Professional Evaluation and Growth Plan

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Contents

1 Introduction **4**

2 Teaching **6**
2.1 Teaching Philosophy: Six Easy Pieces of Active Learning Technique . . . 6
2.1.1 General Approach: How I Teach with Six Easy Pieces (1)-(6) . . . 6
2.1.2 (1) Traditional Lecture Format . . . 7
2.1.3 (2) Peer-Instruction (PI) . . . 9
2.1.4 (3) PhET Simulations . . . 10
2.1.5 (4) Laboratory Activities . . . 11
2.1.6 (5) Synergies . . . 13
2.1.7 (6) Student-Designed Final Projects . . . 14
2.1.8 Outlook . . . 15
2.2 Introductory Course Descriptions . . . 15
2.3 Analysis of Course Evaluations: Introductory Courses . . . 16
2.4 Advanced Course Descriptions . . . 17
2.5 Analysis of Course Evaluations: Advanced Courses . . . 19
2.6 All Courses (Fall 2017 - Present) . . . 21

3 Scholarship **22**
3.1 Ultra-High Energy Neutrino Research with IceCube Gen2 . . . 22
3.1.1 Publication: A Fully Analytic Model of the Askaryan Effect . . . 23
3.1.2 Publication: Greenlandic Ice and the Radio Neutrino Observatory, Greenland (RNO-G) . . . 24
3.1.3 Grant Applications Submitted, and Future Plans . . . 25
3.2 Collaborations with the Office of Naval Research (ONR) and NSWC Corona Division . . . 26
3.2.1 Radio-Frequency (RF) Engineering, Applications to Radar and IceCube Gen2 . . . 26
3.2.2 Research Grants: ONR Summer Faculty Research Fellowships (SFRP) . . . 28
3.2.3 Future Plans: Educational Partnership Agreement (EPA) with NSWC Corona Division . . . 29

4 Service **30**
4.1 Committee Service . . . 30
4.1.1 Educational Policy Committee . . . 30
4.1.2 The Whittier Scholars Program . . . 32
4.1.3 Future Proposals for Institutional Research . . . 32
4.2 First Year Orientation . . . 33
4.3 The Quantitative Success Center . . . 33
4.4 Inclusivity in Introductory STEM Courses . . . 34

5 Advising and Mentoring **35**
5.1 Connections to Teaching, Advising First-Year Students . . . 35
5.2 Advising and Mentoring First Year Students . . . 35
5.2.1 First Year Advising, by the Numbers . . . 35
5.2.2 Navigating the First Year . . . 35
5.2.3 Discernment of Major . . . 35
5.2.4 Equity of Access . . . 35
5.2.5 Inclusion and Belonging: Activities with First Year Advisees . . . 35
5.3 Advising and Mentoring Majors in Physics, ICS, and 3-2 Engineering . . . 35
5.3.1 Discernment within STEM: Major Selection, and Diverse Pathways to Graduation . . . 35
5.4 Advising and Mentoring Whittier Scholars Program Majors . . . 37

6 Conclusion **38**

7 Appendix: Supporting Materials **39**

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 am pleased to report that my students are growing intellectually and achieving professional success. 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.

I have answered each question (a)-(d) for each tenet of my teaching philosophy in Sec. 2.1, after reflecting on what teaching practices I use most often. This exercise has been useful and enlightening. It is my hope that it provides you with useful insight into modern physics instruction. I have also concluded that the *learning focuses* I have shared previously serve as guides to my course creation and course content selection. These ideas were derived originally from my colleagues in my department, and I have modified them and made them my own. Though my teaching practices continue to generate positive student feedback, I have also identified areas of courses that need to be adjusted.

I have new and exciting sholarship to share with you in Sec. xxx. I highlight three recent experiences as examples. 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 a student who has become a dear friend. This result marks the first time our department has published in a *Physical Review* journal in 16 years[2]. In the article, my student and I offer the first fully analytic model of Askaryan radiation. The results represent a significant contribution to my field (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, 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 three ONR Summer Faculty Research Program (SFRP) grants, I am eligible for ONR Senior Fellowship. Our ONR partners at NSWC Corona Division have granted us money and precision RF equipment to boost engineering research for 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. The EPA will be wonderfully beneficial to our students (Sec. 3.2).

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 participate in the United States Antarctic Program (USAP). As part of my

[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).

research[4], I have conducted expeditions to Antarctica through USAP. 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 professional endeavors with the same organization, mental discipline, and curiosity required of explorers. I am thrilled to share that we are sending our first Poet to Antarctica. Scout Mucher, who was my student in INTD290, was inspired to go. I helped Scout qualify as a contractor serving USAP operations in McMurdo station on Ross Island. Scout has now PQ'd (physically qualified), and will journey South when the sun rises this Fall!

For my committee service in AY 2021-2022, I joined the Educational Policy Committee (EPC). I had been in discussions with Prof. Andrea Rehn about joining the Whittier Scholars Program (WSP) council. I agreed to serve on EPC in 2021-2022 because new members were needed, and I put my WSP plans on hold. The major task for EPC was to generate consensus around a revised course system proposal, in light of proposed changes to faculty load. While discussions of the course system and faculty load proposals continued, we also completed many other tasks. These included approving changes to ten major programs and changes to the Center for Engagement with Communities (CEC), raising student per-semester credit limits, revising the definition of a credit hour, and to study the use of "tracks" or "emphases" within major programs at Whittier College.

I led a sub-committee with a goal 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 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. We used this diverse data set to formulate a survey sent to department chairs. The data set and chair responses will be used to inform policy for tracks and options within majors. Having a common language describing options within majors will hopefully help first-generation students better understand 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. I offered a compromise regarding the maximum number of courses per semester that was eventually adopted into the final proposal (Sec. 4.1). I hope this demonstrates for you that I can help build consensus, even when the task is challenging. I give much credit to my colleagues on EPC, and especially co-chairs Profs. Camparo and Householder, for setting a good example. In Sec. 4.1, I propose a few ways in which I can serve Whittier College in the future. 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 (Sec. 4.1).

In Sec. xxx I reflect on my advising and mentoring. You have indicated you are concerned that my advising leads students down a rigid path. You also shared that you would prefer a self-reflective approach to the advising and mentorship section. I have responded to these questions in Sec. xxx. To your point about rigidity, I do not know why the counter-examples to rigidity I provided in my last report did not resonate. I shared my experience with an Physics advisee who, after a period of discernment with me, switched to Digital Art and Design (see Sec. 5.2.1 of my previous PEGP). Philosophically, I motivate my students to take charge of their future in a way that aligns with their values and interests. Our new curricula will include digital portfolios, and our advisees will use these tools and social media tools like LinkedIn to draw connections between projects at Whittier College and future plans that are as diverse as the students themselves. My service to WSP majors also leads students down interdisciplinary paths. In Sec. xxx, I also reflect on my tangible student successes, such as internships, publications, and fellowships.

In Sec. xxx, I describe my new DEI project idea. I had an idea in 2017 to create an app that would facilitate inclusion in introductory STEM courses infused with machine learning to tailor user experience. 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 inclusion in introductory STEM courses given by the Cottrell Scholars Network. I participated in all three of these workshops, and gained useful insights to apply to the project. One of my advisees in computer science has volunteered to lead the app design. We will recruit students from within the Whittier community to develop the digital storytelling aspect of the app. 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 Whittier College has made a positive impact, and that I have earned a place here. I have created and taught new liberal arts and physical science courses that connected my research to social issues and history. I have engaged in fruitful scholarship with my students, and several exciting research pathways have opened for us. I have served committees that have tackled complex issues and built consensus. I have served as a first-year advisor in three different semesters. I have a track record of leading students to successful outcomes. All the while, I have done my best to incorporate your suggestions into my work, and I am grateful for the work that you do.

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

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 especially useful for students who grew up in a bilingual setting. Facet (i) of traditional teaching addresses (B) because I

[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.

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 to the ability to master a concept derived from experimentation well enough to apply it to word problems. Facet (ii) of

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

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 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

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

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 it takes time for them to learn that statistical error occurs naturally. I have created special lab activities focusing on

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

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 grow wide as an idea solidifies in their mind. We cannot always know whther traditional lecture, PhET, or lab will be the

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

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.

(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

[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.

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 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

[12]See supplemental material for example syllabi.

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 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.

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.

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 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.

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

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 and their use in integrated circuits. Several students asked me if my course would be too similar to Prof. Lutgen's course. I told them that my course was about the circuits that create microprocessors and the logic behind the function 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 class size of about 12 students will serve students better due to the nature of the integrated lecture-lab format. The alternative would be to conduct the course in a larger

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.

classroom. Second, we need better coordination with the Math department 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 All Courses (Fall 2017 - Present)

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).

[14]https://jupyter.org/

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 excited 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 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

[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.

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. Raymond plans to apply to graduate school to become a physicist, and these works have helped him to form a wonderful portfolio for his application.

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 and artificial intelligence (AI). 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, included Whittier College in an NSF grant application geared towards AI applications to high-energy astrophysics[3]. The project is entitled "NRT-WoU: Team Science and Science Communication for AI and Multimessenger Astrophysics." The project is an effort to build interdisciplinary cooperation between scientists who care about advancing AI research, and scientists interested in tackling the diverse digital data streams that flow from multi-messenger astrophysics experiments. The term multi-messenger astrophysics means using all available astrophysical messengers to learn about the Universe: gamma-rays, optical photons, cosmic rays, neutrinos, and gravitational waves.

The project has three goals. The first goal is to produce transformational astrophysics research and innovative new AI algorithms. Progress in AI is often driven by people attempting to solve a problem in physics that has practical

[2]See supplemental material for details.

[3]See supplemental materials for project summary. I chose not to include all 28 pages of the grant proposal, but just enough to show the main goals of the project.

applications in other sectors. The first goal is tied to a proposal theme stating that the exchange should be more of an interdisciplinary collaboration. Researchers in AI can contribute and collaborate with astrophysicists in the same way astrophysicists drive progress in AI. The second goal is to increase the training of a diverse group of students with transferable science communication and collaboration skills. To that end, the grant proposal discusses the active training for students in the areas of "team science" and science communication. The third goal is to build new institutional support for interdisciplinary research beyond 5 years after grant acceptance. One example is the creation of a professional MS in Data Science, run jointly by the UCI Schools of Physical Sciences and Information and Computer Sciences. This effort shares traits with Data Science programming begun within our Lux Program.

Whittier College would participate in the UCI NRT proposal via the neutrino science. As founding members of the ARIANNA collaboration [34, 35, 36, 37] and IceCube members, my UCI colleagues and I have been working toward the implementation of my analytic Askaryan model on-board Antarctic stations as described in section 3.1.1. This task is an AI-driven one, with two stages. First, we will implement my analytic equations as a digital model in detector firmware. Second, we will train the firmware with AI to use the model to reconstruct UHE-ν properties from detector data. If a reconstruction of UHE-ν properties is not made in the firmware, we can reject RF background noise in real time. These tasks will improve the sensitivity of IceCube Gen2 to UHE-ν events because the detectors themselves will automatically reject noise in favor of signal. Currently, this process limits the size of the detector array, because humans have to download the data and reject noise offline. In Summer 2018, I began this project with an Ondrasik-Groce Fellowship student named John Paul Gómez-Reed using ARIANNA firmware. With the analytic Askaryan model now published, this project becomes much stronger.

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

Running in parallel with my UHE-ν physics research has been a fruitful engineering collaboration with the US Navy. There is a long history of collaborative engineering research between the military and national laboratory system and the physical sciences in academia. The United States maintains strategic security by collaborating with engineering researchers in academia, who in turn benefit via funding and collaborative opportunities that further research goals. The research, in turn, benefits the people via technological breakthroughs. One of the most famous examples is the Global Positioning System (GPS). The connection to my UHE-ν research is that both the Navy and IceCube Gen2 require me to engage in RF engineering research. This past summer, I have also begun to study the GPS system modernization.

In Sec. 8 of my prior PEGP, I wrote about the opportunity our collaboration with the US Navy represents for our students. The collaboration is funded by the Office of Naval Research (ONR) and takes place at a US Navy laboratory called NSWC Corona Division in Corona, CA. The research has touched on radar and RF component design via computational electromagnetism (CEM), GPS modernization, RF field engineering training, and will in the future include reliability engineering and high-performance computing (HPC). In Sec. 3.2.1, I share how this collaboration has already produced award-winning research that has involved three different Whittier College undergraduates. This research led to an invitation for me to speak at a national CEM conference at MIT[4]. In Sec. 3.2.2, I share how I have been helping NSWC Corona with workforce development using my teaching skills, and how the ONR Summer Faculty Research Program (SFRP) will boost our research in Summer 2024. In Sec. 3.2.3, I share our plans to form a lasting partnership called an Educational Partnership Agreement with NSWC Corona, and the benefit to future engineering students at Whittier College.

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

I received my first Summer Faculty Research Fellowship in the Summer of 2020. Miraculously, the ONR decided that the fellows could conduct research remotely. After a consultation with Gary Yeakley, Dr. Christopher Clark, and Jeffery Benson of NSWC Corona, we concluded I could best serve our mutual interests by designing RF phased arrays. RF phased arrays are groups of individual RF antennas that work together to generate a radar beam that can be steered with no moving parts. This technology is highly useful in field environments that require AESAs: active electronically scannable antennas. IceCube Gen2 and RNO-G will use them as receivers to detect UHE-ν (see Sec. 3.1). The NSWC Corona group, led by Dr. Clark, was interested in developing an AESA for an anechoic chamber testing facility that could mimic radar echos from targets for testing and verification of Navy hardware. I was recruited primarily for my RF engineering background.

[4] See supplemental material, and `https://news.mit.edu/2022/meepcon-comes-to-mit-0817`.

Publication: Broadband RF Phased Array Design with MEEP

Our initial discussions revealed that we needed a free and open-source tool to design phased arrays. This is an example where my teaching greatly enhanced my research. When building COSC330/PHYS306 (Computer Logic and Digital Circuit Design), I had to learn Jupyter (a platform-independent tool for executing computer code in a browser). The free and open-source tool we found useful for designing phased arrays is the MIT Electromagnetic Equation Propagator (MEEP)[5]. The tutorials required knowledge of Jupyter, so my teaching had prepared me well. I launched a project to design a phased array in the [1-10] GHz bandwidth, and a literature search revealed a review published in the open-access journal *Electronics Journal* (MDPI) [38]. The authors mentioned MEEP, but did not include it in their analysis because of the learning curve with the CEM implementation in Python3. I took up the challenge, knowing that the "scale invariance" of Maxwell's equations implemented in MEEP meant that I could use a photonics tool (micrometer wavelengths) to perform computations related to radio waves (centimeter wavelengths).

The result was my first solo-published engineering journal article, and it won Top 10 Most Notable Journal Articles in *Electronics Journal* for six months in Dec 2020-May 2021 (see Supplemental Materials) [39]. The work revealed the world of CEM to me and my NSWC colleagues. It also is an application of high-performance computing due to the acceleration from using many computing cores in parallel. I immediately began to recruit students to dive into this new subject with me. The overall plan is to use additive manufacturing (3D printing) to give rise to free and open-source design and fabrication of RF antennas and phased arrays. There are many applications for these new techniques, but the most immediate will be to lower the cost and time of production for radar systems.

Undergraduate Research and the Fletcher-Jones Fellowship

In the Summer of 2021 I received my second SFRP Fellowship through ONR. I recruited a 3-2 Engineering/Physics major named Adam Wildanger who had been asking about my engineering research with the Navy for a while. He took my COSC330/PHYS306 course, in which I teach students about the connection between the armed services and cutting edge engineering research with applications in civilian sectors. Adam lept at this opportunity, and received a Fletcher-Jones Fellowship for Summer 2021 in tandem with my ONR one. Adam taught me about computer assisted design (CAD) programs so that we could translate our CEM results into a format that can be understood by 3D printers. I built a short curriculum for Adam so he could learn to optimize my initial CEM models and port them to CAD files. Along with our Navy colleagues, we succeeded in printing our first RF antennas. The US Navy has donated sophisticated RF equipment to our engineering labs in the SLC (see Sec. of my prior PEGP).

We discovered that the 3D printing material, which had been advertised as electrically conducting, was not satisfactory for RF design. Though our initial testing in Summer 2021 yielded results that at least matched expectations, I would like to see dramatic improvements before publishing the results. For example, the authors of [40] used similar 3D printing technique to construct a small RF horn antenna. The performance of an antenna is gauged by how efficiently it transmits energy, and how it focuses that energy in the right direction. Though our results were moderately successful in Summer 2021, we have identified and purchased a 3D printing filament with almost three orders of magnitude higher conductivity. At this moment, we are experimenting with it in our machine shop. Meanwhile, Adam graduated to USC via the 3-2 program and is now in his final year there. Soon he will apply to engineering jobs at NSWC and similar institutions, to continue to help us with more open-source CEM applications.

Undergraduate Research with Physics Research (PHYS396)

In the AY 2021-2022, I led a course called Physics Research (PHYS396) that goes beyond my teaching load. My students receive credit for continuing the CEM research. Students like Natasha Waldorf (ICS/Physics and Physics) and Andrew Householder (Physics and Math) helped synthesize Adam Wildanger's results into computer code and documentation that can be learned by new students. Andrew and Natasha provided code that can give a CAD design to MEEP, and MEEP results to CAD. The code base has also been extended to fully 3D antennas from CAD instead of 2D ones extruded into 3D. Further, in PHYS396 we worked with Rudy Jordan in IT to learn to penetrate the Whittier College firewall securly so that my students can run these sophisticated codes remotely. That was our most significant accomplishment, because it took the most work but unlocks new abilities for the students to collaborate with me.

Using my startup grant, I recently acquired a System76 Thelio Major with a AMD Threadripper 3 motherboard. This machine has effectively 128 processors and 0.5 GB of volatile memory per processor. Using parallel acceleration, our designs can increase in complexity and be run faster on multiple processors. All of these processes and documentation were passed on to Dane Goodman[6], who volunteered over Summer 2022. I am running another section of PHYS396 this

[5] `https://meep.readthedocs.io/en/latest/`

[6] Dane is a special person for me, because he has been dedicated to the Whittier College baseball team here for four years including summers. He is now working for free to gain research experience in order to apply for graduate school in astrophysics. Dane has a work ethic and curiosity

Student/Professor	Grant Opportunity	Amount	Dates
Jordan C. Hanson	ONR Summer Faculty Fellow	$16.5k	Summer 2022
Raymond Hartig	Ondrasik-Groce Fellowship	$5k	Summer 2022
Jordan C. Hanson	ONR Summer Faculty Fellow	$16.5k	Summer 2021
Adam Wildanger	Fletcher Jones Fellowship	$5k	Summer 2021
Jordan C. Hanson	ONR Summer Faculty Fellow	$16.5k	Summer 2020
Raymond Hartig	Fletcher Jones Fellowship	$5k	Summer 2020
John Paul Gómez-Reed	Ondrasik-Groce Fellowship	$7.5k	Summer-Fall 2019
John Paul Gómez-Reed	Keck Fellowship	$5k	Summer 2018
Cassady Smith	Keck Fellowship	$5k	Summer 2018

Table 3.1: A listing of the grant opportunities awarded to my students and I.

Fall 2022 semester in which a new diverse group of students will engage with this research. Once we have a working RF prototype with the new conducting material, we should have another publication in *Electronics Journal* with multiple student authors.

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

In the past two years, researchers from several countries have contacted me about my paper in *Electronics Journal* [39]. The authors of [38] contacted me, and they were able to reproduce my results after a fruitful dialogue. As word spread, the creators of MEEP at MIT and Google contacted me over this past Summer (2022) and invited my to give a lecture at a national CEM conference 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[7]. My colleagues in the audience welcomed me as one of their own, and I have decided to continue advancing my CEM research with the Navy over the next few years. At the very least, I have a new set of contacts at other institutions. These professors can accept our students as interns or graduate students, and link our research with industry partners. Primarily, their work focuses on photonics, for which the main application is fiber optic communications and novel optical devices.

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

In addition to my CEM research with Navy colleagues, I have also engaged in the scholarship of application surrounding workforce development for NSWC Corona. I have created two full RF engineering and DSP courses that can be downloaded and viewed by Navy personnel. These have been uploaded to the secure servers at the Corona Division base. The audience for these courses are new or transferred hires that need to review the basics of applied physics in topics like radar and GPS. During the Summer of 2021, I developed a course entitled "RF Field Engineering: A Practical Introduction" that focused on repairing and understanding Navy equipment from a physical and mathematical perspective. In Summer 2022, I developed a course entitled "Introduction to GPS M-Code Signals for Onboarding of Navy Personnel"[8]. These courses are implemented using my teaching philosophy pieces (1), (2), (3), and (5) (see Sec. 2.1). For (5), synergies, there is a synthesizing code example the student must complete to reproduce realistic mathematical models of GPS M-code signals (modern military encrypted GPS signals). My model is shown to match the literature on GPS M-code [41]. For my work in CEM, and for the development of these courses, the ONR award me a third SFRP Fellowship in Summer 2022.

Grants Received: SFRP Status

According to ONR protocols, I become eligible for Senior Faculty Fellowships once I have been awarded an SFRP Fellowship three times. I am eligible to apply in Summer 2023 after a mandatory one-year cooling period. I have included all funding I have received from the ONR, and all student fellowships that I have received up to the present in Tab. 3.1. I have included all equipment NSWC Corona has donated to Whittier College in Tab. 3.2. These items were at first on loan to us, but are now being converted to donations. There are further HPC resources in preparation to be donated to us, pending approval by senior personnel at the lab. Equipment such as the items in Tab. 3.2 are typically donated to colleges and universities when their project life-cylce is complete at the Navy lab and are no longer necessary. In Sec. 3.2.3 below, I articulate a vision for the use of these instruments in Whittier College engineering projects.

that lights up my heart. I made sure to include him in my section of PHYS396 so that he gets course credit.

[7] My lecture slides are included in the Supplemental Material.

[8] The Summer 2022 course slides are included in the Supplemental Material, but I felt including the 2021 course would have been redundant.

Equipment	Purpose	Bandwidth	Cost
Rohde and Schwartz ZVL6 Network Analyzer	Measuring RF power and frequency	9 kHz to 6 GHz	$20k
Rohde and Schwartz NRP-91 Power Sensors (2)	Measuring RF power	9 kHz to 6 GHz	$8k
Aeroflex 3416 Digital RF Signal Generator	Creating RF signals	250kHz to 6 GHz	$12k
Calibration antenna kits (2)	Receiving and transmitting	Varies by antenna	$2k
Calibration test kits for Network Analyzer (2)	Network Analyzer Calibration	6 kHz to 9 GHz	$6k

Table 3.2: A listing of the equipment provided to our labs by the Office of Naval Research.

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

My current point of contact (POC) at the NSWC Corona is Jeffery Benson, who is a telecommunications and software engineer. Mr. Benson has indicated that NSWC Corona is interested in forming a lasting partnership with Whittier College through my scholarship. Known as an Educational Partnership Agreement (EPA), these relationships are essentially memoranda of understanding (MoUs) that open doors for our students. According to the statute governing EPAs (US10 Code 2194), the following activities are examples of collaboration through EPAs with Naval labs:

- Loaning defense laboratory equipment to the institution for any purpose and duration in support of such agreement that the director considers appropriate
- Transferring to the institution any computer equipment, or other scientific equipment, that is
    1. Commonly used by educational institutions
    2. Surplus to the needs of the defense laboratory
    3. Determined by the director to be appropriate for support of such agreement
- Making laboratory personnel available to teach science courses or to assist in the development of science courses and materials for the institution
- Providing in the defense laboratory sabbatical opportunities for faculty and internship opportunities for students
- Involving faculty and students of the institution in defense laboratory projects, including research and technology transfer or transition projects
- Cooperating with the institution in developing a program under which students may be given academic credit for work on defense laboratory projects, including research and technology transfer or transition projects
- Providing academic and career advice and assistance to students of the institution

The statute in US10 Code 2194 also states that "The Secretary of Defense shall ensure that the director of each defense laboratory shall give a priority under this section to entering into an education partnership agreement with one or more historically Black colleges and universities and other minority institutions" defined under the Higher Education Act. Priority is also given to institutions that serve "women, members of minority groups, and other groups of individuals who traditionally are involved in the engineering and science professions in disproportionately low numbers." This gives Whittier College the advantage, since the Navy has an interest in joining with us under the statute to advance the interests of our students.

I could write an entire report on the potential benefits to our students. To stay concise and reflective, I choose to focus on one crucial benefit for our students under the "student internships" bullet above: the SMART program. The Science, Mathematics, and Research for Transformation Program (SMART)[9] is a STEM undergraduate research program that will connect our students to engineering research projects related to my research and that of NSWC Corona. The Department of Defence SMART program will *change the future* for our students that answer this call, because it *grants them college tuition* in exchange for working on the projects developed by myself and my NSWC Corona collaborators. The SMART program offers the most direct path I can imagine for diversifying the STEM workforce. With the tuition burden lifted, students from HSI and HBCU institutions accepted into the program can devote their energy to advancing cutting edge reseach and securing SMART summer internships and professional roles after college. In Sec. 5, I share how we have helped students participate in aerospace, defense, and scientific internships. These opportunities represent springboards for Whittier College graduates to diversify and enhance the future engineering workforce of the United States.

[9]See `https://www.navsea.navy.mil/Home/Warfare-Centers/NSWC-Corona/Careers/Hiring-Opportunities/SMART-Scholarship/`, and the main site: `https://www.smartscholarship.org/smart`.

Chapter 4

Service

As Whittier College moves forward from the pandemic, service to our community has taken on new meaning. We have given more of ourselves to sustain Whittier College than before. In AY 2021-2022, Prof. Andrea Rehn recommended me for the Whittier Scholars Program council. I was, however, asked to volunteer for the Educational Policy Committee, because new members were needed. I decided to step up for Whittier and servce EPC. In Sec. 4.1, I reflect on our accomplishments in EPC, and other committee service topics. This Fall 2022 semester, I am serving as first-year advisor for the third time since I began teaching here. I reflect on my INTD100 exeperiences in Sec. 4.2. I am also helping to form our new Quantative Success Center (QSC) (Sec. 4.3). Finally, I reflect in Sec. 4.4 on a DEI service project I have begun to advance inclusion in introductory STEM courses.

4.1 Committee Service

Here I reflect primarily on my service within the Educational Policy Committee. Since I have been accepted onto the Whittier Scholars Program (WSP) Council, I also reflect on our plans to enhance WSP. Finally, I offer some ideas on how I can serve the college in the future through institutional research.

4.1.1 Educational Policy Committee

Though the charge to EPC in AY 2021-2022 contained many projects and goals, none required as much time and energy as finishing the course system proposal. My honest reflection is that this work was challenging. I trust you to read what I've written within the spirit of honest reflection and service rather than the outcome for the course system.

When I joined EPC, I learned that the course system has been proposed various times in the last 20 years. I asked about the original reasoning, and why my colleagues had spent such time advocating for it. Having served at four institutions of higher education and three Catholic parishes, this debate felt similar to other entrenched debates I have encountered. The original reasons have become blurred, those whose minds were once open have become more solidified, and new factors complicate the discussion. Examples of the latter are the evolving curriculum and the faculty workload. Though the workload is not strictly an issue of educational policy, it is so important to our faculty that it had to be included. Entrenched debates lead to large amounts of accumulated time spent in meetings discussing the proposal. Time *itself* eventually becomes a motivation: "It would be a shame not to pass this ... we've already spent so much time working on it." Given my experiences working at other institutions, these traits are the hallmarks of entrenched debate.

In a lecture entitled "Two Sacred Incompatible Values at American Universities," [42] Prof. Jonathan Haidt (NYU Stern School of Business) defines *motivated reasoning* in the following terms. When someone wants to believe something, they ask internally "*Can* I believe this?" and they search for a single fact to support the claim. When someone does not want to believe something, they ask internally "*Must* I believe this?" and they search for a single fact to reject it. Psychological studies suggest that people engage in motivated reasoning when considering for/against propositions with moral or practical implications for their lives. In discussions, the reasons why members *wanted* or *did not want* to support the course system became clear. Some favored it because they felt it would help financially. Others supported it because they felt it would help their advisees graduate given the loss of January term. Some did not support it because they felt it would hurt a major. Some did not favor it because it seemed to grant degrees to students who do not complete enough academic work.

At first, we were instructed to frame our discussions pedagogically, no matter what our internal motivated reasoning was. One pedagogical task was to define a course. Courses are as diverse as human thought: some are lighter, some more intense, more narrow, or broadly focused. The goal was consensus for a solid course definition, and for the number of courses required to graduate. We were instructed to use 32 courses as the industry standard. A student could take courses that corresponded formerly to 3 credit-hours for a degree with 96 credit-hours, compared to the original 120 to graduate under the credit system. The same calculation with 4 credit courses leads to 128 credits, and performing a weighted average given what students take still produces results lower than our current requirement. The average is weighted because the ratio of 3 credit to 4 credit courses depends on the student. It became necessary to compare the workload for 3 and 4 credit courses. I had assumed that 4 credit courses were more work, but I learned it can depend on how work outside of class is counted[1]. We settled on a definition of about 150 minutes of class time, plus 7-9 hours of work outside of class[2]. This compromise felt, to me, like one born out of necessity to make progress.

Given our experience with the course definition discussions, we took several logical steps to ensure students will graduate smoothly and on time under either system. We raised the students' per semester credit limit to 17, and worked together to secure the approval of the faculty. We also updated the definition of a credit-hour, after reviewing material from 4-year liberal arts colleges within and outside of WASC regarding total credits to graduation given their credit-hour definitions. We began a sub-committee project, which I led, to understand and classify "tracks," "emphases," and "options," within department majors. The goal for that sub-committee project is to standardize language surrounding major programs in order to help students understand their options and plan for graduation. I reflect on the outcome of this project below, after I complete my reflection on the course system proposal.

Another component of the proposal was the proposed cap on courses per major. Since a bedrock goal of the system is graduation in 4 years, there is some upper limit on the number of courses students can take. With a finite number of courses to select, it would be unorthodox for a liberal arts college student to concentrate course selection in a single subject. Some pressed for just 11-12 courses per major. One third of the courses would be in the major, one third would be liberal arts requirements, and one third would be for "exploration." There is a simple counter-argument: some major programs cannot exist with 11-12 courses. Consider the KNS major with "pre-physical therapy emphasis"[3]. There are two ways to estimate the number of courses: count the courses currently required, or total the credits and divide by an appropriate denominator. The KNS department lists 21 courses required. We also find about 21 courses if we total the credits and divide by 3.5 credits per course[4]. Thus, capping majors at 11-12 courses would eliminate one of our most popular majors.

We did find a potential compromise: count only KNS courses (that is, the department of the major) towards the cap. The total KNS courses in the major would stay under the cap (11), since the other courses come from CHEM, BIOL, MATH, PHYS, and PSYC. This logic applies to any major requiring courses outside the major department. Some EPC members eventually revealed their motivated reasoning behind supporting the cap on majors. Some want to incentivize students to take courses in departments and subjects that need more students. I consider my conscience well-formed on this point. Though a central facet of a liberal arts education is experiencing diverse thought, we cannot make students take courses they don't wish to take. The moral responsibility for course selection lies with the students and their families. That being said, some appropriate cap must always be put in place, and even the current system has a credit-limit for majors.

Consider one more example: ICS/Mathematics. ICS/Math has experienced 950% growth since 2018, and it has an average female-to-male ratio of 44%. The popularity and diversity of this major is an asset to Whittier. Students are often unable to enroll in similar programs at larger schools due to overcrowding. We have an opportunity to expand our undergraduate base by meeting student demand. The compromise we devised above does not work, for this 17-course major is interdisciplinary between math and computer science and all 17 courses count. Enforcing an 11-12 course cap significantly alters one of our fastest growing majors. I also note that a female-to-male ratio of 44% is more than double the ratio for all 3-2 Engineering majors over the last six years. We should cherish and build on such diversity in the ICS/Math Program. As a pre-tenured faculty member, I had to summon courage to voice my objection to the 11-12 course cap on majors. It turns out that I was not alone, and we decided to table that part of the proposal..

At one point, the discussion was steered back to financial reasoning. We reviewed calculations that demonstrated a course system would save financial resources. The average courses per student per semester would decline in the course system, with tuition remaining constant, yielding savings. Though we were initially instructed to focus pedagogical reasoning, we were asked mid-year to reconsider financial reasoning. There was a modest financial advantage to the course system over credit, but it arises students take fewer courses on average. Some of us felt that reducing the courses per student per semester was akin to granting a degree for less work. Alternatively, we can think of this as indirectly raising tuition by collecting the same tuition for fewer courses. These are statistical conclusions drawn from the scenario we examined, which focused on averaging over hundreds of students.

[1] For example, a seminar that meets once per week could require 10 hours per week of reading.
[2] This is the definition for a "full" course, but four "cumulative" courses correspond to a full course.
[3] In 2021, 10.5% of all students chose this major. Compare this number to 14% for BSAD.
[4] This major contains 14 courses worth 4 credits each.

Towards the end of the year I helped resolve an impasse regarding the cap on the number of courses per semester students could take. The original proposal restricted students to four full courses per semester (plus cumulatives). Given my experience advising 3-2 Engineering, Physics, and ICS students, I believe this restriction would have lead to painful setbacks to graduation. We examined results from other institutions that suggest a strong course load is correlated with student success. Our own 2019 data indicates that 35% of students took 15-16 credits with a GPA of 3.2, and 51% of students took 13-14 credits with a GPA of 3.0. From the data, allowing five courses poses less risk than initially imagined. Two camps developed nonetheless: for caps, or against caps. I devised a compromise: during the first semester, a cap of four courses, followed by the ongoing ability to take five with advisor approval. Academic probation would remove the ability. My past ESAC committee studies indicated a modest GPA decrease in transition between high school and the first semester of college (Sec. 4.1.1 of my prior PEGP). The compromise solution checks the student GPA at the transition, and also respects the will of the students. The compromise plan was adopted into the proposal. Humbly, these are my honest reflections, and I believe my colleagues always had good intentions. Throughout the year, we tried our best to discern what is best for our students.

Finally, I mentioned above that I led a sub-committee to study the partioning of major programs through "options," "tracks," and "emphases." I began by gathering data and compiling an executive summary (see Supplemental Material). I chose the term "partition" as a neutral term for major sub-classification. The average partitions per major across 27 majors Whittier College is 2.2 ± 1.3. From website data, the divisional breakdown was 3.3 ± 1.0, 1.8 ± 1.3, and 1.9 ± 1.2 for the physical sciences, social sciences, and humanities, respectively (mean and standard deviation). From data taken from DegreeWorks, the resuts are: 2.4 ± 1.5, 2.0 ± 1.3, and 1.9 ± 1.1, respectively. Very few departments have just a single version of the major discipline. Terms like track or emphasis are used to partition majors into sub-classified programs. EPC considered that students could better understand the system if similar structures are common throughout the major programs within an overall curricular design. The hope is that students can take better control of their educational planning. For now, we have sent a survey to department chairs based on my executive summary.

4.1.2 The Whittier Scholars Program

As I shared in my last PEGP report, I have already graduated one student through the Whittier Scholars Program. This was a fantastic interdisciplinary experience. Nicolas Bakken-French was an intrepid sophomore when he introduced himself to me, and he was interested in glaciers. He had heard that at least part of my research involved Antarcticic science, and was curious if this connected to his plans. He wanted to understand and document the disappearance of polar glaciers from a scientific and cultural perspective. Our work sent him all over the world collecting data, gaining field experience and survival training, and photographs of ice fields and glaciers. I was proud of the scientific and cultural report that we submitted in the end, and I felt that we produced a polished product.

I have a new student in the Whittier Scholars Program, Jackson Diamond, who focuses on computer programming applications in medicine. Jackson has been developing his innovation with me that is central to his final WSP project. He is creating a position location system based on Bluetooth signal strengths and trilateration. This would be useful for locating objects with Bluetooth tags with a precision of a few centimeters on the floor of a building. Jackson shares that his first application of this technology would be patient tracking within a hospital. The location of a newbord baby crib, for example, could be remotely monitored for safety and security. I took on Jackson's program after his original advisor (Bill Kronholm) departed. It was an easy service decision to make. WSP needs new professors to step forward, and it is a special privilege that we have such an interesting interdisciplinary program at our institution.

Students like Jackson and Nicolas are why I have volunteered to serve on the WSP Council. With Prof. Chihara now leading the council, our task this year is to streamline and update the program. I look forward to working with Prof. Chihara by recruiting for WSP and enhancing interactions between INTD100 and WSP. Some INTD100 sections would be integrated with introductory-level WSP courses for students keen on interdisciplinary studies. For my part, I will continue to serve as an INTD100 instructor periodically, and advise WSP students periodically. The goal, as Prof. Chihara says, is not necessarily to draw more students into WSP, but to show them the interdisciplinary nature of academia such that they develop an education they find intriguing and impactful. As part of this progress, I hope to strengthen ties between computer science as an interdisciplinary field and WSP. Students like Jackson and Nicolas have shown me that there is still a hunger for a diverse liberal arts education among students in the physical sciences. Through my advising and service, I hope we will create and innovate in a way that makes Whittier College proud.

4.1.3 Future Proposals for Institutional Research

Having reflected on my committee service between 2017 to the present day, I have noticed a common theme. I believe I have the skills to help with institutional research (IR). In ESAC, for example, I helped with the analysis of student admissions data. On EPC, I led a study of major partitions in the curriculum. In Sec. xxx below I share the details of a

DEI service project I have begun with undergraduates. Here I suggest a few ideas for ways I could serve Whittier College IR in the future.

1. In my writing, I often make use of dashboard data created by Gary Wisenand that are available on Moodle. Using these data, for example, I determined the growth rate and gender breakdown of the ICS/Math program. These dashboards need to be updated with data from AY 2021-2022 and beyond. Data projects like these would not be difficult given my experience level. I am interested in questions like the demographic breakdown of introductory STEM courses, the participation of young women in STEM majors, and measuring the growth of the wide variety of major programs and the corresponding "partitions."

2. Since I served on ESAC for two years and EPC for one year (with ERC in between those), I have been exposed to many analyses of student data. An idea for an interesting statistical analysis has been on my mind, related to boosting retention and graduation. I propose to create a tool that visualizes the pathways students take through our major programs. My hope is that the tool will help us to identify and address roadblocks to graduation on a statistical basis, and include results like internships. An example from 2018 using Tableau and IPEDS data, including Whittier College, is given in [43][5]. This particular study visualizes the correlation between SAT and ACT test scores with varying graduation rates in public and private colleges. The data can be disagregated by student ethnicity or race, gender, and by 4-year and 6-year graduation rate. The data shows that, of the students who do graduate from Whittier College, 90% do it in four years.

4.2 First Year Orientation

This semester marks the third time I have volunteered to become advisor to first year students, and the second time I have taught College Writing Seminar (INTD100). My course topics include the philosophy of science and how to identify and contrast *pseudo-science* and *scientific denialism* with real scientific thought. To help improve our students' writing mechamics, I have created exercises on conciseness, hierarchy of details, elimination of ambiguous words or phrases, and overall organization and planning of writing. Only one of my advisees has written a paper longer than ten pages, so this last topic is of special importance for articulating the results of scientific analysis or long-term projects. I will help my students polish their technical writing skill, while stimulating conversation through readings on the philosophy of science.

For our reading, I have chosen *The Scientific Attitude*, by Lee McIntyre (MIT Press). I learned of this book from Prof. Piner, who used it for his INTD100 section. The book is meant for a wide audience of college level readers interested in the defense of reason and scientific thought. There is a wave of science denialism and pseudo-science sweeping through our culture, and I felt this book would help our students develop the intellectual muscle to confront it. The author begins with the *demarcation problem* in the philosophy of science, which is an attempt to articulate the difference between science and pseudo-science. From there, misconceptions about the truth of scientific claims are discussed, followed by defenses of the truth in claims within fields like physics, medicine, and the social sciences. Given that Whittier College is a liberal arts school, my students will learn and discuss the logical framework of claims made by the social sciences, and how they fit into the larger framework of science. Our discussions will conclude with the logical flaws of pseudo-scientific claims made by vaccine and climate skeptics, and creationists.

4.3 The Quantitative Success Center

In Spring 2022, I was recruited by Prof. Gil Gonzalez to serve in a group of colleagues whose goal is to create a Quantitative Success Center (QSC). To say that Whittier College has struggled with student success in introductory math courses in recent years is an understatement. I have been confronted in my years at Whittier with situations I did not know occurred in higher education. A senior in algebra-based physics approached me mid-exam and asked "what does solving for x mean?" I witnessed a student fail College Algebra (MATH076) four times, *and then* enroll in my Algebra-based Physics course. I decided out of curiosity at the beginning of last semester to observe how MATH074 is taught, but I found every single chair empty and the instructor working on a laptop.

My teaching practice is always informed by equity, and I incorporate PER when I teach physics and mathematics. I participated in three workshops on inclusion in introductory STEM courses (see Sec. 4.4 below). I wrote extensively about how I address classroom equity in my prior PEGP (see Sec. 2.2 of my prior PEGP). I hope that I have earned some credibility within the area of teaching physical science courses to a diverse group of students with varying preparation. So trust me when I share, in sincerity, how alarming and frustrating it is to hear the rhetoric some use to describe STEM. As I was editing my DEI internal grant with IDC colleagues, some wrote the following:

[5] A link to the study online: `https://www.highereddatastories.com/2018/08/an-interactive-retention-visualization.html?lr=1`.

> We do not see how, for example, a system designed by white men addresses the needs of students of color and women who are marginalized in STEM.

I was shocked to read that. White professors are *incapable* of helping students from a different background? I chose to respond with logic:

> Consider a proof by contradiction: introductory STEM courses at Whittier College are "systems" often created by white men, so by this logic no students of color or female students should succeed in such courses. But many do, as evidenced by course evaluation data and in our learning outcomes. If they did not, a large fraction of introductory physics students would fail.

I understand if you feel the need to lecture me about DEI, but keep in mind I have taught ≈ 500 diverse STEM students here (in physics and math) and regularly attend workshops on how to teach them better. The majority of my students in physics are students of color and young women[6]. If I, a white man, am unable to address their needs, then a majority of my students should not succeed. **The data demonstrates the exact opposite reality.** Anecdotally, my colleagues in my department also demonstrate success with diverse students. The simplest explanation of the situation with introductory math is that has nothing to do with "whiteness," but teaching style. Anecdotally, my experiences with students and colleagues confirm that introductory math is taught differently than physics at Whittier.

As a pre-tenured faculty I cannot easily influence how my colleagues teach. What *might* influence how math is taught at Whittier College is a QSC focused on pedagogical practices that generate student success among a diverse student body. To that end, I argued for including such qualities in the future QSC director. Our group drafted with consensus a job description that called for the following characteristics: proven teaching experience in mathematics at the college level, knowledge of equitable teaching strategies, and experience in education management. The latter is the most important, for the QSC director will be responsible for helping mathematics instructors become more successful. These interactions will not be easy, but necessary for our students. For my part, I plan to contribute to the QSC by giving lectures about the benefits of PER in mathematics instruction. In my next PEGP report I look forward to sharing good news about progress with the QSC.

4.4 Inclusivity in Introductory STEM Courses

In 2017,

[6]For this semester: 60% people of color and 56% young women in PHYS135A, and 64% people of color and 55% young women in PHYS150.

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).

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

Discernment means the ability

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).

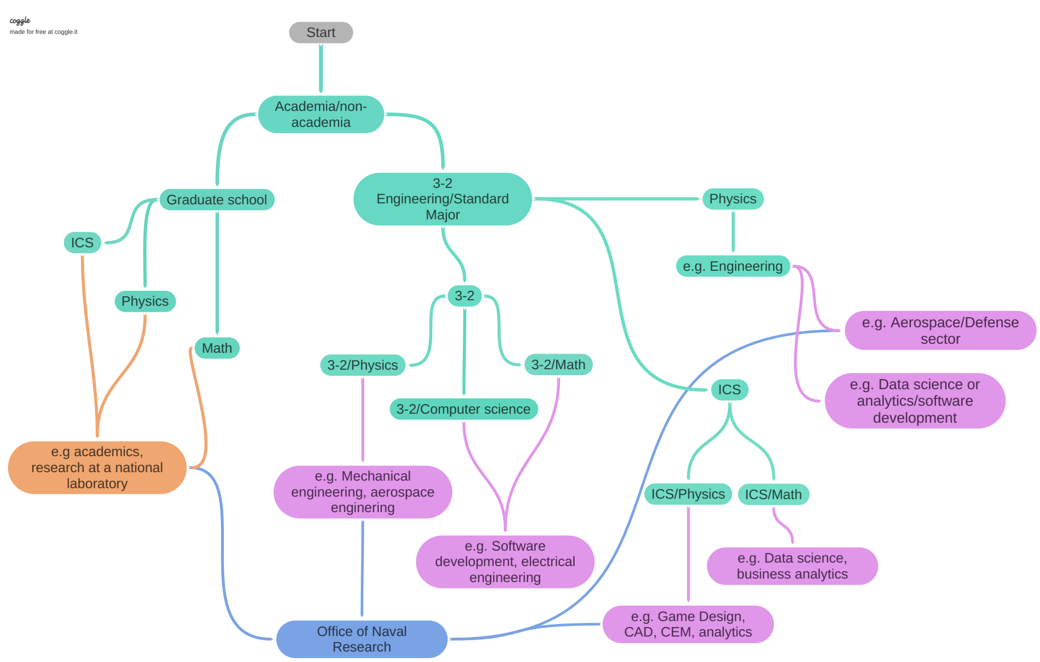

Figure 5.1: A decision-tree that orders my thinking around the advising of my STEM students.

5.4 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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