problems with similar traits. **(iii)** By **linking basic examples together**, students begin to solve harder problems for more complex systems that may be reduced to sub-systems they already understand. Students learn to use the intrinsic *order* of physics to model complex systems. We know from PER how active learning strategies benefit students, but students always request some traditional lecture content. Philosophically, I make the facets of my traditional lecture as active as possible while responding to this request.

Facet (i): displaying the components of physics problem solving.

(a) *For this teaching activity, can you describe your interpretation of the learning process?* As with any subject, students must first understand how to use its components before solving problems or creating something new using those components as one. One example that arises every Fall semester in my courses is the usage of physical units with variables. Solving for the final speed of a system, some students inevitably write "the final speed is 12." My next question is always "twelve what? Kilometers per hour, feet per second ..." Students become aware that there are components of physics calculations they do not yet understand when I break a problem into its components. Once students master concrete examples by following my lead, they can adapt them to model similar systems.

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* Solving a problem with nothing but a piece of chalk in front of the group will always have a place in my teaching. The students engage on their own with a written warm-up before examining the components of the solution. This activity becomes an anchor point that can be copied and studied. This technique keeps traditional lecture *active*, as the student evaluate the steps of their solution against mine. I control the *pace* of this content to maximize the learning of a diverse group of students. This technique also boosts equity, in that we solve the same problem as one group and share the solution on a warm-up form that the students study with each other[3].

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* Two relevant learning goals[4] set for my recent two-semester sequence of algebra-based physics are (A) "to solve word problems pertaining to physics and mathematics," and (B) "to construct mathematical models of mechanical systems." Facet (i) of traditional lecture addresses (A) by breaking a word problem into its components, while translating the words into mathematical statements. As a professor at a Title V HSI like Whittier College, this is

[1] I discussed in Sec. 2.2 of my prior PEGP, and Sec. 2 in general, about how this phase of PI also helps to boost equity and inclusion in my courses. Recall that if one student calls WAT, then we slow down and ensure everyone is ready to proceed.

[2] Ideally, we would do this every time, but there are not yet PhET simulations for all labs.

[3] *Passive* traditional lecture content, in which the instructor simply works a few examples and then moves on, can actually reduce equity. Students already familiar with the content will excel, whereas students with no prior experience will fall behind.

[4] Learning goals are always listed in my course syllabi. See supplemental material for details.

especially useful for students who grew up in a bilingual setting. Facet (i) of traditional teaching addresses (B) because I demonstrate how complex systems can be broken into manageable components. The *active* nature of the tutorial keeps the students engaged, and we all share the same understanding of the problem (*shared meaning*).

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* The most basic reason that comes to mind is that the students ask for it. It's concrete, and feels right to them. Even if more modern PER methods are shown to be effective, I have learned that a course with too little of facet (i) is disorienting to learners.

Facet (ii): memorizable examples.

(a) *For this teaching activity, can you describe your interpretation of the learning process?* The learning process for physics includes memorization and repetition, as a new student of music or a new language learns. Compare the way someone who speaks English begins to learn Spanish, as opposed to *linguistics.* Memorization and repetition plays a stronger role in the former. Compare someone learning to play the guitar to a student of *musical theory.* Repetition and memorization again play a stronger role in the former. Introductory physics students have a similar experience: beginning with active learning techniques involving repetition and memorization are highly useful. Students eventually gain enough confidence to engage with more complex physical systems.

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* At a minimum, once per class session, I provide a written handout (the warm up problems) that I solve after the students have attempted them on their own. The students then have completed document of example problems to study. I deliberately select problems for homework and exams that share some connection to the example base I have built with the students (*shared meaning*).

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* Facet (ii) addresses learning goal (A) above by demonstrating specifically how the words of a problem lead to the actions we take to solve it with mathematical reasoning. When examples are memorized, problems involving similar logical language with different numbers can be solved with ease[5]. Facet (ii) addresses learning goal (B) by providing memorizable models of simple systems that can be combined to build mathematical models (see also facet (iii)). Thus, facet (ii) is both a form of *order* (goal B) and *shared meaning* (goal A) within physics instruction.

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* Practically, these memorizable examples help students complete their homework and to study for exams. Their confidence, and the equity of the class, are boosted. I recall a time I saw my student Deninson Cortez-Cruz stapling together all of my warm up problems. I remarked that it looked like his studying was going well, and he replied: "Oh yes, professor. This packet is like our Bible." I smiled, because I knew that he was going to use those resources to help his lab group ace the class, and they all did.

Facet (iii): linking basic examples together

(a) *For this teaching activity, can you describe your interpretation of the learning process?* Part of the learning process for technical subjects is that an understanding of complex systems comes after understanding simpler ones. For example, suppose I have already covered basic examples of friction and momentum transfer. The students know how to predict the deceleration as a car slides against friction. They also understand how to predict the velocities of objects that collide. If I ask them to predict the final velocity of a vehicle *struck by* another that had been sliding, facet (iii) is *why* they can solve this problem. The wrong approach would be to teach them about friction, then momentum transfer, and conclude that they should be able to solve the complex problem because they know the basic concepts. Rather, *why* facet (iii) is so important is that the students actively learn how to couple simple ideas into complex ones.

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* Towards the end of traditional lecture time in class sessions, I occasionally link two basic examples or concepts together to solve a harder problem for the students. When appropriate, I assign *challenge problems* for bonus points that link together three or more basic concepts.

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* The purpose of facet (iii) is to address learning goal (B): "to construct mathematical models of mechanical systems." I take the time to practice facet (iii) with my students, to develop further in their minds the *order* within physics. This development takes time, but empowers the students to tackle more complex systems.

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* See (c). I would compare this part of the process to a piano student first learning scales and chords before beginning to compose songs. Once students gain confidence with the *order* of physics, they begin to trust it and their problem-solving ability grows stronger.

[5] Sometimes such collections of word problems are called "homomorphic."

2.1.3 (2) Peer-Instruction (PI)

Having reflected on activity (2), I have identified three facets **(i)-(iii)** that make PI useful for students. Students must **(i) form an argument in their own scientific language**, which relates to the principle of *order* because they must mentally order concepts in a way that they understand internally. Students must then **(ii) practice explaining concepts to others.** PI naturally connects to *shared meaning* via facet (ii). Finally, peer-instruction enables **(iii) teaching efficiently.** PI has built-in pace control that keeps students engaged by covering lightly concepts the students understand well, while focusing more intentionally on concepts they find more challenging.

Facet (i): forming an argument in one's own scientific language.

(a) *For this teaching activity, can you describe your interpretation of the learning process?* Causing a student to absorb abstract ideas in a way that they understand, and to confirm that understanding with peers, is critical to the learning process. PI relies on short, conceptual word problems posed in a multiple choice format. These problems reveal cases in which a student is getting correct answers but for the wrong reasons. We ask the students to explain the problem to themselves in their own words while removing confusion added by excessive numbers and formulas. Practicing facet (i) of PI causes students to confront their lack of understanding of a concept, and to gain control over it in a practical way. PI is an active learning technique, and facet (i) represents its starting point.

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* Since PI is such a well-studied technique in PER, I refer the reader to Appendix A, Sec. 7.2 of my prior PEGP, and the following book, website, and conference resource [1, 3, 4].

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* The relevant learning goal (taken from my introductory course syllabi) is (C): "to apply logical thinking to conceptually-posed physics problems." Within facet (i) of my PI modules, students *order* the concepts and problems in their minds in a way that is the most useful for them. Facet (i) also serves goals (A) and (B) because it aids in problem-solving. Often, we observe introductory students mis-applying a physics equation to solve a problem because it is the only relevant formula they understand. By practicing conceptual thinking, facet (i) helps break students out of this habit. They instead *order* a problem conceptually in their minds before solving it with the right technique.

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* I hear the following sentence every single Fall semester in office hours: "I understand the formulas and concepts in physics. I just need help 'translating' the problem into the formulas." Facet (i) is vital for this part of problem-solving growth of the students. In the phase of PI where facet (i) is occurring, students discover that they become responsible for this "translation."

Facet (ii): practice explaining concepts to others

(a) *For this teaching activity, can you describe your interpretation of the learning process?* Our own conceptual understanding of a concept must be confronted by the conceptual understanding of others (*shared meaning*), and physical reality (*order*). The learning process for physics must include the chance to revise one's conceptual understanding by confronting faulty logic and absorbing the logic of others. This process need not be confrontational, however, as in a debate or a sport. Instead, facet (ii) of PI respects our psychology: we are more likely to absorb the thinking of a trusted peer who uses language we already understand.

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* See Appendix A, Sec. 7.2 of my prior PEGP, and the following book, website, and conference resource [1, 3, 4]. I add here that, during the discussion (facet (ii)) phase of PI, I focus my attention on struggling students to help boost class equity. In these side discussions, I listen to my students and share clues with them as their peer. This technique requires a pre-established relationship of trust with the students, so early in the semester I focus more attention on building this relationship.

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* The purpose of facet (ii) of PI is literally to develop a *shared meaning* between peers and instructors. Learning goal (C) is directly addressed, and learning goals (A) and (B) are augmented. Students begin to think more conceptually before solving problems algebraically rather than guessing the formula and plugging in numbers. As an example, consider a student attempting to predict the final velocity of a falling object by plugging in the distance traveled divided by the time duration. This is wrong, because the object is accelerating. During group discussion, a lab partner might explain why the formula doesn't apply: "I don't think you can use that one. This one's more like the accelerating car where you have to times the acceleration by the delta-t." Peers are more likely to get a problem right when they develop a shared understanding.

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* I have noticed that my students naturally form lab groups from peer groups in my courses. They are teammates from varsity sports, friends in the same social society (e.g. Penns, Palmers), or bilingual students. These connections tend to augment the mechanics of facet (ii) because lab group members are already friends and trust one another. Thus, a reason *why* I include PI facet (ii) is that it is in alignment with the group dynamic of my courses.

Facet (iii): teaching efficiently

Philosophically, I think of facet (iii) of PI as an auxiliary benefit that helps the students. When a super-majority of students answer a conceptual question correctly in the first round, we move forward. When this does not happen, we stop and have group discussions. This forms a natural pace control. To boost equity, as I've shared in prior PEGPs, I've built in the WAT function. Students can hit a special button called WAT[6] that causes me to stop and give additional clues, regardless of the proportion of students who've solved the problem correctly. Students know to hit WAT if they are majorly confused, and this is more rare than the sort of confusion that gets resolved in group discussions.

2.1.4 (3) PhET Simulations

Having reflected on my use of PhET simulations, I have identified three facets (i)-(iii) that make them useful for my students. **(i) PhETs foster the extraction of patterns from physical systems** (*order*). The learning process involves pattern recognition, and PhETs provide a space for students to tinker with a system until they recognize the pattern of its behavior. **(ii)** PhETs provide an avenue for students **to construct graphical results.** Data can be generated intuitively with PhET simulations, because the confusions of building the apparatus and dealing with statistical error are gone. Students focus on plotting results in a way that the group understands (*shared meaning*). The third facet is philosophically practical: **(iii)** PhET simulations allow us **to study physical systems we cannot build.** A common example is the topic the solar system, which we use to study gravity.

Facet (i): extracting patterns from physical systems

(a) *For this teaching activity, can you describe your interpretation of the learning process?* Part of the learning process in the physical sciences is to recognize patterns in systems (*order*). PhET simulations allow students to experiment in the absence of statistical error. For example, consider a DC circuit powered by a 5 Volt battery. Students can measure instantaneously the current flowing to various devices in the circuit using a tool. To graph the data and extract Ohm's law (a linear relationship between voltage and current), they simply tune the battery voltage. In real life, the students would have to swap batteries, measure the voltage of each battery, and keep track of errors. These experimental skills are also part of the learning process, but PhET simulations help students to concentrate on *just the pattern recognition.*

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* I incorporate PhET simulations as group activities completed by lab groups within my integrated lecture-lab format. I give the students a brief tutorial on the projector screen, and I provide them with a written worksheet. Working together, they construct a model using the components in the PhET, and graph data drawn from the model on the worksheet. When appropriate, I construct my own version on the large screen, and we all compare results together (*shared meaning*).

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* Learning goals (A) and (B) are augmented indirectly. Students are more likely to solve problems correctly using an equation if they have verified that equation experimentally. Viewed as a pattern of physical behavior, physics equations once extracted from a system can be used to model similar systems by analogy. Goal (B) is also addressed directly, in that PhET activities are an example of modeling a model to describe physical systems. The difference is that they are using a computational tool rather than algebraic ones. Another learning goal is reached by the *order* achieved through pattern recognition is (D) "to practice scientific experimentation, data analysis, and reporting of results." Students must order their thinking by analyzing data from the PhETs and constructing graphical results as a small group.

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* On a basic level, I include PhET simulations because they are based on extensive PER. The appearance of the controls and equipment in the PhET programs feels similar to real lab components. The measurement tools have obvious controls that can be learned quickly. Once the students have done an experiment with a PhET simulation, doing the real version on the lab bench is more straightforward because they already understand the tools and patterns.

Facet (ii): constructing graphical results

(a) *For this teaching activity, can you describe your interpretation of the learning process?* Part of the learning process in the physical sciences is convincing others of the validity of a concept or result (*shared meaning*). This is in addition

[6] `https://knowyourmeme.com/memes/wat`.

to the ability to master a concept derived from experimentation well enough to apply it to word problems. Facet (ii) of PhET activities is about creating a visual representation of experimental data such that another person can be expected to interpret the results and extract the pattern. Thus, the experimenter must think about the details of how results are communicated, and in turn, ask themselves if they really understand the results.

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* Philosophically, I must strike a balance for facet (ii) of PhET. I need to scaffold the graph on the PhET worksheet so that the students can fill in their data, leaving a graph that can be interpreted by peers. On the other hand, I want the students to practice constructing the elements of that graph on their own. These elements include labeled axes, legends, proper numerical upper and lower limits, and data points that include any statistical errors. We build these skills over the course of the first semester, and our graphics gradually become more sophisticated. My expectation for the self-designed final projects (see below) is that all results communicated graphically can be interpreted without ambiguity.

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* Learning goal is (D) "to practice scientific experimentation, data analysis, and reporting of results." The work we do with PhET in facet (ii) is all about reporting of results such that someone else could reasonably understand them (*shared meaning*). We use PhET activities to build good habits, so that when we arrive at lab activities (see below) and the final project, students report their results accurately and unambigiously.

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* On a basic level, I focus on facet (ii) of PhET because without it, science itself goes awry very fast. Even though I might know how I arrived at my physical conclusions, if I cannot display them such that someone else draws those same conclusions, then I am not doing science. Having practiced interpreting each other's graphs in my courses, our students are equipped with an important skill they will use immediately in the scientific and professional communities they join after they graduate.

Facet (iii): studying systems we cannot build

A practical benefit of using PhET simulations is that we cannot always construct systems we would like to study. Consider the relationship between the pressure, volume, and temperature of an ideal gas. The *kinetic theory of ideal gases* tells us that the reason these macroscopic quantities are related is because ideal gases are made of molecules that all have kinetic energy and momentum. Pressure is caused by molecules transferring momentum to vessel walls, temperature is related to the average velocity per molecule, and work done by the molecules on the vessel change the volume. Repeating ideal gas experiments done in chemistry courses would not demonstrate how these phenomena are caused by the *molecules,* and we cannot see molecules on the lab bench. A simulation is more illuminating because we *can* see the molecules in action, and we can tune properties like temperature and observe the corresponding molecular behavior.

2.1.5 (4) Laboratory Activities

I have reflected on we conduct laboratory activities in my courses, and three facets emerge: **(i)-(iii)**. In a book we are reading for my current INTD100 section [5], the author draws the *line of demarcation* between science not science with two ideas. First, *science cares about data,* collected from a controlled experiment. Second, *science is willing to change theories based on new data.* Thus, facet **(i)** of the laboratory tenet of my teaching philosophy is to show the students that **science cares about data** (*shared meaning*). However, raw data can be made to "say" anything if we fudge it enough. Facet **(ii)** is about **learning to keep an experiment under control** (*order*). Students learn through controlled experimentation that IF they perform an experimental action and THEN the data responds accordingly, with no other factors being changed, the most convincing results are generated. Finally, given that no experiment has infinite precision, facet **(iii)** is about **error analysis** (*order*).

Facet (i): science cares about data

(a) *For this teaching activity, can you describe your interpretation of the learning process?* It might seem obvious that physical science courses need laboratory work. At first, some students are not skeptical when we show them how theoretical physics makes a prediction. Some are accustomed to being told what to think, and others place too much trust in the order of theoretical physics. We need to perform experiments to provide the students with hard proof that what we are teaching them is real. Though facet (i) may or may not help with solving word problems, the students see on a deeper level that physics is built upon incontrovertible evidence.

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* Constructing a good lab activity for physics courses is an art form[7]. Design an apparatus that is too complex, and the students will learn nothing. To

[7] I am grateful to Prof. Seamus Lagan for taking time to help me grow in this area.

simple, and the apparatus will not tell the students anything. As a department, we maintain a library of proven labs based on our experience and PER. It is vital that we maintain the integrated lecture-lab format for our courses. The lab activity that provides the proof of a theorem immediately follows the traditional lecture and PI that introduced it. The students are given time and space to apply what they've just learned, and their efforts are rewarded with proof that what they've learned works. For practical reasons, students work on the lab activities in groups of 2-4 (see below).

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* Goal (D) (taken from my syllabi) is "to practice scientific experimentation, data analysis, and reporting of results." Lab groups (2-4 people) work together to understand the lab activity, so they engage in a form of *shared meaning.* When proctoring these lab activities, I usually observe the following behaviors in my students: one student explaining to another why something is not working, how to compute the result from the data, or even waving their hands to model *why* they think the result makes sense. On the lab handouts I provide, I require the students to create graphs, calculate numerical results from raw data, and to report results. Thus, we reach goal (D) as a team. Periodically, we compare results group by group or with my version of the setup at my desk[8]. This prevents the groups from getting stuck on the wrong path.

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* Performing experiments to confirm hypotheses from theory is at the core of physics. It would feel strange to teach an introductory course with *only* theoretical problems. The reasons why we conduct labs in an integrated lecture-lab format are to reinforce the theory the students learn only moments prior, and to give them the opportunity to prove the theory works. Encouraging them to generate this proof tells them that we respect their natural skepticism and curiosity.

Facet (ii): learning to keep an experiment under control

(a) *For this teaching activity, can you describe your interpretation of the learning process?* Sometimes people use the phrase "if this then that" (ITTT) to represent causal connections. For some lab activities, we can give the students a knob, lever, or action that they can use to tune to the effect on the data. One example is my magnetic induction lab, in which a magnet on a spring bounces into and out of a coil of wire. Students view the voltage induced in the coil with an oscilloscope. *Faraday's Law* states that the rate of change of the magnetic field in the coil determines the amount of voltage in the coil. *If* the students tune the velocity of the magnet by compressing the spring more, THEN the size of the oscilloscope signal increases. When the students experience ITTT they see equations like Faraday's Law with new eyes. Laws of physics are not abstract equations, but descriptions grounded in ITTT.

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* See facet (i), question (b). It is important to note that ITTT is less obvious in some labs. One example is a lab covering Snell's Law, which predicts the outgoing angle of a refracted laser beam given the angle of incidence on a glass surface. The glass has a fixed index of refraction that relates incoming angle to outgoing angle. While we can change the incoming angle and see the effect on the outgoing angle, we cannot change the index of glass. However, the students experience ITTT for this property of light via a PhET simulation. In the simulation, we *can* tune the index, and see that the outgoing angle of the laser light changes, even though the incoming laser beam is not moving.

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* Facet (ii) is derived from the principle of *order.* We design our lab activities such that the students are supposed to change only one input at a time to examine the effect on the outcome. Students quickly learn that if too many inputs are changing simultaneously, the data will be useless. So facet (ii) serves goal (D) ("to practice scientific experimentation, data analysis, and reporting of results") in the sense that it enables the data analysis. When students draw a connection between ITTT and data analysis, they tend to design experiments of their own that are kept under control.

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* If we did not think deliberately about facet (ii) when designing lab activities, then student learning would be diminished because the results would only generate confusion. Students are disappointed when their lab "didn't work," and they do not gain anything from the activity. Thus, we design lab activities to be controlled so that the students learn from the results. By the end of the semester, I prompt the students to design their final projects such that they are kept under control.

Facet (iii): error analysis

(a) *For this teaching activity, can you describe your interpretation of the learning process?* Part of the learning process for physics students is to notice that experimental results rarely match theoretical predictions exactly. Understanding why this happens, and learning to improve both the precision and accuracy of our experiments is vital for student success. Introductory physics students usually attribute disagreement between data and theory to "human error," and

[8] I'm grateful to Prof. Glenn Piner for this suggestion.

it takes time for them to learn that statistical error occurs naturally. I have created special lab activities focusing on statistical error[9], and I place them in the middle of the semester after the students are more familiar with lab technique. Learning to accept and manage statistical error, in my opinion, takes longer to solidify in the students' minds than facets (i)-(ii). Because my introductory courses are year-long sequences, I choose not to rush facet (iii) into the process, but to build it slowly.

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* I create specific lab activities that teach both physical concepts and focus on statistical error. We practice error propagation, when multiple measurements with error are combined in a formula to produce a result with compounded error. We practice comparing results across lab groups to show that error is indeed statistical, and not a function of who is performing the measurement.

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* The tenet of *order* with respect to facet (iii) is critical to achieving goal (D). My students learn that we can achieve order out of the apparent chaos of analyzing raw data, which in turn helps them to produce results capable of convincing others that physical laws hold despite imprecision.

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* Error analysis is usually the most unfamiliar facet of lab activity education for my students. Many students do not experience it until they reach college. Thus, I must lead highly scaffolded activities regarding error analysis and propagation to give the students time and space to learn it.

2.1.6 (5) Synergies

My reflections give one facet **(i)** that makes the synergy between traditional lecture, PI, and laboratory activities useful for students: **solidifcation.** In my answers below, I choose as an example my unit on DC circuits. We are equipped with DC circuit tools in our labs, and an excellent DC circuits PhET is available[10]. Thus, I can give traditional lecture content about circuits, have the students discuss circuits via PI, and follow that with an integrated PhET and lab activity. I call facet (i) **solidification** because the students observe the match between there algebraic calculations, the simulation, and the lab activity all in the same class session. Seeing this match gives the students a sense of satisfaction that they understand the topic completely.

Facet (i): solidification

(a) *For this teaching activity, can you describe your interpretation of the learning process?* Students are fully prepared to apply and remix the ideas of physics in their own projects when the ideas solidify in their minds. The ideas feel right on a deeper level if they have correctly demonstrated them as theoretical predictions, ideally simulated, and tested practically in the lab. After solidification, their confidence is such that they stop questioning their understanding of a concept and start using it without hesitation. Picture a baseball player who "just knows" how to hit a pitch without thinking. Consider again the example of DC circuit analysis. Using the ideas that energy and total charge are conserved (constant) within a circuit, students can solve systems of equations that predict currents through multiple devices connected to a battery. The algebra can become complex and confusing. In the PhET, however, current and charge are animated, and the rules of the algebra are illustrated. The students build on the bench the exact same circuit they have constructed virtually, and show that the volts and amps in real life match the simulation. This leads them back to their algebra, which they can force to agree with their lab results. Apprehension fades to confidence when they see that they got it all to work.

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* The incorporation of tools and practices is the same as learning activity (4) (Laboratory Activities). Whenever this synergy bonus is possible, I put it into practice. The limiting factor is the availability of PhET simulations corresponding to each laboratory activity we must perform.

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* The synergy bonus my students derive from solidification is an important part of *shared meaning.* As a group, the students construct an apparatus for performing a measurement, match it to simulation, and understand it mathematically. They confirm that they share a consensus as to *why* it all works together, and their consensus is confirmed when I gather and display the results from each group. All parts of learning goal (D) are enhanced by this synergy.

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* I cannot predict when the light bulb will activate for a given student and a given topic. We all witness these little miracles, when a student's eyes

[9] See supplemental material.

[10] `https://phet.colorado.edu/en/simulations/circuit-construction-kit-dc`.

grow wide as an idea solidifies in their mind. We cannot always know whther traditional lecture, PhET, or lab will be the activity that illuminates a student. By including the synergy activity, I am maximizing the number of light bulbs activated in my class session.

2.1.7 (6) Student-Designed Final Projects

My reflections give two facets **(i)-(ii)** that makes the student-designed final projects useful for students. Facet (i) is about **individual creativity**. The creativity required for a good final project is related to developing both order and shared meaning within a lab group in my courses. Facet **(ii)** is about developing a shared meaning with an audience: **communication of abstract arguments, numerical results, and graphical results.**

Facet (i): individual creativity

(a) *For this teaching activity, can you describe your interpretation of the learning process?* In lieu of a final exam, my students propose, build, execute, and present their own physics project. During the semester, we practice many facets of lab technique and theoretical calculations. The student-designed projects meet a final learning need left unaddressed by our other activities. Schemes for brilliant confirmations of physical laws are often concocted when we have a stroke of creativity. Creativity is a mode of thought very different from methodical algebraic derivation or meticulous experimentation. The students beam when they get a chance to combine their creativity with physics in the final project. I think this is because they finally have a chance to express themselves scientifically. These summative projects allow them to apply what they've learned to a topic about which they are curious. They are confronted by the usual practical concerns and errors of experimentation, but the reward is knowing that they can use physics to understand the world.

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* I first invite proposals from lab groups that outline what they will measure. Proposals must include diagrams and lists of parts they will need, including any lab equipment from our department. Members of lab groups are fully responsible for coordinating the experiment with each other, and creating the final presentation. Though I actively debug experiments with students, I am cautious in that phase to provide just enough guidance such that they see the path forward without doing it for them.

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* Facet (i) is about creating both order and shared meaning. Once the students agree on an idea, they take ownership of it to make it a reality. In our past communications, I have shown you how intricate and exciting these final projects can become. Learning goal (E), taken from my syllabi, is "to practice written and oral expression of scientifically technical ideas." Asking the students to own their idea and make it reality from inception to presentation is the best way I can imagine to address goal (E).

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* I can clearly observe how my students shine in this learning activity. The reason why I include the creative aspect (facet (i)), as opposed to deciding what their project will be, is that they are creatively energized to do science. The results have been wonderful and fascinating to watch.

Facet (ii): communication of abstract arguments, numerical results, and graphical results

(a) *For this teaching activity, can you describe your interpretation of the learning process?* Learning to communicate the results of the final projects is just as much art as it is science. The best way to learn it is to do it and see if people understand you. Students draw upon experiences in activity (3), PhET simulations, to help with creatingi meaningful graphs of data that can be interpreted by the class. One semester, I tried to incorporate more than one student-led project, but the students told me that it made the semester too complicated. I have settled on administering just one summative project. Students can learn by imitating or remixing techniques in past presentations, so I give them example presentations created by me and my students from past courses.

(b) *For this teaching activity, how do you incorporate teaching tools and practices?* The final presentation can be given live in class, or developed using digital storytelling techniques[11]. The results are presented to the class near the end of the semester, and we get a chance to ask the lab group questions. Given the group size (2-4 students) and the average number of students in my classes (≈ 25), we limit the presentations to 15 minutes so that the presentations take 1-2 days. I review the presentations before they are given to the class, to help the students polish them and eliminate errors. During the presentation, I encourage the audience to ask the presenting group questions. Sometimes students feel shy about asking questions, so this is the hardest element of facet (ii) to implement.

[11] See Secs. 2.1 and 2.2 of my prior PEGP regarding digital storytelling and the use of WeVideo. On my syllabi (included in supplemental material), the live or WeVideo options are called option A and B.

(c) *For this teaching activity, can you show how the tenets of your teaching philosophy help achieve learning goals you set for your courses?* Facet (ii) is about developing a *shared meaning* between myself and the presenting group, and between the presenting group and their peers. Showing your results to others is fundamental to science, which is why I've included learning goal (E) in my syllabi. Facet (ii) of the student-led projects gives the students time and space to practice learning goal (E) ("to practice written and oral expression of scientifically technical ideas").

(d) *For this teaching activity, can you focus on the "why" of specific teaching decisions?"* See (d) of facet (i). The students enjoy having a chance to express themselves scientifically as they own these projects and make them shine.

2.1.8 Outlook

In our last communication, you recognized that I have a plan that appears to be working well for the students, and that my course evaluations reflect that. As I've been in my room reflecting on why I teach the way I do, I've found that solving this rubix cube helps me to concentrate. I laughed to myself when I realized that asking a physicist and engineer like me to write about teaching philosophy is like asking me to solve this rubix cube. That is, I know what the final result should be (students successfully learning physics), but I'm less clear on how to lay out the pieces of the philosophy correctly. When I've asked colleagues over the years to describe a teaching philosophy, I never hear a clear definition, but many facets. Some say to express your values. Others say to describe practices and pedagogy. Some say that a personal narrative is important. I've tried to align the facets of my teaching for you in a way that is, if nothing else, easy to understand.

One recent development in my teaching is the inclusion of **online laboratory activities**. We began using services like Pivot Interactives during quarantine, when we were barred from doing any in-person teaching. Online lab activities give the user a chance to play a video of a constructed apparatus in operation. The user can use on-screen tools to collect data from the video. Built into the lab web page are tools for creating graphical results from this data. Data analysis, question prompts regarding conclusions we draw from the results, and grading are all seamlessly integrated. It is tempting to use these online lab services going forward. I am of two minds about this strategy.

Online lab activities will not replace activity (4) of my philosophy, but they have interesting facets that make them useful for students. Online labs remove the confusion inherent to constructing lab apparatuses, which makes them more like learning activity (3): PhET simulations. In fact, online labs and PhETs share facets (i)-(ii) of tenet (3) of my teaching philosophy. They are not simulations, though, because the apparatuses are real but filmed. The data is collected from a physical system subject to statistical error. The potential for statistical error makes online lab activities more like learning activity (4): laboratory activities via facet (iii) of activity (4). The systems being filmed in the online labs are systems we can build in our labs, but sometimes we have not had the time to build them yet.

I imagine, as with all teaching decisions, the question will be resolved by making an overall determination about how well the activities serve the students. If the students' experiences of facets (i)-(iii) of activity (4) are not diminished by including online labs, then we will probably continue to include them. However, if the students begin to view them like PhET simulations, then the line between simulation and reality would be blurred. This is not good for science, and we would boost the number of standard laboratory activities. In any event, I hope it is clear that I have a conscientious teaching philosophy that continues to serve students well at Whittier College, and I always welcome your insight and wisdom.

2.2 Introductory Course Descriptions

Here I describe the introductory courses I taught in AY 2021-20220, with connections to learning activities in my teaching philosophy, departmental goals, and learning focuses listed in Appendix xxx.

Algebra-based physics (135A/B). Algebra-based physics, PHYS135A/B, is a two-semester integrated lecture/laboratory sequence covering classical mechanics (Newton's Laws) to electromagnetism[12]. PHYS135 is a requirement for majors such as KNS, CHEM, and pre-medical students. Students practice problem-solving with algebra, trigonometry, and vectors. I employ the active learning strategies (1)-(6) in Sec. 2.1 to satisfy departmental goals 1, 4, and 6.

The first learning focus for non-majors is **curiosity**, with the measureable goals stated in Appendix xxx. The content associated with learning activities (4)-(6) in Sec. 2.1 are chosen to boost students' curiousity. This is especially true of learning activity (6), the student-led final project in which they design their own physics experiment. I also help the students to practice communication of scientific ideas (**Departmental goal 7**) by giving them an extra credit

[12]See supplemental material for example syllabi.

opportunity in which the communicate the recent findings of scientists at other institutions to the class. Once the students overcome nerves, they begin to volunteer and choose content connected to their major. The second introductory focus is **improvement of analysis skill**. To address this focus, I use learning activities (1)-(3). PI modules, PhET modules, and traditional lecture content form a flexible and diverse strategy for improving the students' analysis skill (**Departmental goals 1, 4, and 6**).

My third introductory course learning focus is **applications to society**. The obvious routes are the applications in the OpenStax texts [6] regarding kinesiology and medicine. The students experience PI modules and example problems with topics such as motion/work/energy in the human body, and nerve cells as DC circuits. The modules I select depends on the students' majors. Including content specifically pertaining to the students' majors is highly beneficial to keep students engaged.

2.3 Analysis of Course Evaluations: Introductory Courses

Question	Text
10	This course had clear goals and objectives.
11	This course was academically challenging.
12	This course offered useful learning tools (such as lectures, discussions, readings, assignments and/or examinations).
13	This course had grading criteria that were clearly identified.
14	This course improved my understanding of the material.
15	This course increased my interest in the subject matter.
16	Overall, I would recommend this course to others.
17	The professor used class time effectively and demonstrated preparation for class.
18	The professor's teaching style and/or enthusiasm for the material strengthened my interest in the subject matter.
19	The professor was able to explain complicated ideas.
20	The professor challenged students to think critically and/or imaginatively about the course material.
21	The professor provided clear and timely feedback.
22	The professor encouraged meaningful class discussions.
23	The professor was receptive to differing views.
24	The professor was available for help outside of class.
25	Overall, I would recommend this professor to others.

Table 2.1: The listing of standard course evaluation quesions.

The course evaluations for PHYS135A/B taught in AY 2021-2022 are shared below. These courses were the only introductory courses I taught this past year. On the course evaluations, questions 10-16 pertain to the course, and questions 17-25 pertain to the professor. Table 2.1 lists the standard questions.

The course evaluation data for algebra-based physics is shown in Tab. 2.2. The question definitions are listed in Tab. 2.1. The data cover three courses: sections 1 and 2 of 135A (Fall), and section 2 of 135B (Spring). Fall courses (135A) cover units and vectors, kinematics, forces, energy, and momentum. Spring courses (135B) cover electromagnetism topics like charge, fields, current, DC circuits, and magnetism.

I have reflected on the student feedback for these courses. I find that the numerical results are in line with recent years. My implementation of the teaching philosophy in Sec 2.1 is generating very positive feedback from the students. Looking for numerical trends in Tab. 2.2, I do see that I still struggle occasionally to boost student interest in physics

Question	Fall 2021 (1)	Fall 2021 (2)	Spring 2022 (2)
10	5.0	4.8	4.9
11	4.8	5.0	4.9
12	5.0	5.0	4.9
13	5.0	4.6	4.7
14	4.9	4.6	4.8
15	4.5	4.1	4.7
16	4.9	4.6	4.8
17	4.8	4.9	4.9
18	4.8	4.8	4.8
19	4.7	5.0	4.9
20	4.8	4.9	4.9
21	4.8	4.9	4.8
22	4.6	4.6	4.8
23	4.9	5.0	4.8
24	4.9	5.0	5.0
25	4.9	5.0	4.9

Table 2.2: Course evaluation results for PHYS135A sections 1 and 2, and PHYS135B section 2. Questions 10-16 refer to the course, and questions 17-25 refer to the professor.

(Question 15). This is true of the course, historically, as many students are nervous to take this course. This year-long sequence of algebra-based physics is a must-pass course for pre-medical students and KNS majors.

The written responses provide some good clues as to how to fine-tune algebra-based physics. In Sec. 2.1, I was reflecting on whether or not to include more online laboratory activities, in addition to the laboratory activities done on the lab bench. There seems to be a common theme in the written responses: the students enjoy the lab activities and even want more of them. The online labs sound like they do not hurt, but there is definitely a preference for hands-on labs. This could help boost the interest and excitement of those last few students who are less interested in physics at first.

The other student comments were about little adjustments they would appreciate: more consistent uploading of grades to Moodle, taking a break in the middle class sessions, and removing the custom questions from the online homework system. Regarding the latter, I have done that already. The online homework system is fully integrated with our OpenStax textbooks (see Sec. 2.2.1 of my prior PEGP), and artificial intelligence is included. The AI tries to assign extra problems to homework sets that are tailored to the student. The idea is to nudge the student to study areas in which they need more practice. We found this feature to be glitchy, and did not add much value. Overall, it is very heartwarming to read the students' positive encouragements in their written responses, and I'm always open to suggestions.

2.4 Advanced Course Descriptions

What follows is a description of the advanced physics and computer science I taught in AY 2021-2022, with connections to departmental goals, learning focuses listed in Appendix xxx, and tenets of my teaching philosophy from Sec 2.1.

Computer Logic and Digital Circuit Design (PHYS306/COSC330). Computer Logic and Digital Circuit Design is cross-listed as PHYS306/COSC330. My first task for the design of this course was to use the advanced learning focus of *strength in all phases of science*, and *to satisfy departmental goals 4-7*. The topic of electrical engineering has many phases, from the underlying mathematics to the hands-on experience of designing and building logic circuits. This is a 300-level course that satisfies requirements in the following majors: Physics, ICS/Physics, ICS/Economics, 3-2 Engineering/Math, 3-2 Engineering/Computer Science. Courses like COSC330 that serve such a variety of students should touch on at least the following sub-topics: (i) binary mathematics, non-decimal base systems, and boolean logic, (ii) basic digital components, clocks and gates, (iii) implementation of boolean algebra with complex logic functions (iv) creation of digital circuits and projects, and (v) analysis of digital data, analogue-to-digital and digital-to-analogue conversion (ADC and DAC).

In the design of this course, I kept in mind my advanced learning focus of *mental discipline* by attempting to make the course challenging for the students within each of the above topics. As with any physical science or engineering course, the design must include the following phases: *mathematics, computer programming and modeling, hardware design and testing, and digital data analysis* (strength in all phases of science)[13]. As with many of my courses, I include student-driven final projects in the design, to meet my advanced learning focus of *communication* within a technical subject. As I teach the course I've designed, I use the active learning strategies (1)-(6) developed in my teaching philosophy (Sec. 2.1). One key difference is that I rarely use learning activity (2) (peer-instruction) in this advanced course, because PI works best for larger courses.

The first half of COSC330/PHYS306 class sessions are spent learning number systems like binary and hexidecimal, boolean algebra and logic functions, and increasingly complex logic circuits. We apply these concepts to designing digital circuits, and we also cover how these tools have applications in business. One example is how to simplify a logic function, and how that technique can simplify a business workflow. The digital design labs rely on the PYNQ-Z1 system-on-a-chip (SoC). To set up a system the student, I install a Linux operating system on a laptop, and use it to download an operating system for the SoC. The PYNQ-Z1 is called a SoC because it has both programmable logic firmware (PL) and a processing system (PS) like a small computer. The default operating system for PYNQ-Z1 contains example code the students use to learn. Students create digital circuits inside the SoC by writing code in Python3. When traditional lecture and lab activities are woven together in this course (learning activities (1) and (4) of my teaching philosophy), the students achieve an understanding of embedded digital systems.

I provide a bridge to one of my other advanced courses, COSC360 (digital signal processing - DSP), by finishing the lab activities (tenet (4) of my teaching philosophy) on an ADC lab. The students capture analogue voltage signals from an external source, digitize it using the SoC, and graph it using Python3. This lab activity serves as model for how sensor data is digitized, and the starting point for DSP. For the final projects, the students design sensors, timing-based systems like traffic-light controllers, video and sound processing systems, and robotic systems. As with the final

[13] An example syllabus is in the supporting material.

projects in my introductory courses, the results can be presented with digital storytelling or live. The students leap at the chance to express themselves scientifically with these projects.

Digital Signal Processing (COSC390). Digital Signal Processing (DSP) is now listed as COSC360, and it is a 300-level ICS course satisfying requirements in the following majors: Physics, ICS/Physics, ICS/Economics, 3-2 Engineering/Math, 3-2 Engineering/Computer Science. Similar to the design of COSC330/PHYS306, I used *Physics Department goals 4-7* and my advanced coures learning focuses to design (and re-design) this course. One key difference is that I *also* use two aspects of my introductory learning focuses when designing this course (*curiosity and applications to society*). The reason is that a portion of my COSC360 students are non-majors taking a January-term course simply because it sounds interesting.

DSP encompasses the myriad of ways we capture, process, and filter analogue signals like audio signals, medical sensors on the heart and brain, and images. DSP gives students vital practice with loading, cleaning, manipulating, and graphing data. DSP is used by a wide variety of students in fields beyond engineering. Our students also practice a vital STEM skill in DSP: Fourier analysis. This technique allows a student rearrange data comprised of *time-dependent* signals into *frequency-dependent* signals. One economics student, for example, was able to find periodic trends in the stock market using this technique.

My course design touches upon the first advanced learning focus (*mental discipline*), by including both the underlying mathematics of DSP, and practical applications. One such application is the sampling, digital filtering, and visualization of electronic music. I have taught this course twice, once in January 2019, and again this past January 2022. We meet for three hours each morning for three weeks in the January term format. Homework sets are assigned each day, and kept short but challenging. The students find this style refreshing and efficient. I would like to re-design the course for a semester-length format, and the students have requested that in the past. If given the chance to do that, I would incorporate the first advanced learning focus through more extended applications to music, the stock market, and image analysis.

The second learning focus for advanced course design is *strength in all phases of science.* COSC360 follows COSC330/PHYS306 conceptually. One can think of COSC330/PHYS306 as learning the building blocks of digital components. Some of those components help create scientific instruments that sample and digitize analog data. DSP is the subject of what follows *after* sampling and digitization. The students have creatively applied the material: my student Noah Wilson created an analysis of Federal Reserve interest rate data over many decades using DSP, and my student Jake Householder used Fourier analysis to study periodic trends in the stock market. As with COSC330/PHYS306, we conclude the course with final projects (learning activity (6) of my teaching philosophy) that foster communication of technical ideas in line with department goals.

Electromagnetic Theory (PHYS330). Electromagnetic theory is a course taught in every department of physics. It is an advanced theoretical physics course utilized by 3-2 engineering, physics, and math students. It builds upon vector calculus (MATH241) and calculus-based physics II (PHYS180), and vector calculus is built from single-variable calculus (MATH141 and MATH142). I taught this course in Spring 2022 for the first time in-person. I utilized my standard toolkit of learning activities (1)-(6) from Sec. 2.1. However, the students in this course are more advanced, and ready for less of learning activity (2) (peer instruction) and more of learning activity (1) (traditional lecture with warm ups).

The first learning focus for advanced course design is *mental discipline*, so I begin the course with a rigorous review of vector calculus, augmented with online tutorial videos. We use the ubiquitous textbook for this course entitled *Introduction to Electrodynamics, 3rd ed.* by David Griffiths. The book contains a thorough mathematical warm-up chapter, and we choose to complete it and draw upon the concepts throughout the semester. When I was in college, we used the 2nd edition and spent one 14-week semester covering most of the book. Other institutions spend two full semesters covering the whole book. My task set by my department is to cover the first half of the book in one semester. This exposes the students to (i) review of vector calculus, (ii) the distribution of electric charge and the electric fields created by charge, (iii) the energy and voltage corresponding to those fields, (iv) how those fields behave inside materials, (v) moving charge, current, and magnetic fields, and the associated energy, (vi) the behavior of magnetic fields behave in materials, and (vii) how light is actually radiating electromagnetic waves.

The second and third learning focuses for advanced course design are *strength in all phases of science,* and *communication.* PHYS330 is one of our upper-division electives that is centered on abstract problem-solving and numerical prediction/modeling, so laboratory activities do not play a role. We build beautiful, intricate theoretical ideas that the students will use in future engineering and scientific contexts. I try to include demonstrations of modern computational electromagnetism (CEM), with experience drawn from my research with the Office of Naval Research (ONR). See Sec. 3 for more details. As with COSC330/PHYS306 and COSC360, we conduct final projects in line with learning activity (6) of my teaching philosophy, department goals, and my third learning focus for advanced courses.

Question	Fall 2021
10	4.9
11	4.9
12	3.9
13	4.3
14	3.9
15	3.7
16	3.7
17	5.0
18	4.4
19	4.0
20	4.4
21	5.0
22	4.8
23	5.0
24	5.0
25	4.3

Table 2.3: Course evaluation results for COSC330/PHYS306.

2.5 Analysis of Course Evaluations: Advanced Courses

The course evaluations for advanced STEM courses described in Sec. 2.4 are shared below.

Computer Logic and Digital Circuit Design

The course evaluation results for COSC330/PHYS306 are shown in Tab. 2.3. The questions pertaining to the professor (questions 17-25) are generally higher than those pertaining to the course (questions 10-16). When I saw the numbers in Tab. 2.3, I was not surprised and I know of three reasons why the course went the way it did. First, some history is relevant. This is the third time I have taught this course, and I have built experience teaching it. The last time I taught this course was during Spring 2020, and the scores were very high despite the rapid transition to online teaching that semester (see Sec. 2.6 of my prior PEGP). In Spring 2020, I found the right balance of laboratory activities and traditional lecture, and the transition to DSP topics worked well. The students felt like hackers from the movies and were generally impressed by the material. Students gave me high marks and praise in the written responses. For Fall 2021, some students felt the exact opposite about the course material as their peers from 2020.

I think there are three reasons why this occurred. First, I was asked to move the course to the Fall semester, which placed it after some of the COSC students had taken Prof. Lutgen's course on microprocessors. Some students asked me if my course would be too similar to microprocessors. I told them that my course was about what happens (essentially) beneath the hood of microprocessors: the digital circuits that make up the logic of computer chips. After creating the course from scratch in Spring 2018, I've always had a mindset of recruitment for COSC330. I want to ensure that enough students take the course to justify the work required to put together such a large, complex integrated lecture-lab course on engineering. This led me to accept students that I should not have accepted into the course, namely those who already took microprocessors. I think these students felt they were repeating the same material on a more introductory level. It seems like one student wrote along these lines in the evaluations.

The second reason is that I accepted too many students into the course (16) when it worked well at 12 students. It turns out that at least one of my students was not prepared to take this advanced course, and I should have provided better guidance about when they should enroll. Also, the integrated lecture-lab format is highly effective when I had two students per lab group in this course. However, with the higher number of students, some lab groups had to be three people which left one person passively observing. The lab component of this course drove its success last time, so the larger class made the students' lab activities more awkward.

The third reason is related to the second. With the larger class size, I could not devote the time I would have liked to the students who were struggling. Toward the end of the course, some were mastering the material, some had seen it already in microprocessors (with Prof. Lutgen), and some where struggling. I had to advise the students' final projects in addition to helping with homework and labs, and it felt a lot harder than in Spring 2020. As we transitioned to the DSP material in COSC330, and as I began to pitch the Jan Term COSC360 (DSP) course, a subset of my students showed eagerness to take COSC360 while others did not. The students who did take COSC360 later gave me stellar reviews (see below).

Thus, I recommend four modifications for COSC330. First, I think a smaller class size (≈ 12) will serve students better due to the nature of the integrated lecture-lab format. Second, we need better coordination with the Math department

Question	Jan 2022
10	4.9
11	5.0
12	5.0
13	4.8
14	4.9
15	4.5
16	4.6
17	5.0
18	4.9
19	4.6
20	4.8
21	4.6
22	4.5
23	4.9
24	4.9
25	5.0

Table 2.4: Course evaluation results for COSC360.

so that the course does not overlap with microprocessors (COSC390). Third, we should spend more time in the laboratory, as it seems students prefer learning activity (4) (from Sec. 2.1) as opposed to learning activity (1) for this type of course. Finally, since the students seemed to appreciate the DSP content so much, we should further integrate it into COSC330. I would like to form a two-semester sequence from these two courses, COSC330 and COSC360. I do not mean one would be pre-requisite for the other, but that the two courses should be more integrated.

Digital Signal Processing

The results for DSP (COSC390) are shown in Tab. 2.4. This is the second time I have taught this course. The students rewarded me with high marks. There is a common refrain through the written responses, and it is familiar from the last time I taught DSP (Jan 2019). The students are asking that we make this a full-semester course. Now that this course is in the course catalog as a full course, with a designated course number (as opposed to its former number, COSC390: special topics), we are prepared to offer it regularly. The final hurdle is to sort out with the Department of Mathematics when we should teach COSC330 and when we should teach COSC360. Normally, this would be a logistical problem because there are a finite number of students who would take advanced programming and engineering courses.

According to our institutional research, this is changing. COSC360 is a course suited, for example, to students in the ICS/Math major. The ICS/Math major has grown by more than 900% since 2018. Given the demand for graduates in engineering, data science, and software development, I forsee sufficient demand for a semester-long version of DSP. Both sets of students in 2019 and 2022 requested it, and now there will be no January term going forward. There is a wrinkle in this argument, because Prof. Glenn Piner now teaches a data science course (COSC180). COSC360 is at the 300-level, however, with more advanced mathematics. Thus, I expect first-years and sophomores to take COSC180, and juniors and seniors to take COSC330 and COSC360. Overall, I am very pleased with the results of DSP, including the fact that we have served non-majors who have performed interesting final projects despite not having the same technical background as the majors.

Electromagnetic Theory

The course evaluation results for PHYS330 are shown in Tab. 2.5. In general, the results are good. Spring 2022 was the first semester in which I taught this course outside the module system, and the first time I've taught it in person. After reflecting on our experience in PHS330 for Spring 2022, I'm relieved and happy. This is one of our most advanced theoretical physics courses, and it is based on no fewer than seven pre-requisite courses. Students must pass Calculus I-III, Calculus-based Physics I-III, and Modern Physics, before taking Electromagnetic Theory. My students in Spring 2022 took Calculus III during the module system. As I related in my prior PEGP, asking *human beings* (let along college students who sometimes work jobs) to finish a course like Calculus III in just seven weeks is not reasonable. People can only absorb so much technical or abstract material in a short time. I was aware of this issue, however, so I utilized the vector calculus review chapter (Chapter 1) of our textbook to help the students prepare. In addition to learning activity (1) (Sec. 2.1), I created many video tutorials for my students based on Chapter 1.

One student wrote in the course evaluations that they would like to see more visualization, more 3D modeling and animation of the electromagnetic fields. It just so happens that my research has been focused lately on computational electromagnetism (CEM) (see Sec. xxx). I recently gave an invited lecture at MIT on my CEM work. One of the

Question	F2020
10	4.8
11	5.0
12	4.6
13	4.6
14	4.6
15	4.6
16	4.6
17	4.6
18	4.6
19	4.8
20	5.0
21	5.0
22	4.8
23	5.0
24	5.0
25	5.0

Table 2.5: Course evaluation results for PHYS330.

organizers, a long-time MIT professor of applied physics and math, explained how we can use CEM codes to enhance our teaching of electromagnetic theory. Incorporating CEM into PHYS330 would be very similar to incorporating the Python3 code that operates the PYNQ-Z1 board in COSC330. I can use Jupyter[14] notebooks to run CEM calculations hosted on Moodle and run via the web browser. I think this will enhance PHYS330 for the students by connecting it to modern engineering applications.

2.6 The Future

things

[14] https://jupyter.org/

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	COM1/Intro
Fall 2019	INTD255	3.0	23	CON2
Spring 2020	COSC330/PHYS306	3.0	13	Advanced
Spring 2020	PHYS135B-01	4.0	23	Intro
Spring 2020	PHYS180-02	4.0	24	COM1/Intro
Summer 2020 (Session II)	MATH080	3.0	11	Intro
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
Spring 2021 (Module 2)	PHYS135B-02	4.0	17	Intro
Spring 2021 (Module 3)	PHYS135B-01	4.0	25	Intro
Fall 2021	COSC330/PHYS306	3.0	16	Advanced
Fall 2021	PHYS135A-01	4.0	24	Intro
Fall 2021	PHYS135A-02	4.0	25	Intro
Jan 2022	COSC360	3.0	16	Advanced
Spring 2022	PHYS135B-02	4.0	25	Intro
Spring 2022	PHYS330	3.0	12	Advanced
Summer 2022	MATH080	3.0	3	Intro
Students/Credit: 5.1	**Credits/Course:** 3.6	**Students/Course:** 18.4	**Credits/year:** 21	**Advanced/Total:** 24%

Table 2.6: This table is a summary of courses taught in five years, plus Summer sessions. Not included: PHYS396 (Physics Research for Credit), PHYS499 (Senior Seminar), and PHYS495 (Independent Studies).

Chapter 3

Scholarship

We as facutly at Whittier College classify scholarship according to the Boyer model, and my scholarship tends to fall within the categories of the scholarship of discovery, and the scholarship of application. In Sec. 3.1 I describe my physics research in the area of ultra-high energy neutrino physics (UHE-ν). In Sec. 2 of my prior PEGP I shared how, through my scholarship, Whittier Colllege is now a member institution of the IceCube Collaboration (Gen2) (`https://icecube.wisc.edu`). I have published original scholarly work with the help of an undergraduate research student that represents a significant contribution to the future of IceCube Gen2 (Sec. 3.1). I also write about my future plans with high-performance computing (HPC) and machine learning applications for IceCube Gen2, and grant submissions we have written for this purpose.

In Sec. 3.2 I describe my growing relationship with NSWC Corona Division, a US Navy research laboratory in Corona, CA, through the Office of Naval Research (ONR). Primarily an engineering and computer science research facility, NSWC Corona serves the Navy through advances in logistics, reliability research, metrology, and radio-frequency (RF) communications and radar. My relationship with ONR and NSWC Corona has produced a publication, three summer fellowship grants, and grant resources like lab equipment for Whittier College. The work has inspired collaboration with academics in engineering and physics at other institutions. This summer I was an invited to speak about our ONR research at a national conference at the Massachusetts Institute of Technology (MIT). Finally, in Sec. 3.2 I am pleased to share that our colleagues at NSWC Corona would like to form an Educational Partnership Agreement (EPA) with Whittier College. If adopted, the EPA will provide enduring research experiences, internships, and career prospects in engineering for the next generation of Poets.

3.1 Ultra-High Energy Neutrino Research with IceCube Gen2

Cosmic rays are high-energy protons, electrons, and nuclei propagating through space near the speed of light. They carry information from other regions in the galaxy, and in some case, other galaxies. Since the discovery of extremely energetic cosmic rays more than a half century ago, the quest to uncover their sources continues. Despite progress in experimental capabilities and theoretical insight, we do not yet know the acceleration mechanism for those particles with energies that have been measured in excess of 10^{20} electron-volts [7]. Being electrically charged, cosmic rays paths are curved by electromagnetic fields in space. By the time the cosmic ray arrives at Earth, the arrival direction no longer points back to the origin. In addition, interactions with cosmic microwave background (CMB) photons can block ultra-high energy cosmic rays from reaching Earth [8] [9].

Neutrino astronomy offers a powerful tool to discover the physics associated with cosmic ray acceleration, which is not accessible with other *messengers*: cosmic-rays, gamma-rays, and optical photons. Charged cosmic rays which interact with gas, dust, or radiation near an accelerating object produce gamma-rays and high-energy neutrinos. These neutrinos are called *astrophysical* neutrinos. Whereas gamma-rays can be absorbed in dense environments, astrophysical neutrinos can escape and travel unimpeded to a detector ([10] and references therein). Neutrinos travel at the speed of light in straight lines, undeflected by electromagnetic fields. This allows for identification of sources, as well as the potential for finding sources that emit both neutrinos and gravitational waves [11].

The most energetic cosmic rays that do escape their source can interact with the CMB en route to the Earth, generating *cosmogenic* neutrinos with a characteristic energy distribution peaking at 10^{18} electron-volts [12] [13]. Astrophysical and cosmogenic neutrinos offer a window into regions of the Universe far beyond what is possible with other messengers. A flux of neutrinos originating outside the solar system with energies between 10^{13} and 10^{15} electron-volts has been measured by the IceCube collaboration [14]. Previous analyses have shown that the discovery of ultra-high energy neutrinos (UHE-ν, energy greater than 10^{15} electron-volts) will require a detector with a larger volume because the flux decreases with energy [15]. UHE-ν are the ones that could potentially explain the origin of cosmic rays. UHE-ν also provide the chance to study quantum mechanical interactions never probed before [10] [16].

Utilizing the *Askaryan effect*, in which UHE-ν creates a radio-frequency pulse, greatly expands the effective volume of UHE-ν detector designs. This effect is important for UHE-ν detection, because radio pulses travel more than 1 kilometer in Antarctic and Greenlandic ice [17, 18, 19, 20]. Stations can be placed 1 km apart, and the volume of the overall array of stations is large enough to capture UHE-ν. The large volume is necessary for two reasons. First, cosmic rays and neutrinos at these energies are rare enough that a 10×10 km^2 target is necessary. Second, neutrinos do not always interact in dense matter quantum mechanically, unlike protons or heavy ions. To ensure that we record the UHE-ν that do interact, we must construct a large detector.

3.1.1 Publication: A Fully Analytic Model of the Askaryan Effect

Given the importance of Askaryan radiation for UHE-ν science [21, 22, 23, 24, 25, 26, 27], I embarked in 2020 on a mission to be the first to publish a fully analytic model of Askaryan radiation. A fully analytic model differs from semi-analytic and fully simulated models because the latter two cases involve computations that cannot be written mathematically. I describe four advantages of fully analytic models below. Making this project fully analytic represented new exploration for me in mathematical physics. My normal role in my department is to be the engineer and experimental physicist. During quarantine, however, I could not access my lab. In truth, the idea had been on my mind since 2017, when I first published on the subject as a CCAPP Fellow at The Ohio State University [28]. I am pleased to share that my final results have been published in *Physical Review D* [29]. Physical Review D (PRD) is one of the most impactful journals in elementary particle physics, field theory, gravitation, and cosmology[1]. In Secs. 3.5 of prior PEGP, I shared how this work was submitted to PRD and favorably reviewed (published on the physics arXiv: `https://arxiv.org/`). After over a year in review, the editor was told to add another reviewer. I ultimately succeeded after rewriting the manuscript in 2021-2022.

The publication has marked a milestone in my career, for three reasons. First, this work is the first I have published in PRD, which is considered the top journal in my field. Second, this is the first time I have helped a Whittier College undergraduate publish in a peer-reviewed physics journal. Raymond Hartig, a double-major in physics and mathematics, has been an enormous help in verifying my calculations and incorporating our equations into IceCube Gen2 detector simulations. I have published other papers in my time at Whittier College, and I have always involved undergraduates in my research. But my work with Raymond represents the first time we have published undergraduate research in a *physics* journal, as opposed to an engineering journal. Third, this work represents the first time I have published a paper on theoretical or mathematical physics, as opposed to experimental or applied physics. As I described in Sec. 3.5 of my prior PEGP, this work represents my third published paper in a peer-reviewed journal in my time as a Whittier College physics professor in satisfaction of departmental guidelines for tenure.

Undergraduate Research and the Fletcher-Jones Fellowship

My first child was born in May 2020, just as the first wave of the pandemic began exponential growth. Suddenly, all laboratory research halted, and I needed a project I could complete at night after the baby was asleep. Thankfully Raymond Hartig, a student I had been preparing for some mathematical physics project during the Spring 2020 semester, won a Fletcher-Jones Fellowship from Whittier College. Using pen and paper, and communicating over Discord, we sought to expand my work from Ohio State into a fully-analytic time-domain model [28]. Raymond explored one path while I explored another, until we found the right path. To say he worked hard is an understatement. We arrived at the central results, and began a manuscript during January term of 2021. The results are a formula for the electromagnetic field versus time, emitted by a neutrino hitting ice at the speed of light. This field will be a critical signal for IceCube Gen2. Raymond applied for the Ondrasik-Groce Fellowship in the Summer of 2021. After we learned we were unsuccessful, I paid him from my research startup grant so he could continue helping with the paper.

Undergraduate Research and the Ondrasik-Groce Fellowship

This Summer, Raymond and I won the Ondrasik-Groce Fellowship to advance the Askaryan model research. Our idea is to use the model to measure the energy of the UHE-ν in IceCube Gen2. Imagine detecting a radio pulse deep within

[1]Physicists use a metric called an impact factor to gauge the strength of a physics journal. The impact factor provides a functional approximation of the mean citation rate per citable work. An impact factor of 1.0 means that, on average, the articles published 1-2 years ago have been cited one time. PRD had an impact factor of 5.4 in 2021, placing it in the top 5 APS journals, and the top position for high-energy particle physics journals. For comparison, *Astroparticle Physics Journal*, another journal frequently used by my colleagues, has an impact factor of 2.7.

Antarctic ice, potentially caused by a UHE-ν. The actual data collected is a waveform captured by RF channels built from antennas, amplifiers, and filters. Using the waveform to deduce UHE-ν properties requires us to perform a simulation using some Askaryan model and knowledge of the RF channels. Our first task this Summer was to incorporate our newly published model into NuRadioMC, the flagship simulation package for IceCube Gen2. I shared in Sec. 3.5 of my prior PEGP that I created one of the pillars of NuRadioMC by solving the ray-tracing problem of RF pulses in Antarctic ice [30] [31]. Raymond has done a good job of incorporating our model into NuRadioMC, and checking that the results match other (non-analytic) models. Now that this job is done, we are working out how to measure the UHE-ν energy using simulated neutrinos in IceCube Gen2. The analytic nature of our model makes this possible because one of the parameters in the model is derived from the UHE-ν primary energy. One the protocol is established, I believe this will represent our second PRD publication.

Three Applications of the Askaryan Model and Future Plans

There are at least three main advantages of analytic time-domain models. The first pertains to our Ondrasik-Groce Fellowship project: UHE-ν properties like total energy may be derived directly from the waveforms if they are matched to analytic ones. Second, evaluating a fully analytic model provides a software speed advantage compared to other models. Third, analytic models may be embedded in detector firmware to form a filter that blocks noise and enhances the UHE-ν detection probability. This feature will greatly enhance IceCube Gen2 prospects because of the rare nature of UHE-ν signals. My vision for the future of this work involves three tracks.

The first track involves UHE-ν template analysis. NuRadioMC, is broken into four pillars. Currently, UHE-ν are simulated first as events (NuRadioMC pillar (1)) and the RF emissions (Askaryan signals) are generated next (NuRadioMC pillar (2)). Our ability to match simulated waveforms to potential UHE-ν waveforms from the detector is limited because we cannot scan through properties of the simulated cascades of particles created by the UHE-ν, only the UHE-ν properties. For example, two UHE-ν with the same energy could generate different cascades with different shapes of electric charge. The cascade shape affects the waveform shape and therefore the interpretation of future IceCube Gen2 data. Conversely, if the effect of the cascade shape is understood, one can measure the UHE-ν energy using templates [29].

The second track involves embedding the model itself in detector firmware. The detector cannot distinguish small signals from noise. Noise and signal data that trigger detectors and are both saved. We try to isolate UHE-ν signals in large data sets comprised mostly of radio noise once the data has been transmitted to the USA. All data has to be shipped with limited bandwidth, and we cannot ship it continuously. Embedding the model on the detector would allow the detector itself to locate and flag priority events that appear to match UHE-ν. The physics community expects IceCube Gen2 to provide this type of alert system so that other detectors could search for UHE-ν sources identified by IceCube Gen2. Thus our approach makes possible an approach that is fast enough to solve the problem.

The third track involves the connection between computational electromagnetism (CEM) and our Askaryan model. In NuRadioMC the simulated signal is created by code in pillars (1)-(4) sequentially. That is, the Askaryan model is mixed with detector response after ray-tracing. In reality, the radiation flow does not have to follow strictly ray-tracing, but the 3D index of refraction of the ice. It is a wave that generally follows ray-tracing, but also reflects from internal ice layers, propagates horizontally, and can change shape. All the effects not captured by the smooth index of refraction function, n, will affect the signal. Fully-analytic Askaryan models have a unique advantage: analytic equations can be implemented as CEM sources, and CEM codes can account for all those effects. The analytic model is in a unique position to provide advanced insight when combined with CEM.

3.1.2 Publication: Greenlandic Ice and the Radio Neutrino Observatory, Greenland (RNO-G)

During my time in graduate school at UC Irvine, and as a post-doctoral fellow at the University of Kansas, I conducted expeditions to Antarctica to gather data and deploy UHE-ν detector prototypes. We collected radio sounding data to measure the RF transparency of the ice, to ascertain whether the ice could be used as a detection medium for IceCube Gen2 and its associated prototypes. A radio sounding experiment is when an RF pulse is transmitted through ice and the echo is received. The echo time is related to the ice thickness, and the strength of the returning RF pulse is related to the ice transparency. I published a paper in the Journal of Glaciology on the RF transparency of the Ross Ice Shelf [17]. In 2017-2018, my colleagues and I wrote a second paper revealing that classically forbidden RF ray-tracing behavior can occur in the same ice [32]. The Radio Neutrino Observatory, Greenland (RNO-G) project was formed in the hope that Greenlandic ice would also have sufficient RF transparency for a UHE-ν detector. Initial measurements from a 2014 expedition to Summit Station, Greenland, were conclusive enough to begin RNO-G development [18]. The

2014 expedition, however, was limited to just a single RF frequency, and the raw data was not easily distinguished from RF background noise.

Thus, a new mission to Greenland was undertaken to collect data at a wider range of frequencies with larger signal strength. I am a member of the RNO-G collaboration, and I have helped RNO-G to submit grant proposals for hardware development. I was asked to be an internal reviewer for the peer-reviewed article once the expeditioners returned with the new RF transparency data. An internal reviewer in physics is someone who serves a scientific collaboration through critiquing and revision of journal articles before they are submitted for formal peer review. Given the size of physics collaborations in my field (sometimes we have ≈ 100 scientists in one collaboration), internal reviewers play a vital role in maintaining the flow of polished, professional results. I helped to fix errors and analysis issues in the manuscript. I am happy to share that we have published the results in the Journal of Glaciology this Summer [33]. The results indicate that Greenlandic ice is almost as transparent as the ice at the South Pole, and suitable for RNO-G to move forward. This is the second time I have reviewed an article as a Whittier College professor, but the first time I've been trusted with the responsibility as an internal reviewer.

3.1.3 Grant Applications Submitted, and Future Plans

In my scholarship related to IceCube Gen2, we have been active in the area of grant-writing for computational physics. I have two ongoing efforts to share with you. If either of the projects below is successful, it will empower our Askaryan field research and enable new endeavors with IceCube Gen2 simulations and data analysis.

Supercomputers and the Wisconsin IceCube Particle Astrophysics Center (WIPAC)

In the Spring and Summer of 2022, members of the IceCube Collaboration submitted a grant proposal that included Whittier College[2]. We worked with the Wisconsin IceCube Particle Astrophysics Center (WIPAC: `https://wipac.wisc.edu/`) to develop a proposal that will advance high-performance computing (HPC) to serve our field and many other forms of science. The proposal is entitled "MRI: Acquisition of the Heterogeneous Accelerator Lab (HAL) at University of Wisconsin-Madison." MRI stands for Major Research Instrumentation, and the MRI program through the NSF is used to build resources and tools for science at universities and labs. If successful, this grant will provide resources for the construction of HPC resources augmented by special systems known as computational accelerators. Thus, the proposed system is known as HAL, or Heterogenous Accelerator Lab.

Accelerators are specialized instruments: different scientific problems can have different optimal hardware deployment. Having a diverse array of computational hardware within an HPC system enables exploration of artificial intelligence (AI), simulation, and data processing techniques across a wide variety of scientific fields. To maximize the utility of a new HPC system in such a quickly evolving technological landscape, HAL will consist of heterogeneous hardware and co-processors designed to serve all of these fields. HAL personnel will focus on the deployment, management, and operation of a dynamic and heterogeneous pool of accelerator capacity. In addition to the diverse computational capability, HAL will broaden participation by diverse groups of researchers at the undergraduate level if the NSF approves it.

The HAL team has made a committment to the empowerment of Whittier College students. If funded, access to HAL will be provided to students and researchers at Whittier College as if they were UW-Madison researchers. By sharing its resources via the Open Science Pool (OSP) compute federation, HAL will enable Whittier College students to take advantage of new computing power in their projects. For example, Whittier College students involved in machine learning and AI projects in the ICS/Math and 3-2 Engineering/Computer Science areas could have access to systems capable of completing projects we cannot currently complete with our in-house resources. Further, our students would benefit by learning to connect to and interact with the Open Science Grid.

Machine Learning in High-Energy Astrophysics

During the Spring of 2022, my colleagues at UC Irvine who are also IceCube collaborators included Whittier College in an NSF grant application geared towards machine learning applications to high-energy astrophysics.
xxx

[2]See supplemental material for details.

3.2 Collaborations with the Office of Naval Research (ONR) and NSWC Corona Division

intro

3.2.1 Radio-Frequency (RF) Engineering, with Applications to Radar and IceCube Gen2

what led to the paper, and the implications of it

Publication: Broadband RF Phased Array Design with MEEP

this was all me baby

Undergraduate Research and the Fletcher-Jones Fellowship

Include Adan Wildanger and 3-2 program

Undergraduate Research with Physics Research (PHYS396)

Include Dane Goodman and Andrew Householder

Invited Lecture: First Annual MeepCon at MIT (Summer 2022)

first invited lecture 45 min killed it

3.2.2 Research Grants: ONR Summer Faculty Research Fellowships (SFRP)

t

Workforce Development: Active Learning in the Armed Services

course 1 and 2

Grants Received: SFRP Status

money, equipment, and include mention the MSF as well

3.2.3 Future Plans: Educational Partnership Agreement (EPA) with NSWC Corona Division

mention equipment, high-performance computing, reliability engineering, internships

Chapter 4

Service

A key part of our

4.1 Committee Service

In 2017, my department had arranged my schedule such that I did not serve on a committee for the first year. By Fall 2018, I had developed the idea that I could serve Whittier College through data analysis. I was interested in the connection between the high school preparation of our students and their ability to pass introductory courses required for their major. On the Enrollment and Student Affairs Committee (ESAC), in Fall 2018, I learned that this is a topic with which many administrators and intructors had been struggling. I spent two years working on ESAC, and I watched as our committee carefully approached consensus while remaining respectful of the diverse perpectives that included athletics, student life, and instructors. In the second year, we began discussions with Falone Serna, Vice President of Enrollment Management, to implement the policy result of the prior year. On ESAC, I also learned about first year orientation, for which I volunteered in 2019 and 2020.

In 2020-21, having served two years on ESAC, we decided it would be good for me to experience service with other types of committees.

4.1.1 Educational Policy Committee

My sub-project, the survey. Framing the issue of the course system, understanding it. Mathematical analyses of the proposals: (a) financial implications (b) pedagogical implications (c) curricular implications (d) the compromise i offered that was accepted regarding maximum course loads

4.1.2 The Whittier Scholars Program

Another year, another advisee, acceptance to join the WSP board

4.1.3 Future Proposals for Institutional Research

Full utilization of the Tableau dashboards left by Gary Wisenand, growth of the ICS/Math major etc.

4.2 First Year Orientation

In the Fall of 2018, I was invited by Prof. Seamus Lagan to help with the first-year orientation.

The second mentoring experience in 2020 occurred during the height

4.3 Open Educational Resources (OER) Workshops

I was invited to give two lectures at OER workshops

The OpenStax Tutor system

In my OER lectures, I also gave examples of OER usage in advanced courses.

4.4 Center for Engagement with Communities: The Artemis Program

In Sec. ..., I wrote about my experiences serving the Artemis program. To avoid covering the same ground twice, I give just a simple summary of the facts here.

Chapter 5

Advising and Mentoring

I reflect on my role as an advisor and mentor at Whittier College below.

5.1 Connections to Teaching, Advising First-Year Students

Advising and mentoring students resembles our teaching practice, because we must create a sense of *order and shared meaning* in the mind of the student surrounding the curriculum.

Physics professors often classifiy students into two broad categories: *non-majors* and *majors* (see Sec. 2.1). Most of our advisees as teachers fall into the first category.

Advising non-majors follows a basic progression: introducing them to the curriculum and campus (*order*), beginning a conversation surrounding major selection (*shared meaning*), and future course selection.

5.2 Advising and Mentoring First Year Students

A

5.2.1 First Year Advising, by the Numbers

B

5.2.2 Navigating the First Year

C

5.2.3 Discernment of Major

D

5.2.4 Equity of Access

E

5.2.5 Inclusion and Belonging: Activities with First Year Advisees

5.3 Advising and Mentoring Majors in Physics, ICS, and 3-2 Engineering

After reflecting on my advising practices with my STEM students, I realized that there is an implicit decision-tree that lives in my mind (see Fig. 5.1).

Semester	**Number of First Year Advisees**
Fall 2019	15
Fall 2020	14
All semesters	**Physics, ICS, and 3-2 Majors**
	Cassady Smith (Physics '20)
	John Paul Gómez-Reed (Math/ICS '21)
	Nicolas Clarizio (Physics, Business Admin. '19)
	Alex Ortiz-Valenzuela (3-2 Engineering/Physics '22)
	Raymond Hartig (Physics and Math '23)
	Adam Wildanger (3-2 Engineering/Physics '21)
	Matthew Buchanan Garza (ICS/Physics '23)
	Natasha Waldorf (ICS/Physics '24)
All semesters	**Whittier Scholars Program Majors**
	Nicolas Bakken-French (WSP '21)

Table 5.1: A summary of my advisees, broken into three categories: first-year advisees, STEM majors, and WSP majors. There are some first year advisees who have chosen ICS/Math for their major, for whom I remain a mentor. One example is Emily List (ICS/Math '23).

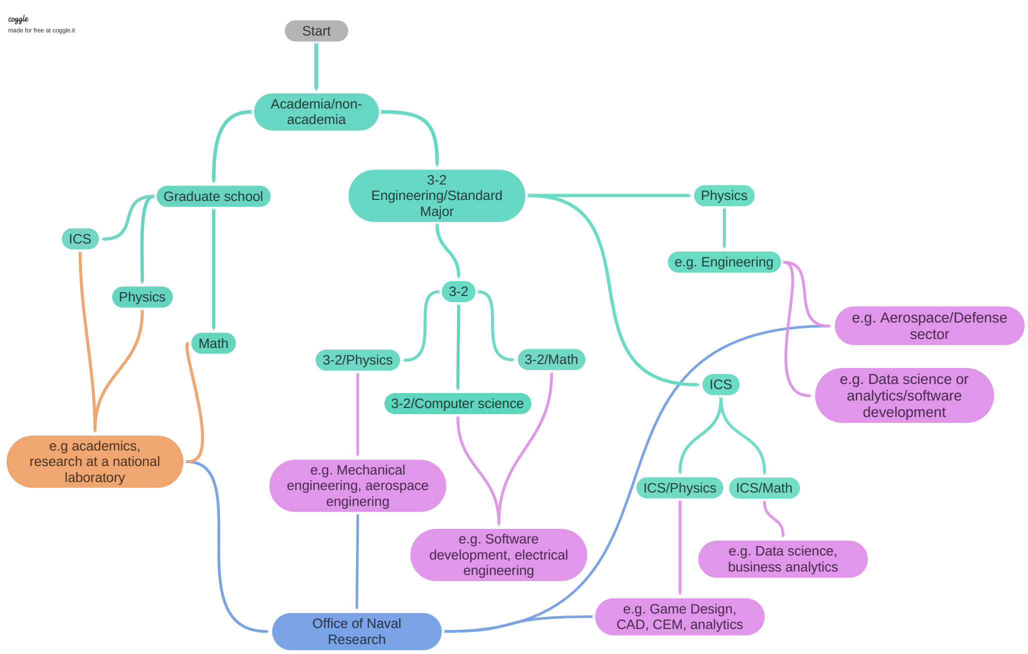

Figure 5.1: A decision-tree that orders my thinking around the advising of my STEM students.

5.3.1 Discernment within STEM: Major Selection, and Diverse Pathways to Graduation

Discernment means the ability

5.4 Advising and Mentoring Whittier Scholars Program Majors

I have had a wonderful time recruiting students for the Whittier Scholars Program. There are two moments that stand out for me. The first happened when I accompanied Nicolas Bakken-French to his final meeting with Profs. Rehn and Kjellberg,

Now mention Jackson Diamond, and the connection between WSP and computer science

Chapter 6

Conclusion

This semester marks the beginning of my sixth year with Whittier College. These years have been filled with both wonderfully uplifting experiences, but also sacrifice. I hope that my writing

Respectfully submitted, Jordan C. Hanson

Chapter 7

Appendix: Supporting Materials

A simple listing of supporting materials referenced throughout the report is given below.

1. **Previous Letter from Faculty Personnel Committee**
2. **Letter from Department of Physics and Astronomy**
3. **Curriculum Vitae**
4. **Course syllabi**
   (a) PHYS135A: Algebra-based physics 1
   (b) PHYS135B: Algebra-based physics 2
   (c) PHYS150: Calculus-based physics 1
   (d) PHYS180: Calculus-based physics 2
   (e) PHYS306/COSC330: Computer Logic and Digital Circuit Design
   (f) PHYS330: Electromagnetic Theory
   (g) COSC360: Digital Signal Processing (DSP)
   (h) INTD100: College Writing Seminar
   (i) INTD255: Safe Return Doubtful: History and Current Status of Modern Science in Antarctica
   (j) INTD290: A History of Science in Latin America
   (k) MATH080: Elementary Statistics
5. **Course Evaluations** (each corresponds to courses listed above)
6. **Published Papers**, lead author
   (a) "Observation of classically 'forbidden' electromagnetic wave propagation and implications for neutrino detection." JCAP (2018).
   (b) "Broadband RF Phased Array Design with MEEP: Comparisons to Array Theory in Two and Three Dimensions" Electronics Journal (2021). Results from this paper also published in the Proceedings of the International Cosmic Ray Conference (ICRC) 2021.
   (c) Two notices from Electronics Journal indicating the above paper was in the Top 10 Most Notable articles in the journal in 2020-21.
   (d) "Complex Analysis of Askaryan Radiation: A Fully Analytic Model in the Time-Domain" (Phys. Rev. D) 2021.
7. **Other Papers**, contributed but not the lead
   (a) "A search for cosmogenic neutrinos with the ARIANNA test bed using 4.5 years of data." JCAP (2020).
   (b) "NuRadioMC: simulating the radio emission of neutrinos from interaction to detector." European Physical Journal C (2020)
   (c) "Probing the angular and polarization reconstruction of the ARIANNA detector at the South Pole." JINST (2020).

8. **Letters of Recommendation** (Advising and Mentoring)
    (a) Cassady Smith (2017)
    (b) Nicolas Haarlammert (2017)
    (c) John Paul Gómez-Reed (2018)
    (d) Nicolas Clarizio (2020)
    (e) Eliott Bergerson (2020)
    (f) Razmig Bartassian (2020) (2 letters)
    (g) Raymond Hartig (2020)
    (h) Taylor Watanabe (2020)
    (i) Raymond Hartig (2021)
    (j) Danny Diaz (2021)
    (k) Adam Wildanger (2021)
9. **Examples of Student-designed Final Projects**
    (a) Taylor Watanabe (MATH080), presentation
    (b) Teani White (PHYS135B), presentation
    (c) Emmie Fernandez (MATH080), presentation
    (d) Natasha Waldorf (INTD100), writing project
    (e) Scout Mucher (INTD290), infographic
    (f) Elmer van Butselaar (PHYS135A), paper
    (g) Andrew Householder, digital storytelling project
10. **Letters from Students and Colleagues**
    (a) Chistopher Clark, PhD (Office of Naval Research)
    (b) Taylor Watanabe, student from PHYS135A/B and MATH080
    (c) Raymond Hartig, student from PHYS150/PHYS180, PHYS306, INTD290, physics advisee
    (d) Nicolas Bakken-French, Whittier Scholars Program advisee
    (e) Email correspondence from Profs. Gragnani and Fedeli of Universtà de Genova regarding potential radar design collaboration
11. **ESAC Admissions Data Presentations**
    (a) Results presented November 15th, 2018
    (b) Results presented December 6th, 2018
12. **Grant Proposals and Evidence of ONR SFRP Grants**
    (a) Cottrell Scholars Grant Proposal
    (b) SFRP, Summer 2020
    (c) SFRP, Summer 2021
13. **Open Educational Resources (OER) Workshop Lectures**
    (a) Workshop January 28th, 2020
    (b) Workshop July 28th, 2020
    (c) Workshop March 2nd, 2021
14. **Course Materials Referenced in Teaching Section**
    (a) Error analysis in PHYS180, group lab activity
    (b) Paper about the contributions of Mexican astronomers in the late 18th Century, reading assignment for INTD290 (A History of Science in Latin America)

(c) Unit on nerve function, PHYS135B, lecture notes and activities
(d) Number systems of the Maya and Inca, asynchronous activities for INTD290 (A History of Science in Latin America)
(e) Spring Force Lab, lab activity for PHYS135A and PHYS150
(f) Example of an article bonus (see Teaching Section)
(g) Information on Artemis Program (see Service Section)

15. **Research Related Materials**
    (a) ***Whittier Scholars Program Thesis, Nicolas Bakken-French***
    (b) LA County Aerospace Cluster information sheet (See Research Section)
    (c) "The Changing Face of Aerospace in Southern California," report referenced in Research Section
    (d) Study regarding physics students by the American Institute of Physics (AIP) (see Equity and Inclusion Section)
    (e) IceCube Collaboration List of Institutions (See Research Section)

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