REFRAMING CONCEPTUAL PHYSICS: IMPROVING RELEVANCE TO

ELEMENTARY EDUCATION AND SONOGRAPHY MAJORS

by

David Gregory LaFazia

An executive position paper submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Education

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ABSTRACT

This study outlines the steps taken to reframe the Waves and Periodicity unit within a conceptual physics course. Beyond this unit reframing process, this paper explores the activities that made up the reframed unit and how each was developed and revised. The unit was reframed to improve relevance of the activities to the Elementary Education and Diagnostic Medical Sonography majors who make up the bulk of the course roster.

The unit was reframed around ten design principles that were built on best practices from the literature, survey responses, and focused interviews. These principles support the selection of a biology-integrated themed approach to teaching physics. This is done through active and highly kinesthetic learning across three realms of human experience: physical, social, and cognitive. The unit materials were designed around making connections to students' future careers while requiring students to take progressively more responsibility in activities and assessments. Several support strategies are employed across these activities and assessments, including an energy-first, guided-inquiry approach to concept scaffolding and accommodations for diverse learners.

Survey responses were solicited from physics instructors experienced with this population, Elementary Education and Sonography program advisors, and curriculum design, learning strategies, and educational technology experts. The reframed unit was reviewed by doctoral-level science education experts and revised to further improve the depth and transparency with which the design principles reframe the unit activities.

The reframed unit contains a full unit plan, lesson plans, and full unit materials. These include classroom and online activities, assessments, and templates for future unit and lesson planning. Additional supplemental materials are provided to support Elementary Education and Sonography students and program advisors and also further

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promote the reframed unit materials and design principles. The unit is designed to be educative in nature and serves as a model for the reframing of other units. A number of the design principles are highly transdisciplinary in nature and may be applied for reframing instructional units outside of the physics and science disciplines.

Chapter 1

INTRODUCTION AND PROBLEM STATEMENT

Conceptual Physics at Delaware Technical Community College

The Conceptual Physics (PHY111) course at Delaware Technical Community College (DTCC) is designed to meet the laboratory physics requirements of certain majors and also students who intend to transfer to four year universities. The course description reads:

"Physics 111 takes into account the major Physics and Earth Science topics covered in the Delaware Science Coalition (grades 1-6) science modules (kits). The course will be taught with an emphasis on understanding the material as well as developing an idea for how the material could be taught in an elementary environment" (DTCC, 2010). [See *Appendix A*]

From this description, the face value connection of the course to Elementary Education students is apparent. Less obvious is the connection to another group of students who take this course as a program requirement: Sonography students. Diagnostic Medical Sonography is a program that requires students to take this foundational physics course very early in their course sequence in preparation for an additional and much more technology-specific ultrasound physics course (Acoustical Physics). I have taught this Acoustical Physics course in recent semesters and so have become increasingly aware of the distinct needs of these students. This two-course physics sequence works to support students seeking a crucial principles and instrumentation certification in ultrasound physics for career credentialing.

Along with these two primary groups, a typically low number of engineering technologies and other non-education, non-allied health majors also take the course. The prevalence of these two well-represented majors (namely, Elementary Education and Diagnostic Medical Sonography) provides an opportunity to improve relevance for both majors within the scope of the Conceptual Physics course objectives. This focus does not prevent me from also providing for the needs of all non-physics majors who may take the course. Instead, this study sought to improve overall course content and delivery for all students while capitalizing on a unique opportunity that takes especial advantage of the typically two-major representation.

My typical class size ranges between 14 and 18 students. At the College, the course is offered as both traditional face-to-face and hybrid (an approximate 50% online and 50% face-to-face blend) format and is typically offered over a 16-week semester with shorter (10-week) summer sessions. However, I teach only one section per semester (Fall, Spring, and Summer), and these are exclusively in the hybrid format. Given the instructional rigors involved in employing this delivery method, I have endeavored to adhere to design principles that support courses with online components and, as evidenced in this study, have subjected my unit materials to professional scrutiny towards improvement as a blended course. The limited traditional, face-to-face contact with students serves to magnify the need for my deliberate approach to curriculum design and delivery to support learning. Fortunately, the College has strong distance learning support services for instructors which I utilized in my unit reframing process.

Tensions and Questions Leading up to this Study

Although I have been teaching Physics on a full-time basis since the Fall of 2005 (initially at the high school level), I did not begin teaching this Conceptual Physics undergraduate course until the Summer of 2009. Back then, my lesson materials were basically outlines, and I had little idea of how to meet the needs of adult learners—let alone the specific needs of Elementary Education and Sonography students. That said, my passion for teaching students with diverse backgrounds who were more often than not latecomers to science led me to continually improve my approach and the supports I offered each class.

My Conceptual Physics students tend to do well, and I work hard to make sure that I support their learning in the midst of the everyday and sometimes overwhelming challenges they face. Part of my approach has been to make the course goals and sequence as transparent as possible. More recently, I have been working to make connections between theory and classroom practice. The unit developed from this study is the culmination of these efforts and was designed to address student perceptions that the course was not relevant to their majors and also to meet certain instructional challenges. These include questions on improving content delivery, helping students to see the relevance of the course to their lives and chosen careers, and the challenge of helping students engage with the content despite initial trepidation and the perception that it is simply a graduation requirement.

These questions and the instructional challenges I recognized early on prior to this study are presented in Figure 1.



Figure 1 Tensions and Questions Leading Up to This Study

These tensions and questions are engaged throughout this executive position paper. They became three research questions that were explored through literature reviews, surveys, interviews, and layers of expert reviews—the result being a full unit on Waves and Periodicity developed specifically around improving the relevance of the course for my students.

Seven years and almost a score of semesters teaching this course later, I feel confident in making some observations about the students in these two majors. Primarily, my students are Elementary Education (or other Education) students near the end of their Associate's Degree and also Sonography major pool students near the start of their program of study. Over the course of my research, I gained greater insight into the needs and approaches to learning physics of both groups of students. These valuable lessons from the surveys and interviews conducted serve to inform the design principles on which the unit materials are founded.

There is a significant difference between the timing and in-program relevance of the Conceptual Physics course for Elementary Education and Sonography majors.

Figure 2, below, illustrates how Conceptual Physics fits into the programs of study for these two distinct majors:



Figure 2 Conceptual Physics As a Component Along Majors' Pathway to Careers

Education majors typically take this course as one of the final classes needed to transfer on to a four-year degree. They often are either already working in the education field in some capacity (e.g., substitute teaching) or have some field experience. My colleagues at the College and I have noted that Elementary Education students, especially, tend to approach this class with some trepidation and sense of disconnect between the course, itself, and their career expectations. One of these colleagues, Dr. John Hilton, conducted a study that investigated a highly similar population. The study found that "[a] majority of the elementary education majors [were] unsure of how or even if science [would] play a role in their future classrooms" (Hilton, 2011, p. 108). In his work, Hilton found that two-thirds of his Elementary Education students were not sure if the Conceptual Physics course was even needed while the remaining third thought it would be useful "if I end up teaching science" (p. 80, Table 4.11).

Paired with this was a markedly fearful expectation for what it would be like to take the course (p. 80). In my own prior experience, this fear had seemed to branch from poor past experiences and/or performance in high school physics courses, a complete absence of physics background or a large gap in time between this course and those experiences, or a very common lack of confidence in applied mathematics—the false perception being that this math-light course would be riddled with equations. Hilton's (2011) study confirmed the prevalence of this fear of the course above all other expectations held by Elementary Education majors while a meager one participant said they hoped the course would be enjoyable (p. 80, Table 4.10).

This mirrors my own classroom in that those of my students who enter the course with an existing appreciation for science tend to take the lead. On the other hand, their apprehensive peers struggle with seeing themselves as being able to learn science principles (let alone teach them in their own classrooms someday). As a whole, they do not seem particularly sure of what science content they will be expected to teach (if any), but I have found that they tend to be curious about this subject once broached and are often eager for information, resources, and strategies that can be directly translated into their future careers. This situation underscores the problem of improving relevance (primarily career relevance) for Elementary Education majors.

Diagnostic Medical Sonography Pool students are involved in a competitive admissions process to gain entry into the program (thus the "Pool" designation). Based on this, the students strive to earn a grade of a B or higher in the Conceptual Physics course. Many of my Sonography students believe that they must earn an A in order to continue on into the Sonography program. As was shown earlier in the illustration of the pathway to career entry, the Conceptual Physics course is certainly a type of

gatekeeper course, and it is calculated into the overall grade point average that is used to determine eligibility for program admission.

Given the importance of the course for their program aspirations, Sonography students in this course tend to be very focused on their performance, although they have at this point little insight into how physics will apply to their career (again, career relevance). They seem to be in fact ignorant, initially, of the underlying nature of diagnostic ultrasound technology and the skills they need for career success. That said, I have found them typically self-aware of their own ignorance of the sonography field to the point that they are hungry to hear from me what their major actually entails. Although this has up until now worked in my favor in that I have an eager audience in Sonography students, it also sheds light on a gap that begs filling as early on as possible. It brings up a question of which these students only have an unpracticed understanding: "What is Sonography, really, and how will this course help me be good at it"? Even when students saw the scope of the course outlined for them they lacked a valid frame of reference. To answer these questions of relevance (and primarily career relevance) for both majors, the connections are made explicit to students and also program advisors through the unit materials.

Looking back at a similarly mixed population, Hilton noted that his Elementary Education students' "responses continue to support the trend of a weak affinity for science" (2011, p. 82). However, a difference emerged with his allied health program students who were initially "unsure of why the course was required" but who later "described a strong awareness of how the course connected to their program"—resulting in increased motivation for engagement with the course material (Hilton, 2011, p. 108).

Hilton found that there was a marked difference between the Physical Therapy

Assistant (PTA / allied health) group and the Elementary Education majors:

"...as the conceptual physics class progressed, the PTA students **all became aware** of how the experience **connected to their program**, because they could see the needed concepts in other classes and at physical therapy clinics. Conversely, because **the elementary education students do not have a vision of how science fits into their future classrooms**, they **do not have the same opportunity** to connect their college science classes to their education program" (Hilton, 2011, p. 83, emphasis added).

In my classes, the PTA-equivalent (Sonography majors) do not have these same opportunities to make the connections between class and clinic. This is because they are so early in their program (being program acceptance hopefuls as part of the major pool) and have extremely limited experience and (as I discovered through my research) a poor enough understanding of exactly what ultrasound technologists do in the field. Was it possible to not only help my Elementary Education students make clear connections between coursework and their future teaching responsibilities but also to duplicate the awakening for Sonography students that was experienced by these Physical Therapy Assistant majors?

To further understand my Elementary Education students as pre-service teachers, I considered a study on high school biology curriculum materials aimed at gauging how these materials "[supported] the development of teachers' pedagogical content knowledge" (Buoni, 2012, p. xi). What I found most applicable for my own students were the underlying implications for Elementary Education teachers. As incoming teachers, my students will be expected to make use of the departmental materials available (specifically, materials provided after training with the Delaware Science Coalition). These materials are adapted to educational standards and "many of the goals of the activities are engaging and demonstrate solid inquiry-based lessons" (p. 4). Buoni notes also that they are "generally a welcome curriculum package for many elementary teachers" (p. 4).

Although secondary biology was the primary focus of that study and the *Next Generation Science Standards* were not finalized and subsequently adopted until the following year in Delaware, the implication remains that my Elementary Education students will be expected to achieve fluency in inquiry- and standards-based teaching methods. In Buoni's study, there was a significant lack of adaptation in, especially, the initial years of teaching (2012, p. 81). If the findings from this study are at all indicative of an overall trend throughout education in Delaware, the need to prepare students for adoption and proper application of these inquiry-based, standards-focused materials becomes ever clearer. As a support course, the responsibility for Conceptual Physics instructors is to ensure that course activities help prepare the Elementary Education majors for this environment.

Although the Conceptual Physics syllabus was designed with these Delaware Science Coalition materials in mind (DTCC, 2010), the connections between lesson materials and accepted standards is left to the syllabus reader to deduce on their own. Additionally, the course objectives are very clear on what should be learned, but there is no particular call for taking the inquiry-based approach for which pre-service teachers must prepare. Again, it is the responsibility of the individual instructor to 1) understand this need for connections to professional standards and 2) provide students with opportunities to experience and practice the inquiry-based approach.

Taking all of these tensions and considerations into account, the instructor should be ready to answer students when they question how best to wrap their heads around concepts and how the concepts will help prepare them for program and career

goals. The first question can be answered through application of best practices and support strategies aimed specifically at the typical Conceptual Physics population. The second is a matter of making explicit connections between content and career goals through the course materials and activities. The research questions that are introduced in the next section address these tasks and form the foundation of the Waves and Periodicity unit materials developed during this study.

Problem Statement and Research Questions

Students enrolled in both the Elementary Education and Sonography majors require support from the Conceptual Physics course for their professional goals. I completed this study to take a critical look at the needs of my students in relation to the Conceptual Physics course materials and then begin to support their learning as optimally as possible through the focused, high-quality reframing of a single unit. This single unit (on Waves and Periodicity) is situated as one of the final units of the overall course and consequently builds on the previous units (i.e., Science Methods, Energy, Force and Motion, and Atomic Nature / Fluid Dynamics). At the same time, it complements the units following it (Electricity and Magnetism, and Earth-Space Connections). It was therefore chosen as an ideal forum in which to expose Sonography students to the physics behind their chosen profession and also help Elementary Education students make relevant connections between their profession and traditionally abstractly understood concepts. In order to better define these instructional approaches and understand career-relevance within these two fields (and how this knowledge might guide my unit reframing), I asked the following research questions: RQ1: Which instructional approaches should be employed to meet the needs of this population?RQ2: What challenges exist in the prominent fields of these students which can be supported by the scope of this course?

RQ3: To what extent might the findings from RQ1 and RQ2 be enacted within the course?

Figure 3 provides a basic outline for the methods I followed in answering these questions. Overall, a series of literature reviews supported the development of several preliminary design principles, survey instruments and interview protocol that expanded these principles and laid out the final steps for unit review and revision. I reference variations on this image several times throughout the pre-, intra-, and post-unit development phases.



Figure 3 Basic Outline of Research Methodology

In the next chapter, I expand on each of these literature review stages and explain their role in the development of ten design principles and the resulting unit materials. The Waves and Periodicity unit, itself, is aimed at improving relevance for my students, and these literature reviews consequently also provide much of the rationale and justification for undertaking this study.

Chapter 2

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

The literature reviews that follow laid the foundation for my instructional reframing of the Conceptual Physics unit. By them many of the design principles were first identified and later developed. The literature reviews also served to inform the survey questions and inspired several of the unit materials toward improved relevance and engagement cognitively, socially, and physically. I present the literature reviews in three phases: pre-, intra-, and post-unit development literature reviews.

Pre-Unit Development Literature Review

This pre-unit development phase of literature review covered a broad territory. It helped to define the initial design principles and set the stage for data collection through surveys and interviews. In order to better understand the goals of my students, I first identified considerations when teaching adult learners. From there, I investigated best practices and issues in teaching physics (in general) and introductory physics (more specifically). Moving from these, I honed in on teaching physics to non-physics majors and selection of a theme for the unit—finally resting on literature that began to define the needs of Elementary Education and Sonography majors. Figure 4 illustrates the components of this literature review and how it was situated within the overall study.



Figure 4 Pre-Unit Development Literature Review Components

In this sense, I moved from a broader, discipline-based view of relevance to (once that foundation was set) a more focused, career-based perspective. Along the way, the literature revealed avenues for personal- and social-relevance, as well. These came in the form of health awareness, science agency, and other socioscientific issues. I emerged from this first phase of the literature review with each of these areas of relevance contributing to the design principles. However, the dominating focus remained career-relevance.

Teaching Adult Learners

It is common knowledge among professional educators that students come from diverse backgrounds and approach learning in many varied ways. These principles form the foundation of pedagogical knowledge, and an awareness of these learning styles and emerging science perspectives is generally considered key to being an effective teacher. At the community college level, my classes are almost exclusively made up of adult learners (with the occasional exception of a visiting high school student). What follows is a brief overview of the characteristics and needs of adult learners.

I teach the Conceptual Physics course exclusively on week nights or weekends. Students enrolled in evening courses tend to have dependents and work many hours outside of classes (Thompson & Deis, 2004, p. 78). Often, they are latecomers to science who "enter postsecondary science through alternative routes rather than directly from high school" (Mueller, 2008 via Jackson & Seiler, 2013, p. 826). Although many barriers to these students' persistence through their programs exist (p. 826), and there is much potential for poor self-views of science efficacy (p. 827), there are also examples of these non-traditional situations being used as motivation by students to continue. This seems most strongly represented when students successfully connect their life goals to science (Jackson & Seiler, 2013, p. 848), and I have seen this evidenced in many classroom- and online-discussions from my own students.

Thompson and Deis (2004) outline four principles for teaching adult learners that resonate with my past training and experiences with non-traditional students and helped inform my thinking. They identify adult learners as considering themselves responsible for their own learning, being collaborative learners, goal-oriented, and having a need for "immediate application of theory to practice" which is "as real as

possible, and as immediately applicable to their own lives as is reasonable" (p. 81). This is foundational to adult learning theory. As Knowles (1980, via de Luca et al., 2012) notes, they are ready to learn "when they experience a need to know or do something in order to perform more effectively in some aspect of their lives" (p. 18). Research aimed at the most recent generation of adult learners identifies them as teamoriented—setting them up for collaborative, cooperative, interactive, and social learning (Wilson & Gerber, 2008, p. 31). They prefer "[linking] content to 'real life' applications" (Monaco & Martin, 2007, p. 44, Table 1) and "[learn] best by discovery" (Markulis et al., 2011, p. 190).

Taking these as fundamental pedagogical approaches for my population, I summarized them as a need for content to be contextualized within life-relevant situations and a call for collaborative learning through social construction. This acknowledges the fact that "[learning] is mediated by the social environment in which learners interact" (NRC, 2000, pp. 118-119). It was my responsibility as the unit designer and instructor to help engineer and structure this social learning environment—both online and on-ground. Acknowledging that my students "[learn] best by discovery" (Markulis et al., 2011, p. 190) seems simplistic, but it has implications for inquiry learning where students "take control of their own learning" (NRC, 2000, p. 119). This is explored in much greater detail in an upcoming section. Setting that aside for the moment, two of the final ten design principles were solidified: real-life relevance and social construction of knowledge. In Figure 5, I begin to build a framework of these guiding principles.



Figure 5 Social Construction and Life Relevance as Design Principles

These key takeaways set the stage for the unit reframing, but many gaps remained. What does "life relevance" mean for an introductory physics course (or for science in general)? How can engagement during social construction be maximized, and what does this engagement look like? The following section looks at issues and strategies of teaching science. It primarily helps to answer questions of personal- and social-relevance while presenting a singularly useful instructional strategy (kinesthetic teaching) that I employed in the unit reframing to engage the whole student. Employing this teaching strategy with purpose completes the loop on relevance by tying in careerrelevance (as a skill to be modeled with Elementary Education students and as practice for spatial reasoning and physical coordination for Sonography students).

Issues and Strategies for Improving Personal- and Social-Relevance

Picking back up the issues of personal- and social-relevance (so closely interlinked that I do not try to make any great distinction between the two), I first

examined how socioscientific issues were applied at the middle-school level using the "Choice, Control and Change (C3) science curriculum" (Mallya et al., 2012, p. 244, emphasis original). This approach took a slightly different direction in establishing the connections between physics and the human (physical and social) experience since students were asked to consider "their food environment," "purposefully [making] healthier choices," and "[expanding] ... food and activity options" (p. 244). The study focused heavily on science agency (p. 248), which empowers students to take action in their own lives and to influence those around them. Two examples of the questions asked reveal just how applicable this line of reasoning is to everyday, rather common experiences: "How can we use scientific evidence to help us make healthy food and activity choices?" and "How can we make sure that we get the right amount of energy to help our bodies perform the way that we want them to?" (p. 248). This link between energy as a key physics concept and making important decisions in everyday situations is nontrivial as it provides an excellent illustration of how physics can directly relate to human physiology and socially understood ideals. But how can activities within a unit be used to support personal and shared meaning-making of these concepts? In other words, where might the two preliminary design principles of Social Construction and *Life Relevance* be made to intersect?

One socioscientific issue illustrates a plausible starting point. Its origins are with the Centers for Disease Control and Prevention (CDC) and the U.S. Department of Health and Human Services (USDHHS). Delaware is near the higher end of the scale for the prevalence of obesity among adults—at around one third the adult population self-reporting obesity in 2013 (CDC, 2014). Youth are also heavily affected by obesity in the United States (USDHHS, 2010). To help combat this epidemic, the Surgeon

General has outlined health initiatives and active living strategies (USDHHS, 2015). Students who are engaged physically in learning activities may question the point of the extraneous motion. If the cognitive theory does not impress them, perhaps the basic biological benefits they are receiving throughout the unit will. Are there reasons beyond socioscientific tensions to incorporate physical activity within our typically cognitive- and social engagement-exclusive classrooms? Are not so many classrooms aimed at keeping students *in their seats* as if they were jarred brains that can (at the highest level of permitted freedom) contribute to discussions?

In truth, the idea of *movement in the classroom* is a recurring subject in early childhood and elementary education discussions (see Margolis, 2015, Anderson, 2015). It is a common practice in the earlier years to "learn through play" (Conklin, 2015). However, movement, itself, is closely related to how we learn—regardless of age—and is linked back to research on human cognition. In the words of one researcher and author, "We can no longer limit the learning environment to 'sitting still, being quiet, and memorizing stuff" (Hannaford, 2005, p. 13). She goes on to explain that "movement and sensory experiences are the fertile soil for continual brain development and growth for a lifetime" (p. 13). One specialist in kinesthetic teaching expounded on this, claiming that "by letting students *experience* the curriculum through their bodies, we help them make deeper emotional, interpersonal, and kinesthetic connections to academic subjects" (Griss, 2013, emphasis original). For my unit in a post-secondary physics setting, this manifests itself as a shift from students simply being physically involved with lab equipment to students being an actual part of the lab apparatuses. This becomes *movement with a purpose*, and the human physical experience

(considering movement and functions both internal and external) is made a laboratory environment all its own (consider McGuigan, 2009 and Lewis & Mohazzabi, 2014).

Teaching Introductory Physics: Support Strategies

In order to have an approach that is this physically engaging and also incorporates contextualized peer co-construction of knowledge, the fabric of the course or unit must also encourage a supportive classroom culture. In my own experience, this struggle with how to make meaning and properly compartmentalize concepts has seemed due to a mismatch between everyday experience in word usages along with a general sense that newly introduced concepts are presented with limited applicability to students' lives—thus leading to my students' general difficulty in developing a personal (let alone shared) language of physics. This is reflected in a study of perspectives from stakeholders in an introductory physics course where the problem is framed as physics students not being able to "'define the words they use in the English language'...there [is] a language problem between how words [are] used in everyday speaking and how they [are] used in physics" (Dickinson & Flick, 1998, p. 242). My research resulted in identifying strategies for addressing this issue. The premise I make here is the close relationship between the *use* of physics language (i.e., application of concepts) and understanding the concepts to which they are attached.

In keeping with this premise, a science education project funded by the Australian Learning and Teaching Council, described as "[a] cross-disciplinary approach to language support for first year students in the physical sciences," led to several studies in science education language support (Zhang et al., 2012, p. xii). In the chapter titled *Language Problems of First Year Science Students*, a number of strategies

towards the construction of a shared language and other supports were suggested (p. 8). These studies presented findings on common misconceptions in making meaning of physics concepts. Some of the language of physics strategies were clearly a component of a potential constructivist pedagogical approach as they pointed directly to the need for group construction of concepts and definitions. With this, the use of everyday language should be employed to define content prior to using the scientific language (Brown & Ryoo, 2008, p. 529). Out of the same project (Zhang et al., 2012), a study on *The Benefits of Teaching Students the Language of Physics* was conducted. The author, Jurgen Schulte, wrote:

"Many non-science majors find first year physics quite daunting, if not intimidating. Of the many factors contributing to this experience are two that stand out quite prominently, students believes [sic] that physics is difficult; and difficulties trying to learn physics at a pace that **presumes full command of the language of science and physics**" (Schulte, 2012, pp. 160-161, emphasis added).

The study identified a number of commonly troublesome physics topics and measured learning gains based on strategies to help students' skill-building in the language of physics. Although the study was aimed mainly at students who came from non-English speaking backgrounds, it was found that "students from an English speaking background benefit from such intervention" as well (p. 178). Given the diverse student population found in a typical Conceptual Physics course, either scenario is appropriately placed within this context.

As foreshadowed, the literature suggests a number of strategies to aid in the building up by students of a "disciplinary literacy" (Shanahan & Shanahan, 2008, p. 40). In a report outlining their findings from a two year study on "advanced literacy instruction embedded within content-area classes," Shanahan and Shanahan outlined several "comprehension strategies" in support of both "disciplinary reading tasks" (e.g., reading assignments for comprehension and use) and preparation "for the reading, writing, and thinking required by advanced disciplinary coursework" (p. 40).

The authors looked at multiple stakeholders such as chemists, historians, and mathematicians in the context of middle- and high-school education. One problem brought up in terms of science text comprehension was that the "abstract language that is used in chemistry texts is daunting...because it makes the subject matter more distant and disconnected from <u>everyday experiences</u>" (p. 53, emphasis added). The group of stakeholders began to "[focus] on the creation of discipline-specific strategies" such as "structured note-taking or structured summarization." In these cases, "students [were] required to take notes in a <u>chart format</u>," which was "not just about understanding text," but was aimed at understanding the science discipline (p. 54, emphasis added).

The following quotations further explain the structure of some of these strategies:

"One was a mathematics-structured note-taking strategy. In this strategy, students would write the mathematics "big idea" that was being studied in the first column. In the next column, they would write the explanation of the big idea, and in the following columns, they would provide an example, show a formula, make a graph or diagram, or **otherwise illustrate** the big idea. They were to complete this work **as they were reading** and then use it as a study guide prior to a unit test. ... Students [were] asked to think about the most likely connections and to write these on the chart. One of the history teachers engaged in a quasi-experimental study of another history strategy — one he called "the multiple-gist" strategy. In this strategy, students read one text and summarize it, read another text and **incorporate that text into the summary**, then read another text and **incorporate that text into the summary**, and so on" (pp. 55-56, emphasis added).

This approach suggests that summarization should be ongoing and is meant to drive the revision of conceptual understandings. It also reveals the value of keeping a record of these learning artifacts for future reference. Students were not left to their own devices entirely, however. It was suggested that "if a concept was being defined, the precise … definition" was to be used when the idea was added to the chart (p. 55). This was in a mathematical context, but the lesson is not out of place within a physics
classroom. Taken together, the importance of language support strategies as socially constructed guides to structured conceptualization becomes apparent. In the design principles, this is addressed in the *Social Construction* component—as the organization of these summarization strategies presents an opportunity to extend individually designed organizers to the whole-class experience.

In order to support this extension into social construction of knowledge, I developed my own semi-structured summarization strategy: Word Banking. Word banks or word walls are common enough in classroom settings. However, in this case, I have taken an online educational technology (Padlet®) and turned it into a *virtual* word wall. This Word Bank is meant to be a living document—allowing for students (with some guidance and reassurance of accuracy on my part) to develop a malleable record of their own understandings of physics ideas and resources. This became a major feature of the unit. Figure 6 shows how the Word Bank is introduced in the first lesson of the redeveloped unit. It is situated within the introductory online lesson for the unit and sets the stage for the socially designed physics language support strategy employed throughout.



Figure 6 Word Bank Introduction from Lesson02

On their own, none of these support strategies can add particular relevance to the unit specific to the Elementary Education or Sonography fields, although it does model a strategy that my Education students could readily employ in their classrooms, and comprehension of physics concepts is crucial to the career progression of Sonography majors. The next section considers strategies for not simply teaching introductory physics but teaching it to non-majors. Many of the initial design principles were revealed during this leg of the literature review.

Teaching Physics to Non-Majors

It is the recognized task of a fundamental physics instructor "to reach more than those students who [will] go on to become physicists" (Ferrini-Mundy & Güçler, 2009). While there have been a number of studies that focus on primary school pre-service teachers, less prevalent are studies explaining the needs of—and strategies for teaching fundamental physics concepts to—health majors (a broader category into which my Sonography students may be categorized). This relative lack of literature emphasized my need for input through research means external to existing studies (i.e., surveys and interviews). That said, in a broader sense it is not unbelievable that strategies which work for general studies and other non-physics majors apply also to these students especially when placed within the context of the pedagogical approaches previously identified.

Among physics education research there have been a number of curricular frameworks developed and implemented. From these, one has been shown as uniquely able to "[demonstrate] replicable positive shifts in students' attitudes and beliefs" independent across instructor or institution type (Goldberg et al., 2010, p. 1265). This is of course in addition to "[demonstrating] large conceptual gains" as have certain other curricula (p. 1265). I felt that this advantage was well suited to meet the physics discipline learning needs of future P-8 educators and medical workers (i.e., sonographers). For that reason, I chose to incorporate the design principles for that curriculum into my own framework. These are, in their original form:

- 1) Learning builds on prior knowledge
- 2) Learning is a complex process requiring scaffolding
- 3) Learning is facilitated through interaction with tools
- 4) Learning is facilitated through interactions with others
- 5) Learning is facilitated through establishment of certain specific behavioral practices and expectations (Goldberg et al., p. 1266)

Principles one and four point to social learning. Students should be given opportunities to share their prior knowledge, critically examine it, and subject it to the scrutiny of their peers in light of new knowledge. Throughout this process, principle five bounds these interactions socially and institutionally while providing guidance to students. Principle three is a natural part of the Conceptual Physics course and deals with the level of active and hands-on learning within a program. Lastly is an acknowledgement that learning truly is "a complex process requiring scaffolding" (principle three) (Goldberg et al., 2010, p. 1266). Before exploring these in more detail, Figure 7 provides a visual on how these components made their way into the design principles for my study early on. Note how these principles are complementary to the *Social Construction* principle already in place.



Figure 7 Active Learning and Scaffolded Inquiry as Design Principles

There are numerous studies within physics education research arguing that active learning, specifically using inquiry methods that require students to move beyond content and to take on the mantel of science as an endeavor greater than the classroom (Marshall and Dorward, 2000), are more effective than traditional methods. One researcher in particular has championed the idea that "traditional approaches are inadequate" for the training of pre-service teachers (McDermott, 1990, pp. 140-141) and that there is "a mismatch between standard curriculum and teachers" in what is taught versus which principles they are able to apply (McDermott et al., 2006, p. 763). These studies show the advantages—particularly for pre-service science teachers— "within a learning environment that [supports] freedom to ask questions, a *constructivist approach*, and a slow pace of learning, and [provides] interesting facts (*relevant to life*) that [contain] content that would be useful to teaching" (Zacharias, 2003, p. 795, emphasis added). This is a direct reiteration of the pedagogical strategies outlined previously, plus it provides insight into how concepts are to be introduced. This takes shape as a "contextual approach" in which content is introduced only as it is needed along with the progression of the course (Loverude et al., 2011, p. 49). Scaffolding of ideas and content takes place as needed to allow for the social construction of knowledge through guided inquiry methods, where "students need practice...building up to increasingly open and complex levels" (Bell et al., 2005, p. 33).

What, then, is inquiry? What should a classroom based around inquiry learning include? "Inquiry instruction is a hallmark of the current science education reform efforts" (Bell et al., 2005, p. 30), and it "is an active learning process in which students answer research questions through data analysis" (p. 31). Inquiry, as its name implies, presupposes curiosity (a form of initial cognitive engagement) with the subject. The cognitive progression of inquiry as part of human nature is explained in terms of science methods. I summarize these components of basic, innate human inquiry as 1) curiosity about a stimuli, 2) search for reasons and predictions for "what will happen next," 3) reflection on our environment "by observing, gathering, assembling, and synthesizing information," 4) measurement towards information analysis and model creation, 5)

comparison of results to known values, and 6) the ability to change our views and understanding (National Research Council [NRC], 2000, p. 5). It is through inquiry learning that students gain insight into how scientific knowledge is acquired, science's tentative nature as it can "[change] in response to new evidence," and the sociopolitical responsibility of scientists (p. 21)—which responsibility, at least on a personal and social level, I propose should be included in any inquiry learning environment. At the very least, students must be able to "justify their proposed explanations" and communicate them to others (p. 25).

Inquiry is not a cut-and-dry approach to teaching science. Just as scientists work within differing boundaries and parameters depending on their subject, so the inquiry classroom can be more or less "open" and guided (NRC, 2000, p. 29), which vary less or more the amount of information given to students to explore concepts (Bell et al., 2005, p. 32). These variations in what inquiry learning looks like in classrooms can be boiled down to four levels. These are the "confirmation, structured, guided, [and] open" levels of inquiry (Banchi & Bell, 2008, p. 26). Although inquiry should be experienced across each of these levels (NRC, 2000, p. 30), this requires "substantial scaffolding" (Bell et al., 2005, p. 31) and "extensive practice" (Banchi & Bell, 2008, p. 26).

Confirmation inquiry activities provide students with the question to investigate and step-by-step instructions (Banchi & Bell, 2008, p. 26), and "the expected results are known in advance" (Bell et al., 2005, p. 32). There are no examples of confirmation inquiry in my reframed unit, as this unit is situated much later in the course at a point where confirmation inquiry is to have been grown out of. Structured inquiry is featured in my unit. It is where "students investigate a teacher-presented question through a

prescribed procedure" (Bell et al., 2005, p. 32). A major difference, though, is that "students generate an explanation supported by the evidence they have collected" (Banchi & Bell, 2008, p. 26). An example of this, pulled from my unit materials, is the sound interference exploration activity outlined in Figure 8.



"Best place to sit in the Theatre" - activity

What happens when you have two wave sources interacting with one another? Does the dynamic change when you're within an enclosed space? Let's explore these and other questions!

Think: Have you ever been in a theatre (e.g., at a concert) and experienced "dead spots"? What about in a car – particularly one with a custom sound system? If so, keep these experiences in mind as you conduct the following exploration:

Using the online tone generator (from <u>onlinetonegenerator.com</u>) which you used previously for the hearing test, select a moderate (low frequency) tone at a tolerable volume which can still be heard throughout the room. Allow this to "ring" continuously.

With the speakers side-by-side about 30 cm apart, walk around the room. Map out any differences in volume that you might hear (e.g., against the walls, in the middle of the room, &tc.).

Describe the differences, if any, you perceive. Why do you believe these differences are occurring in those locations?

If you change the angle of the speakers, does this affect your map? What changed, if anything? If you change the distance between the speakers, what effect does this have, if any? Does increasing or decreasing the frequency of the tone from the two sources have an effect? What happens to your perceived "differences" (if any previously) if you unplug the secondary speaker?

Figure 8 Best Place to Sit in the Theatre – Speaker Sound Interference Activity

This could easily be changed into the third level of inquiry—guided inquiry which also "features a teacher-presented question but leaves the methods and solutions open to students" (Bell et al., 2005, p. 32), although students still "need guidance as to whether their investigation plans make sense" (Banchi & Bell, 2008, p. 27)—thus the name *guided inquiry*. The speaker sound interference activity is the only example of high-fidelity structured inquiry in my reframed unit. This was done given the general complexity of the expectations on the students and the corresponding time constraints within the lesson. All of the other laboratory-based activities within the unit fall under guided inquiry. That said, in a fully reframed course, it would be important to include scaffolding of inquiry through confirmation and later into and from structured inquiry. This is especially true since "confirmation and structured inquiry...are very common in elementary science curricula" (Banchi & Bell, 2008, p. 27) and so Elementary Education students must be prepared for their own version of inquiry scaffolding in their future classrooms.

This unit does not feature the fourth level of inquiry (open inquiry), although it should be recognized that opportunities for open inquiry could be planned at the end of a fully reframed course. That said, given the broad-topic nature of the Conceptual Physics course where new concepts are introduced in rapid succession and there is little time for open inquiry, I recommend that these be carefully and responsively crafted to match the skill level of the students in each classroom. Each type of inquiry activity can be transformed into another by providing more or less information to students.

In this way, I define inquiry to be the use of active learning strategies (e.g., the use or development of tools and models) to answer questions with unobvious solutions and the potential to extend beyond just traditional physics content. The value of this idea is supported by studies on the conjoined twin of inquiry: Problem-Based Learning (PBL). Although I did not feel it was necessary to move forward with adoption of all of the principles prescribed within this approach, one key component of PBL which resonated with my goals was that it offers "learning transdisciplinary with knowledge, skills and attitudes" where "boundaries between subjects exist but are somewhat arbitrary. [This approach encourages] deep learning independent of subject 'discipline';

[encouraging students to] critically think about knowledge, themselves and peers" (Woods, 2014, pp. 5338-5340). This component did not appear to be unique to PBL, and I felt comfortable adapting it in this study as a philosophical orientation to teaching. This suggested that not only should my students conduct "their own sense-making" (Goldberg et al., 2010, p. 1276); they should also do so within a social, interactive context. Additionally, it helped me to see the plausibility of blending in content traditionally kept outside the bounds of physics courses. This allowance makes room for the acknowledgement of the human experience as being not only cognitive and social, but also physical (through the breaking down of boundaries between other natural sciences—e.g., biology). This simplification of the human experience is represented in Figure 9 and carries through as a more holistic view of students.



Figure 9 The Simplified Human Experience: A Holistic Approach to Teaching Students

Having solidly positioned the plans for this unit within a scaffolded inquiry schema aimed at simultaneous physical, social, and of course cognitive engagement, the next section presents the literature on teaching physics non-majors that led me to adopt a theme around which the unit could be structured. In fact, three components emerged. An overarching theme of connections to the human body was selected to combine personal, social, and career relevancies with the physical realm of human experience. To support this theme, two supporting strands were selected: Energy-first—to uphold physics discipline-relevance and the cognitive realm of experience for language of physics development—and kinesthetic teaching as an instructional strand aimed at linking the cognitive and physical realms. Together, these components provide an integrated support system for learning and motivation.

To Theme or Not to Theme

Support for the decision to select a theme in which to ground physics content is available in practical case studies, particularly when considering the theme as a "motivational tool" to physics non-majors (Busch, 2010, Donaldson, 2010) and when seeking to increase the post-course applicability of physics concepts for non-majors (Martinuk et al., 2011). One physics educator found that the "combination of using student-centered learning methods and selecting subjects of relevance to the students" lives...helped provide a positive learning experience for...students" (p. 581).

In this way, I conceptualize the reframed unit to be one built around a central theme while being supported by these two strands. Each is aimed at improving a type of relevance of the unit to Elementary Education and Sonography students. What follows here is an overview of the literature used to initially identify and understand how each component is integrated. The theme of connections to the human body (or basic human physiology and biology) along with the supporting strands of kinesthetic teaching (previously defined in detail) and an Energy-first approach to learning are

employed to constantly engage with the three realms of the human experience identified earlier. As a consequence, the unit materials have a built in redundancy of inquiry learning, kinesthetic engagement, and socially built understandings. In effect, the same concept is investigated cognitively, physically, and socially both as part of the content design and the instructional methods.

It is plain that learners inevitably "construct their own understandings" (Mulhall & Gunstone, 2008, p. 438), and that physics instructors must—as these understandings are being built—"[help] students see physics as useful and meaningful in their lives and majors" (Dickinson & Flick, 1998, p. 244). The case for concept scaffolding and theming as a way to avoid the pitfalls of "minimal guidance" (Kirschner et al., 2010) is made through an understanding of the "human cognitive architecture" (p. 76) (i.e., how students reason and make connections). The unit developed from this study takes an Energy-first approach to content <u>as a *component*</u> in an overall scaffolding scheme. This is a natural progression for a physics course, since "[energy] is arguably the central unifying concept in physics" (Hobson, 2004, p. 113).

This energy-centric approach to physics content delivery has been applied successfully by not only me but also by my peers and mentors in the field of physics and physical science education (reference Ford et al., 2013). Given the popular focus on the importance of energy (in terms of consumption, production, and availability), sociotechnical connections are also easily recognizable. Energy concepts are wellpositioned to be an integral part of the socially constructed, shared language for this course, and it is possible to transition smoothly between colloquial, popular applications of energy and those that are more discipline-relevant. As introduced earlier, this is accomplished through the development of a shared language while the classroom (both

online and face-to-face) is to be engaging for the students mentally, socially, and physically. The resulting Waves and Periodicity unit supports student learning based on these approaches across the realms of human experience. This specific use of theming is illustrated in Figure 10.



Figure 10 Themed Engagement between Three Realms of Human Experience

Having established kinesthetic teaching and the Energy-first approach as supporting strands, what call is there to use an approach that connects the human body to physics concepts? There are actually a number of socioscientific promptings that lead to the adoption of the human body as a primary theme for teaching physics. For instance, the National Science Foundation (NSF) suggests a "synergistic" approach to teaching undergraduate physics. In this approach, they outline the need and some potential advantages for integrating biology concepts into physics courses (and vice versa). One of the co-authors, Gary White, related the following from his experience as a physics instructor:

"Personally, I have found that relaying physical principles using biological examples better motivates students to work at understanding the ideas. A typical student comment is, 'Oh, I see, this does relate to my life." (Woodin et al., 2013, p. 121).

The Federation of American Scientists (FAS) set out a series of Grand Challenges for the discipline of Physics for the 21st Century. Among these was the call to apply physics to biology and medicine as a means of better understanding both. They specifically identify one "[domain] for the application of physics" as "the biomechanics of motion," among other relevant areas (Patel & Jarudi, 2003). Although my Conceptual Physics students almost certainly will not be moving on to careers as physicists and biologists, their training adds to the foundations of STEM Education (for Elementary Education majors) (see NRC, 2010) and matches closely with the needs of allied health and other technology practitioners (for Sonography and other non-Education majors). Providing a transdisciplinary approach to physics content through incorporation of human biology adds an extra layer of preparation (<u>read</u>: career relevance) for new instructors who are being asked to teach across the disciplines. This is certainly also in keeping with the practice of identifying and making use of crosscutting concepts with which pre-service teachers should have a keen interest (consider NRC, 2012).

The intentional pedagogical pairing of physics and the human body is not actually new, although existing studies are primarily concerned with the most apparent aspect: human locomotion. In a 1997 study on techniques for teaching physics to nonscience majors and training pre-college teachers, long-standing experiments in physics education were compared in order to design "an ideal physics course" (Schwartz, 1997, p. 114). In one example program, education majors were taught "using a hands-on constructivist approach" (p. 113). An "NSF-sponsored program entitled ACTION PHYSICS" featured "the use of sports and movement as a theme to teach science to inner city junior high school teachers and students" (p. 114).

To get the whole picture, I considered a study in opposite approaches: an interdisciplinary teaching situation where "measurement in mathematics with locomotor movements / movement concepts in physical education" (gym class) were combined (Chen et al., 2011, p. 51). The researchers found that "the students saw the vivid connections between physical education and mathematics and *became more interested in both subject areas*" (p. 49, emphasis added). For my unit, instead of incorporating a core area (mathematics) into a setting defined by health and movement, the target Waves and Periodicity physics unit incorporates health and movement (e.g., an electric tooth-brush activity that relates hygiene to rotational motion and energy flow diagramming) which topics also add a layer of personal and even social relevance.

I have in my own classroom discovered that this theme of forming connections to the human body (or human physical experience) is unavoidably connected to my students' perceptions of physics concepts. In fact, the misconceptions that life teaches them I have found to be quite persistent. Throughout a typical discussion, it is not unusual for one of my students to ask, 'But what about when I...?' as they struggle to make "personal sense" of the science involved (Driver et al., 1994, p. 6) and reconcile it in the context of the human physical experience. I do not believe that this Aristotelean inevitability must forever be a barrier to learning. It is, however, necessary to first acknowledge that "[students] build new knowledge and understanding on what they

already know and believe" (NRC, 2000, p. 117) and that they can "formulate new knowledge by modifying and refining their current concepts and by adding new concepts to what they already know" (p. 118). The following section is a discussion of literature linking a closely-related strand (body motion for learning) in support of this idea that—through the integration of movement to help students physically and socially relearn their experiences in the context of physics content and through the freedom of inquiry-minded, active learning—this constant need of students to analogize principles and physics language to everyday experiences and functions becomes a strength.

These teaching strategies have all been aimed at improving self-, social-, and discipline-relevance. However, the heart of this reframing is based on career-choice for my Elementary Education and Sonography students. The next section—the final component of the pre-unit development literature review—provides insight into improving career-relevance for these students. It also highlights the need for data-collection through surveys and interviews with program and other experts.

Key Strategies for Teaching Education and Sonography Majors

Although there are many resources available for teaching physics to non-majors, my review of the literature did not yield any specifically tailored to meeting the needs of this exact population. Regardless, the studies reviewed typically included students from other majors alongside pre-service teachers. It stood to reason then that the strategies discussed would also support learning for my own class mix. That being said, the future application of concepts in potential graduates' careers should certainly depend on the expectations placed on these future employees held by each individual field. Until I completed my data collection and analysis, this was an incomplete picture

due to both the need for increased resolution for this exact population within the College's context and also the significant imbalance in favor of physics instructional strategies aimed at pre-service educators without much insight into teaching physics for Sonography-bound students.

The National Science Teachers Association (NSTA) Board of Directors issued a Position Statement on *Teaching Science and Technology in the Context of Societal and Personal Issues* (NSTA Board of Directors, 2010). Although they reference the older National Science Education Standards (see National Research Council [NRC], 1996), these positions appear to have carried over into the *Next Generation Science Standards* (see NGSS Lead States, 2013) and are appropriately still included as part of the NSTA official positions. This particular position statement points to socioscientific issues. It includes the following recommendation for science instruction, among others: "incorporate scientific issues that are personally and socially relevant, and developmentally appropriate, as a way to generate interest in and motivation to engage in relating science to personal and societal issues" (NSTA Board of Directors, 2010). It is in this context that future teachers must be fluent. Little imagination is required to realize that this applies also to future health practitioners (e.g., sonographers) whose very careers are shaped by these socioscientific tensions.

Solely for Education majors, however, is the expectation that they must *teach* to this effect. Since "[teachers] often try to implement instructional materials in their classrooms that are very similar to those...used in their college courses," it is clear that "teaching methods are learned by example" (NRC, 2000, p. 93). This underscores the career relevance of *how* physics is taught to pre-service Elementary Education teachers. Considering this a call to prepare scientifically proficient and capable employees, the

design principles and instructional strategies were selected with this challenge in mind. The expanded design principles from this pre-literature review are presented in Figure 11.



Figure 11 Pre-Development Design Principles

Career relevance, above the other recognized areas of relevance, emerged at this point, although greater resolution was needed in this area—not gained until the intradevelopment phase during program advisor surveys and interviews. From this initial career readiness perspective, a third support of critical importance to career success was identified: passing certification exams. For Elementary Education majors, a primary step towards certification is the successful completion of an Education Testing Service (ETS) Praxis-II examination (ETS, 2014b). For Elementary and Middle-level Education majors, they are required to take either a science subtest or a content certification test, respectively (ETS, 2014a).

Certification exams are also a large part of career readiness in the medical ultrasound field. The American Registry for Diagnostic Medical Sonography (ARDMS) is the major accrediting body for sonographers. Although physics principles are a part of other certification exams, one exam in particular-the Sonography Principles and Instrumentation (SPI) examination—is the primary test of a sonographer's knowledge of physics concepts and applications (ARDMS, 2015). After a student pursuing the Diagnostic Medical Sonography degree successfully completes the Conceptual Physics course, they later take a course specifically built around ultrasound physics: Acoustical Physics (DTCC, 2014). The Conceptual Physics course plays a supporting role for this second physics course. Naturally, concepts that are introduced in the first course are applied in the second. This relationship made it possible to better identify which physics concepts were to be stressed in order to encourage success in the subsequent Acoustical Physics course and, ultimately, towards earning of the industry credential. This is done primarily through adoption of the Joint Review Committee on Education in Diagnostic Medical Sonography (JRC-DMS) National Education Curriculum: Common Curricula ([JRC-DMS], 2008).

An additional challenge in the education field is the call for educators at all levels to prepare their pupils for entry into a society demanding increased STEM (Science, Technology, Engineering, and Mathematics) awareness and participation. One researcher, in response to the issues which had also prompted the publication of the *A Nation at Risk Report to the Nation* (National Commission on Excellence in Education, 1983) cited "underprepared teachers" as a barrier to students entering "science-related professions" and that "traditional approaches are inadequate (McDermott, 1990, pp. 140-141)". This call for improved STEM preparation has since

become a critical thread in the tapestry of our century. There has been much work done towards meeting this challenge (see National Science Foundation [NSF], 2007, Kuenzi, 2008, Bybee, 2010), and it has become a driving initiative in the State of Delaware (see Markell, 2010, DTCC, 2015c).

Diagnostic Medical Sonography, being a STEM-career in its own right, is certainly also a part of these reforms. From this perspective, not only is the Conceptual Physics course tasked with "the responsibility...to provide appropriate instruction for teachers" (McDermott, 1990, p. 144) towards socioscientific literacy and competency, but also it is entrusted with the preparation of future STEM workers. Although this study uncovered scarce research focused specifically on Sonography students, studies on teaching fundamental physics to life sciences and pre-medical students provided strong support for the integration of biology with physics concepts (Crouch & Heller, 2012). This has, importantly, been extended beyond these students to include all nonphysics majors in support of improving scientific literacy (Parthasarathy, 2015).

The following section outlines the literature findings that took place during the development phase in order to inform the activity and assessment designs and select the platform for sharing of unit materials as educative curriculum.

Intra-Unit Development Literature Review

The design principles formed the overall design framework for the development of the unit materials for this study. As previously illustrated, this collection of guiding principles was incomplete pre-unit development. During the development phase, the data collection process (which parallels this literature review study in the subsequent chapter) helped to complete the design principles and allowed for selection and development of high quality unit materials. However, it was recognized that future adopters and adapters of these materials would need easily accessed and pedestrianly followed educative curricular materials (e.g., lesson outlines). These would need to contain instructional notes and research-based guidance on common misconceptions, assessment strategies, and considerations for accommodating diverse learners. The need for these components, along with the parallel findings from the subsequent chapters, made clear the need for an additional design principle: high quality standards for course material development. The inclusion of this design principle is illustrated, below:



Figure 12 Quality Curriculum as a Design Principle

Since *Career Relevance* as a design principle was solidified through data analysis in the pre-unit development phase, it is here shown as fully integrated in with the newly identified *Quality Curriculum* component. This seemingly obvious principle required significant effort of literature investigations, data collection and analysis, and expert review processes to satisfy. Those literature review components that contributed the most to my adoption and expansion of this design principle are illustrated in Figure 13.



Figure 13 Intra-Unit Development Literature Review Components

This first section explores the method by which I chose a framework with which to present and share my unit as an educative resource.

Selecting a Format for Educative Curriculum Organization

Before outlining specifics of unit materials, I first identified a lesson design framework. This was not only to provide assurance that I was mapping out each lesson around the best practices identified, but it also provided a vehicle by which I might more readily share the developed unit and other materials with future adopters. Proper use of an instructional framework speaks to providing fidelity between and across lessons, future units, and classrooms. Already being aware of some common instructional frameworks (and having put many into practice), my task of choosing a framework about which to organize my unit materials, activities, and assessments was simplified. Instead of focusing on frameworks that I have used myself as a former high school physics teacher or those currently adopted by state or local groups, I reviewed multiple frameworks based on appropriateness to my teaching situation.

Understanding by Design (UbD) and Learning Focused Strategies (LFS) both provide very specific curriculum documents to be populated by the designer. LFS also maintains flexibility (Learning Focused, 2015): always a desirable trait when the hope is to extend a curriculum beyond one classroom. *Design Thinking* (DT) has the strong social constructivist connection with an emphasis on cross-disciplinary connections (Stanford University Institute of Design, 2015). This cross-disciplinary approach might have proven useful to the Education majors, in particular, since they need to think along those lines in the field, but there was little draw in the framework for Sonography majors. The *Instruction Analysis, Design, Development, Implementation and Evaluation (ADDIE)* framework held a lot of merit in terms of its past applications when linking career field expectations to curriculum (Interstate Renewable Energy Council [IREC], 2012). Finally, I saw that the *Universal Design for Learning* (UDL)

principles tied in cognitive theory strongly (including the need to engage an individual on multiple levels—e.g., physically) with the added benefit of providing many examples of completed curricula (National Center on Universal Design for Learning, 2014). A summary of my assessment is provided in Table 1.

Although each model had its own merits, and the Center for Creative Instruction & Technology (CCIT) group at my College recommends the Understanding by Design (UbD) lesson design framework (DTCC, 2015b), I settled on the ADDIE framework given its focus on career and technical education applications, acknowledgement of a broad range of supports for learners toward high-quality lessons, and its flexibility in design. It might still be argued that any of the frameworks could be adapted to meet the needs of my unit reframing. Having had experience with multiple design frameworks in the past, they all do serve the same fundamental purpose. However, the ADDIE framework provided the most freedom in how I applied its components—allowing me some creative license. I considered the other models to be too structured and, therefore, restrictive, to allow for a free-flowing reframing based around design principles (instead of being driven by a lesson development framework). In the end, I chose this framework to house my reframed unit materials and assist in making the unit materials into an educative curriculum. This choice required me to spend more time initially in document creation, but it also met my need for flexibility which I was able to then build into the lessons.

Table 1Choosing an Appropriate Curriculum Design Framework: Five Strong Design Models

	Design Model	Basic Description	Notes (and Citation)
46	Understanding by Design (UbD)	A backward design framework with an emphasis on teaching strategies, assessment, and learning transfer	Relatively simple lesson outline materials, seems particularly well-suited to K-12 and citizenship. (McTighe & Wiggins, 2012)
	Design Thinking (DT)	A design model which focuses on cross-discipline, socially constructed meanings.	Seems to straddle applications in management and K-12. Includes components of other models (e.g., empathy) and seems to be geared towards a softer version of the engineering design process used throughout the Next Generation Science Standards. (Stanford University Institute of Design, 2015)
	Learning Focused Strategies (LFS)	A backward design instructional framework focusing on standards-integration and curriculum mapping.	A very definite design approach with multiple resources and strategies. (Learning Focused, 2015)
	Instruction Analysis, Design, Development, Implementation and Evaluation (ADDIE)	An instructional design system geared directly at course creation or revision.	Emphasizes learning theory over the softer applications (e.g., empathy). Proven for education based around career competencies. Seems very similar to the engineering design process used throughout the Next Generation Science Standards. (Interstate Renewable Energy Council, 2012)
	Universal Design for Learning (UDL)	Curriculum design principles aimed at learning equity based on cognitive theory.	A definitely strong application of learning and cognitive theory. Clear principles and multiple examples available. (National Center on Universal Design for Learning, 2014)

The next section provides an overview of the *ADDIE* framework and introduces the templates created in preparation for the unit materials development phase. Importantly, it also explains the call for ongoing reflective practice that is central to the *ADDIE* framework.

The ADDIE Framework for Instructional Design: A Brief Overview

The *ADDIE* framework has a decades-long history. It has gone through some modifications since its inception; I here have adapted it from its use as a curriculum design tool within the International Renewable Energy Council (IREC). The *ADDIE* framework is revisionary in nature, and ultimately requires reflection throughout course delivery. This reflective practice is primarily evident in the formative and summative assessment components.

The *ADDIE* acronym refers to five (cyclical and interwoven) steps: Analysis, Design, Development, Implementation; Evaluation (IREC, 2012). The Analysis phase questions why the education (denoted as "training" in the Interstate Renewable Energy Council context) is needed. It is during this step that "knowledge, skills, and attitudes (KSAs)" (p. 6) needed by the population in question are identified to determine if and to what extent training might be necessary. The Analysis process includes also defining the student population (background knowledge or experience, attitudes, specific needs) and taking stock of the "educational and technical equipment and resources…available" (p. 7). It is here that I include awareness of student misconceptions in lesson content. This phase also underscores the need to mirror "conditions…students face when they go…to the job" (p. 7). During the Design phase, "learning objectives and criterion-referenced testing procedures" (p. 8) are specified. Considering that my Education and Sonography students have very clear career objectives laid out for them, professionally (NGSS Lead States, 2013, ARDMS, 2015) and that the course's learning objectives are set by the existing syllabus, these resources informed the bulk of the unit reframing in this phase. Also under Design fall the ever-critical and learning objective-linked "[assessments], test items, and checklists...to determine whether students are competent" (IREC, 2010, p. 10).

The Development phase focuses on "lessons, learning activities and strategies, and media [selection]" (p. 11). The IREC Best Practices material offers some guiding questions for all phases in support of effective instruction, and those for this section in particular complement the pedagogical aspects of the theoretical framework that I developed. These include, among other guidelines, providing practice opportunities, formative ("confirming and corrective") feedback, and "[adapting] media" (p. 13). Figure 14 illustrates this within the context of the Unit template which I designed for this study.





Figure 14 Sample Phase Component from the Unit Template for the *ADDIE* framework as adapted from IREC, 2012

During the Implementation phase, the lessons are carried out or "presented to the students" (p. 14). For the unit reframing, these components and notes will be included (in future practice) to ensure opportunities for reflective practice. Implementation under the *ADDIE* framework brings up questions of student motivation, types of questions to invoke higher order thinking, and strategies for lesson introduction and media use. Summarization and time management considerations are also important components (p. 15) which, as included in my unit reframing process, make for a smoother first iteration. Transparency of timing and clarity of the resources and how they are used are intended to facilitate the adoption of the reframed unit by new and veteran instructors. In the final phase of the *ADDIE* framework—the Evaluation phase—data to determine course success are collected (p. 16) along with determining whether "the results justify the time and effort spent developing the course" (p. 17). This includes the collection and review of summative assessments, among other sources. Perhaps more importantly for my own study, this phase also includes the following questions:

- Which experts should review the materials before a course is presented to students?

- Which changes should be made to improve the course after it is presented? (p. 17)

The first of these two questions was of primary importance to my research, and in fact both helped to answer my research questions.

The remaining three sections of the intra-unit development literature review phase outline the importance of making accommodations for diverse learners, addressing misconceptions, and assessment strategies. The threads of accommodation and assessment were immediately incorporated into the unit reframing. This includes also a component on the methods employed to identify and addressing common misconceptions.

Accommodations for Diverse Learners

There is significant literature available on physical accommodations for students with disabilities. Also readily available are decades of studies and theories on types of learning styles, student self-assessments, and related materials. Given the wealth of literature available, I selected three representative resources to describe this component of my unit reframing. These were chosen based on the further insight they provided around the *Quality Curriculum* design principle and the recommendations that came

from the College's Center for Creative Instruction & Technology (CCIT) review of my preexisting Conceptual Physics materials.

The first study considered learning styles within diverse groups. It pulled from existing models (primarily Kolb, 1976, via Mestre, 2006) to identify a "four-stage cycle" of learning that moved through "reflective observation," to "abstract conceptualization," through to "active experimentation," and on to "concrete experience" – the latter of which is a characteristic of "Accomodators...who use concrete experiences, or attempt to make any situation concrete" (Mestre, 2006, p. 29). Without going into the remaining learning styles, the article noted that "Latinos, white females, African Americans, and Native Americans tend to fit in this category" (p. 29). The first three groups describe the vast majority of my typical Conceptual Physics roster. This note on learning styles complimented the idea that my students demand content to be "as real as possible, and as immediately applicable to their own lives as is reasonable" (Thompson & Deis, 2004, p. 81). Pulling from Moeller (2000, via Mestre, 2006), it was noted that this learning style was "the most dominant learning style in the nontraditional learning environment" (p. 29).

In terms of lessons for improving hybrid course design, the article explained that web-based materials should be written to require interaction from students where they "think about an issue, respond to a question, and get immediate feedback" and also to find ways to "provide a more personal connection" and "include visual or kinesthetic modalities" (p. 30). In my own unit, this is accomplished through online interactions between students, the extension of inquiry activities that require activation across the identified three realms of human experience, and heavy use of varied and even

kinesthetic formative assessment strategies (e.g., drawing within a video response through Zaption® software).

Moving beyond learning styles to accommodations for students with disabilities, I focused on physical disabilities such as visual and hearing impairments. Buggey (2000) points out that the Americans with Disabilities Act of 1990 not only prompted universities to "[make] changes to physical structures and established systems of academic support," but that "[when] designing online courses, the same access criteria apply" (p. 42). The article outlines three main principles to consider when designing an online course. These are 1) "keep it simple," 2) "design for students with specific disabilities," and 3) "measure accessibility" (pp. 44-45). The first and second principles are in place to allow assistive technologies to do their job easily. The final principle considers a method for instructors, or curriculum designers, to gain feedback and a "line-by-line site analysis with recommendations for improvement" (p. 45) for their online materials.

While my reframed unit incorporates on its own a wide range of assessment strategies, I also included suggestions for alternative activities and roles of learners with physical disabilities throughout the lesson outlines (reference *Appendix B*). With a curriculum so infused with movement-based activities, this is obviously a concern. My third primary resource for integrating accommodations for diverse learners focused specifically on physical accommodations within the face-to-face laboratory environment. In their study on "making science accessible for students with physical disabilities," Kahn et al. set out specific strategies for modification of activities to meet learning objectives (2014, p. 37). These ranged from the use of large print, increased work space, positioning considerations with laboratory activities (e.g., height when

students require wheelchairs or have other height-dependent physical challenges), among others. I recommend that these strategies be employed on an as-needed basis depending on student accommodation needs. In most cases, the modifications are basic adjustments which allow students with physical disabilities to explore and gain understandings on which they might otherwise miss out.

The next section identifies the research backing behind common misconceptions on wave behavior and periodic motion. These were integrated directly into the unit primarily in the types of questions students are asked to explore in the guided inquiry activities and (just as heavily) in the assessments that permeate the unit materials.

Addressing Common Misconceptions

In this course, my students are introduced to physics concepts prior to applying them. As a veteran physics teacher, I was aware of several typical misconceptions my students possessed. These ranged from basic ideas on human body applications (e.g., the idea that our voices are made up of single frequencies) to more traditional misapplications of physics concepts (such as the idea that longer pendula swing faster). I noticed, especially, significant problems with students' comparison of light and sound wave natures and behaviors. For both Elementary Education and Sonography majors, these misunderstandings pose challenges for their future careers.

Students come to class with preconceptions about what they are going to learn (and how they should approach it). This phenomenon is described as *framing* (Hammer & Hutchison, 2009). "The central idea of framing is that people generalize knowledge from past experiences for use in making sense of what is going on in subsequent situations they perceive to be similar" (p. 509). Clearly, students have been with their past experiences and held onto their preconceptions for much longer than they will engage with the course material. These preconceptions too frequently are deeply engrained misconceptions about what they will see in my course—whether it be proper use of mathematics, the true nature of everyday experiences, or how to correctly apply physics language outside of the colloquial context.

A number of studies have been completed on undergraduate physics misconceptions. The most prominent of these lesson-specific misconceptions are included in the notes provided on each individual lesson plan. The figure below provides an example of these:

2. Who are the students?

What knowledge, skills, and attitudes are already in place? What misconceptions may be present? Again, basic self-awareness is important. For the typical student, these activities and discussions will relate directly to their own lives (in fact unavoidably in most cases). The major problem in terms of misconceptions is that the real world is not as simple as ideal world physics. E.g., the "Chattering Teeth" activity will in most cases not yield a uniform frequency or amplitude over time. A common misconception among students is that wave speed depends on frequency (Kennedy & de Bruyn, 2011, p. 1159, Pejuan et al, 2012, p. 673. Stepans, 1996, p. 174). Students also may believe that the speed of sound is greater in the direction in which the source is moving (Pejuan et al, 2012, p. 683), which has direct implications for the Doppler activity. In terms of units, students tend to confuse frequency with time due to their close relationship (Stepans, 1996, p. 174).

Figure 15 Identifying Misconceptions in Lesson03

Many of the ideas presented in my class are commonly experienced phenomena. However, it is likely that my students did not think much about the phenomena at the time of the experience, and it is difficult to say what conceptions each student may have internalized (thus the need for formative assessment through the use of Zaption® and other strategies early on and throughout the unit).

Stepans' (1996) text on commonly held misconceptions in (physical) science provided a starting point for my study. Stepans noted that students have significant difficulty with understanding what is happening with sound media on the small scale, how destructive interference really works, a general misunderstanding of human vision, and a broad misapplication of frequency concepts. The continuation into this decade of these misconceptions among physics learners is reinforced by the findings of Kennedy & de Bruyn (2011) and Pejuan et al. (2012). Caleon and Subramaniam (2013) provide insight into misconceptions on the production of a single wave pulse versus continuous wave forms (p. 659) which has immediate applications in ultrasound technology.

The literature-based overview of misconceptions, summarized in Table 2, strongly informed my unit reframing. These misconceptions were grouped into overall categories and incorporated directly into the unit and lesson plans for inclusion in assessment and activity design. Confusion on the nature of sound and waves in general was evident.

Table 2Common Misconceptions with Wave Nature and Behavior from the
Literature

	Misconception Frequency Count	Misconception Description (with Citation(s))	
Category	Unique Resource Count		
Wave Propagation	73	Motion of media misunderstood as being the motion of the wave (Stepans, 1996, p. 174). Belief that wave speed depends on frequency (Kennedy & de Bruyn, 2011, p. 1159, Pejuan et al, 2012, p. 673. Stepans, 1996, p. 174). Belief that the speed of sound is greater in the direction in which the source is moving (Pejuan et al, 2012, p. 683). Sound only travels through air (Stepans, 1996, p. 184). Sound can travel through space (Stepans, 1996, p. 184).	
Wave Production	4 3	Uncertainty about what happens with a single "jerk" to a string versus a continuous wave (Caleon & Subramaniam, 2013, p. 659). Very diverse view of what sound actually is, especially in terms of moving particles (Pejuan et al, 2012, p. 680). Sound "can be produced without using any materials" (Stepans, 1996, p. 184). The harder an object is hit is related to sound pitch (Stepans, 1996, p. 184).	
Wave Characteristics (Non-Speed Specific)	<u> </u>	Belief that wave intensity is related to wave speed instead of tension and mass density (Kennedy & de Bruyn, 2011, p. 1160). Confusing frequency with time (Stepans, 1996, p. 174). "[White] light is colorless and pure" (Stepans, 1996, p. 200).	
Wave Interactions and Incidence	<u> </u>	With superposition, only adding pulses together at the peak instead of at all points in the pulse (Kennedy & de Bruyn, 2011, p. 1159). Belief that waves permanently cancel each other out due to destructive interference (Stepans, 1996, p. 174). "[a] color filter adds color to a white beam" (Stepans, 1996, p. 200). Only mirrors reflect while other objects only absorb (Stepans, 1996, p. 200).	
Human Experience Connections	<u> 2 </u>	The human eye gathers light (as if it were active and not passive) (Stepans, 1996, p. 200). Light only illuminates objects and "[makes] them visible" (Stepans, 1996, p. 200).	

Stepens' (1996) book reported misconceptions that addressed all five categories (wave propagation, wave production, wave characteristics, wave interactions and incidence, and human experience connections). Of these, the first four categories were further substantiated by the other studies on physics misconceptions. The unique resource count shows the number of unique citations used while the overall misconception frequency count includes duplicated resource citations within a category. Armed with these understandings, I was able to developed focused assessment questions aimed at revealing these misconceptions early on and bringing them into both online and face-to-face forums for examination. It is these assessment strategies that I now discuss in the next section.

Assessment Strategies: Considerations for Blended Learning

Assessments provide the pulmonary action for the flow of information between myself and my students. Formative assessment takes place continually in informal ways, but for this study I identified a number of specific, formalized strategies (both formative and summative) and integrated each into the lesson plans. Given the hybrid nature of the course, I have broken these down into face-to-face and online assessment strategies. A type of mixed formative-summative assessment (in that it is carried longitudinally and organically through a unit) is explained separately at the end of this section. Standard summative assessments such as WebAssign® and exam questions also featured strongly within the unit.

Face-to-Face Assessment Strategies

Assessment is naturally an extremely important part of the teaching and learning process. On the instructor's side, it "[helps] instructors understand their students'...learning and develop appropriate interventions to improve that learning" (WestEd, 2010, p. 16), and is an important part of teacher learning and reflection (DeLuca et al., 2012, p. 21). For students, it integrates feedback and "feedforward" (Tong, 2011, p. E152), helps students set their own learning goals and become more aware of their own learning (WestEd, 2010, p. 18), and enhances immediate and long-term learning (Smith, 2010, p. 30).

In my ongoing desire to identify misconceptions and support conceptual change within this unit, I formalized specific formative assessments in a thread that carries through the majority of the lessons. An especially useful assessment strategy which I have adopted for this unit involves student self-assessment. In the unit materials, I call these "Checks for Understanding," and they appear at regular and highly strategic intervals. These are meant to "[engage] students in assessment of their own thinking and performance...to be more self-directive in planning, pursuing, monitoring, and correcting the course of their own learning" (NRC, 2000, p. 80). At times they are used to identify and challenge the common misconceptions outlined previously. In other instances the unit includes these checkpoints to ensure that all students have reached a basic understanding before calling them to move on to an expanded view or a new concept. If some students did not dive into the inquiry activities as thoroughly as intended, these are also opportunities to make sure that they have a chance to consider the concept(s) at hand to the desired depth before moving forward.

Another strategy is the use of the Kahoot!® online quizzing tool. Although I only employ this tool once in the sample unit, it is an assessment technology which I piloted during the course of this study and found to be very flexible and engaging. Without giving a full breakdown of the capabilities and limitations of the Kahoot!® assessment tool, in short, it serves to gamify formative assessment in an easily-accessed (via smartphone, computer, or other internet-capable device) and quickly designed and launched package. Although an online tool, Kahoot!® is solidly an in-class educational technology.
Maximizing Assessment for Online Lessons

There are different methods of assessment to employ in online learning simply by virtue of the environment and technology. Benson (2003, p. 71, via Vonderwell & Boboc, 2013) maintains that meaningful assessment in an online environment depends on tapping the potential of online tools, although the "fundamental principles of assessment" are not changed by the platform (p. 23). It has long been a goal of mine to ensure that the online portion of my Conceptual Physics course be as rigorous and fruitful as the in-class portion.

Many of the activities in this unit were built with a very strong guided inquiry approach in mind. In the face-to-face portions of my class, these activities are relatively easy to arrange for students to engage each other and the tasks. Online, however, this type of collaboration is limited, especially using asynchronous technologies. I have had little success employing synchronous technologies for the hybrid portion of the course since the allure (anecdotally speaking) of a hybrid course for my students tends to be that the online portion of the course can be completed at their own pace and around their own busy schedules. To this end I fell back on a tried and true asynchronous tool: the discussion board. However, for this reframed unit I adapted an existing guided inquiry thought lab to an online, group discussion board activity. In this way I hope to reproduce online the level of inquiry-based engagement which should be evident in the face-to-face environment. Given the fact that discussion boards allow for open viewing of each individual student's participation, it is possible that this approach may actually also encourage participation by those who may otherwise take a smaller role in face-toface inquiry activities. Vonderwell and Boboc (2013) recommend the use of an online "Questions Wall" (p. 25) and a "Minute Paper" (p. 24). These correspond to my use in the unit of the Word Bank and discussion board, respectively. The "Minute Paper"

face-to-face equivalent, incidentally, is an "Exit Ticket" in my on-ground lessons while the discussion board replaces its paper-based counterpart.

In addition to using Padlet® for ongoing assessment, I also used Zaption®, which allows users to embed questions within video files and receive feedback after completion. For my purposes, I used this to help identify misconceptions at the start of the unit and to encourage early argumentation in the classroom environment. However, the types of questions which can be integrated into video files may also be used for more summative purposes. These online educational technologies were chosen based on feedback from the College's CCIT group, and they are in keeping with Vonderwell and Boboc's (2013) "considerations for the design and use of formative assessment strategies in online classes" (p. 25) and their "online journaling" examples (p. 24). The next section picks up this trail of journaling and applies it to the unit as a whole.

Assessment through Journaling: A Calculated Approach

One key component that emerged from my literature review was the idea of journaling as a means of uncovering persistent misconceptions throughout and at the end of a unit. One study by Schleigh (2014) supports the language of physics instructional strategies already in place with the study, where now students work collaboratively in "round robin" journaling and the use of "white boarding" strategies as embedded assessments (p. 47). Interestingly, the lesson used as an exemplar of these assessment strategies is based around the *Next Generation Science Standards' PS4.B: Electromagnetic Radiation* and the related *4-PS4: Waves and Their Application in Technologies for Information Transfer* standard (both of which are integral to the career connections for pre-service teachers in *Appendix C*), among others. I have summarized the six stages, here: 1) initial ideas as pre-assessment, 2) silent argument through round

robin journaling, 3) student-designed and completed investigation, 4) round robin white boarding, 5) student research; 6) final argumentation writing. This closely reflects the inquiry approach to learning supported by word banking—minus journaling.

In another science application, Scharmann and Butler (2015) use journaling to assess student learning and acceptance of evolutionary science. The study fits in well to inform my own use of journaling in that it acknowledges that science concepts (in this case, evolutionary science) should be taught using a "student-centered pedagogy [that] encourages active learning, generates personal observations, encourages group discussion of evidence, and considers the merits of each individual's observations prior to constructing a consensus position" (p. 18). The setting for the study was also in a community college biology course for non-majors (p. 16), which lends further credence to the applicability of this approach to my own students. The four steps employed are not too fundamentally dissimilar from that of Schleigh in that students form understandings on their own and as a group with the creation, revision, and ultimate presentation of understandings. These steps include: 1) identify the task, problem, or question, 2) generate a tentative argument, 3) interactive poster session; 4) write to learn (p. 17).

A recent study investigated journaling as a way "to enhance learning from an online course" (Hwang et al., 2015). "[Results] showed that keeping a learning journal had the strongest effect on learning achievement" (p. 114). The authors had adopted Anderson and Krathwohl's (2001, via Hwang et al., 2015, p. 118) taxonomy for learning, teaching, and assessing. This taxonomy is summarized in six steps; reproduced here as they appear in Hwang et al., 2015:

- 1) Remember retrieve relevant knowledge from long-term memory;
- 2) Understand construct meaning from instructional messages, including oral, written, and graphic communication;
- 3) Apply carry out or use a procedure in a given situation;
- 4) Analyze break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose;
- 5) Evaluate make judgments based on criteria and standards;
- 6) Create put elements together to form a novel, coherent whole or to make an original product. (p. 118).

Taking these three major research studies into consideration, I developed a journaling approach that integrates these as end-of-unit assessments while allowing the social collaboration pieces to show up as the design and delivery of a separate mini-teaching activity. This journaling approach is reproduced in Figure 16 for reference.

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Complete your Waves & Periodicity Unit Journal Entry

Here are the writing prompts to help guide your Journal Entry for this Unit: I have provided a rubric, here, to help guide your completion of this Journal Entry.

1) After having completed this unit, what skills do you have which you would not otherwise have developed?

2) Explain in detail what a wave is, in your own words.

3) Explain in detail what periodic motion is, in your words.

4) Are waves and periodic motion related? If you believe so, defend your position.

5) Review the Exam Practice questions and attempt to complete them on your own prior to viewing the video solutions. How do you rate your performance before viewing the videos? How do you rate your understanding after viewing the videos?

6) Write a new problem you would ask a student to complete on an exam for this content if you were the instructor.

Figure 16 Waves and Periodicity Journal Entry Prompts

By this point in the study, my survey data analysis had revealed a tenth and final design principle (the tenth being a latecomer: *Outside Applications* to broaden student perspectives and content applications). Figure 17 provides a completed picture of the ten design principles that went into the unit reframing. Since this final design principle

did not appear until the survey analysis was complete, its development as a guiding principle for the overall unit reframing is not presented, here.



Figure 17 Ten Design Principles: A Complete Picture

Taken together with the pre- and intra-unit development literature reviews, many of these resources influenced the unit material activity *choices*, directly. Each of these references are demarcated in the *Newly Developed Unit* outline at the end of the activity names—along with a note on whether they were directly adopted or altered from their original form in some way. An example of how to identify this among the other components of the *Newly Developed Unit* outline is shown on the next page indicated as *Literature References as Activity Origins*. In my search for appropriate resources, the design principles shaped my criteria for selection. This process is detailed further in the next chapter.



Figure 18 Navigating the Unit Design Outline

An overview of each of these resources is presented in Table 3. The table indicates their position across the ten design principles. It also shows how each was distributed across the seven lessons that made up the Waves and Periodicity unit.

						Desig	gn Pr	incipl	es (#)					Les	ssons	s (#)		
Resource In-Line Citation	n Resource Type	Activity Type	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7
AIA, 2016	Web - Tweet™	Formative Assessment				х	х					х			х				
Blanksby et al, 1981	Article	Formative Assessment				х	х	х	х		х			х					
Crouch & Heller, 2011	Article	Research/Investigation	х			х		х	х	х						х			
Edelman, 2012	Textbook	Demonstration	х		х			х	х						х				
		Webquest + Simulations					х			х		х				х			
Hewitt, 2008	Textbook	Small Group Lab		х		х	х					х			х				
Hwang et al, 2015	Article	Summative Assessment				х				х	х								х
JRC-DMS, 2008	Web - Document	Discussion		х	x	х	х				х				х				
		Whole Class Kinesthetic	х			х		х							х				
		Demonstration	х	х		х	х	х	х								х		
Lewis & Mohazzabi, 2014	Web - Video	Demonstration	х		х			х	х						х				
		Whole Class Kinesthetic	х	х		х		х				х					х		
McGuigan, 2009	Web - Video	Homework	х			х		х	x	х						х			
Ostdiek & Bord, 2013	Textbook	Demonstration				х	х	х	х					х					
		Discussion	х	х	х	х		х	x						х				
		Research/Investigation	х			х						х							х
Pantidos & Patapis, 2005	Article	Whole Class Kinesthetic		х		х	х	х						х					
		Whole Class Kinesthetic		х	х	х		х							х				
		Whole Class Kinesthetic		х	х	х		х								х			
Pfister & Laws, 1995	Article	Whole Class Kinesthetic	х	х		х		х	х					х					
Roseberry et al, 2010	Article	Discussion	х	х	х	х	х	х	х						х				
Schwartz, 1997	Article	Whole Class Kinesthetic	х			х		х	х		х			х					
Stepans, 1996	Book	Formative Assessment				х	х					х		х					
		Demonstration	х		х			х				х			х				
		Formative Assessment				х	х					х			х				
		Formative Assessment				x	х					х					x		
	Design Principle an	d Lesson Representation TOTALS	13	10	8	22	12	17	11	4	4	9	0	6	11	4	3	0	2

Table 3 Pre- and Intra-Unit Development Literature Review Activity Contributions

The final phase of the literature review took place after the development of the unit and prior to the evaluation of the materials by curriculum design (CCIT) staff and a small panel of science education experts. The brief literature review that informed the latter of these two review processes is presented in the next section. I found it important to include this small literature review as a model for future adapters of this methodology. Depending on the scope of the work, variations in approach, and the discipline in which the reframing is situated (not to mention the resources available to the adapter), this literature review phase might be significantly more complex—in which case this review would serve as a starting point.

An illustration of how this review fits into the overall design scheme is provided in Figure 19.



Figure 19 Post-Unit Development Literature Review Component

Post-Unit Development Literature Review

Buggey (2000) suggests that online course materials be subjected to professional scrutiny in order to assess accessibility for learners with disabilities (p. 45). For my unit, I extended this same idea back to the Collaborative Course Review conducted with the CCIT group (see *Appendix D*), where the design principle of *Quality Curriculum* incorporated the feedback on supporting assistive technology in my online materials. In this case, the follow-up was not complex. Following the same method, instead of contacting my "disability support department on…campus," (p. 45), I asked the CCIT group to again review my newly reframed materials.

The unit review process completed by the science education experts was significantly more time-intensive than the post-unit development CCIT unit review. The method I employed to assist in this review process was very similar to that used in Buoni's study (2012, p. 46), which involved a significant time and labor component for reviewers. Applied to this study, the original heuristics that study employed were replaced with my ten design principles. In order to offer deeper insight for each principle, some were broken up—resulting in fifteen overall "principle descriptors." These, along with a basic narrative to introduce the raters to the task, were meant to help explain for what each rater was to be looking. Just as the heuristics tool was employed in Buoni's study, I used the Excel® Spreadsheet program "to compare the relative strengths and weaknesses of every lesson" (p. 48) in my own context: the reframed Waves and Periodicity unit. In this way, each of the design principles was subjected to expert review to determine whether my unit accomplished the goals each principle demanded.

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In the next section, the theoretical framework is presented as a collection of these design principles. These are, again, based on the literature reviews and later research findings on improving relevance (primarily career relevance) across Elementary Education and Sonography majors.

Theoretical Framework

These ten design principles encompass the student and industry demands for life- and career-relevancy, social development of a shared language supported by an Energy-first approach, engagement of the whole student, and a human biologicallybased theme from which to make inquiry-informed, contextualized meaning of the physics concepts. They also reflect feedback from the College-embedded Center for Creative Instruction & Technology (CCIT) to ensure fidelity to the standards of the College as they relate to hybrid course instruction. Additional components resulted from data collected during this study. The design principles are provided in their full form in Table 4.

Table 4Theoretical Framework for the Reframing of Conceptual Physics: Ten
Guiding Principles for Content Design and Delivery

- 1. Content is directly related to students' real life experience.
- 2. Students co-construct meaning through the development of a shared language and peer engagement.
- 3. Terminology is foundationally introduced with an Energy-first approach which is continued throughout the course.
- 4. Students are actively engaged with the content cognitively, socially, and physically.
- 5. Concepts are scaffolded by being introduced as class inquiry demands.
- 6. Concepts are introduced contextually using a unifying, relevant theme.
- 7. Biological applications are explored in conjunction with physics content.
- 8. Course adheres to high standards of content delivery and design.
- 9. Course embeds opportunities to explore and practice career-relevant skills for sonography and/or education majors. 10. Applications beyond the unifying theme enrich the learning experience.

Together, these design principles support my students' learning of course content and empowerment beyond the classroom in relevant, 21st Century applications of physics concepts. Each component poses its own challenges, but by constructing my unit around these principles my students will be better served in a more relevant approach to and setting for content delivery. Again, the theme of incorporating human biology into physics (or the human body) has been paired with the supporting strands and other practices outlined within these design principles. Although it shares center stage with other approaches through Design Principle 7, it does form the core of the Waves and Periodicity unit and has influence across the design principles. The following chapters provide an overview of my methodology (Chapter 3) and a presentation and discussion of my research findings (Chapter 4).

Chapter 3

METHODOLOGY

The goal of my study was to alter the methods and types of content delivery and instructional materials which make up a Conceptual Physics unit on Waves and Periodicity toward improved relevance and usefulness for Elementary Education and Sonography students. This ultimately culminated into a full set of unit materials and ancillary resources designed around the ten principles outlined in the previous chapter. This was accomplished by updating the materials used in the unit based on best practices for the population (non-physics majors in a community college setting), for the delivery method (i.e., hybrid), and through the adoption of an overarching theme (supported by the Energy-first and kinesthetic teaching strands) that incorporated 21st Century challenges towards the development of a unit "that reaches out to the lives, communities, and experiences of students" (Price and McNeill, 2013).

This unit reframing was done through careful exploration of existing studies (i.e., literature review), use of instructional support services at the College, and feedback from stakeholders and science education specialists. Table 5 provides an overview of the research methodology employed to achieve this goal.

Table 5Methodological Overview for Instructional Redevelopment in Conceptual
Physics

Research Question	Data Source(s)	Method(s) of Data Analysis	Outcome				
1. Which instructional approaches should be employed to	Literature on teaching introductory physics to relevant populations. Literature on 21 st century teaching strategies.	Review of literature targeting best and promising practices specifically applicable to a typical conceptual physics classroom population.	• 1. Theoretical framework for the				
meet the needs of this population?	Input from instructors who have met with success in teaching physics to similar populations (5 participants).	of instructors with face-to-face or telecommunicated interviews following based on greatest potential applicability of instructor experience.	redevelopment of instructional practices (content, modality, focus, and assessment).				
	Guidelines and feedback from the College's Center for Creative Instruction & Technology (CCIT).	Application of CCIT's Course Design Matrix and cooperative use of the Instructor Collaborative Course Review process. Survey instrument for CCIT faculty and staff (3 participants).	pedagogical strategies for direct use or modification. _				
2. What challenges exist in the prominent fields of these students which can be	Literature on tensions and challenges in the primary program major areas as they relate to understanding physics topics and identifying the needs of this population and support strategies.	Review of literature and online resources from professional organizations to identify documented challenges for which these students must be prepared. These also include Next Generation Science Standards and Sonography Principles and Instrumentation commetencies	 Tabulated representations of how the conceptual physics course can be used to support these areas. Supplemental resources aimed 				
supported by the scope of this course?	Input from Education and Sonography instructors, program advisors, and department heads (6 participants).	Survey instruments and interviews (post- surveying) with department leaders and expert instructors.	at helping students make connections to career goals and challenges.				
3. To what extent might the findings	Course syllabus with course objectives along with updated theoretical framework		1. Clear list of instructional goals.				
from RQ1 and RQ2 be enacted	Results from previous literature reviews and additional readings: specifically, course material	Map out course material, modality, and assessment strategies in conjunction with course objectives from the syllabus.	2. Tabulated resource showing how these instructional goals are met and in what sequence.				
within the course?	samples and strategies, assessment strategies, and misconception research.		3. Sample unit, to include lesson outlines, full set of materials, sample assessments, and related				
	Information on prominent curriculum design models (e.g., Design Thinking, Learning Focused Strategies, Understanding by Design, Universal Design for Learning).	Brief review of prominent curriculum design frameworks to determine which might be most suitable for use in the development of a sample unit.	teaching resources. 4. Full course outline showing how the other units within the course might be updated along the same lines as the sample unit.				
	Input from experts in science education (3 participants).	Experts review course plans, materials, and other instructional resources post- reframing.	5. Feedback from science education experts at the College based on a full review of the proposed instructional changes. Used to inform areas in need of further refinement and also future research avenues.				
			6. Memorandum to physics department leaders with recommendations.				

KEY: Italics = Pre-Unit Development | Bold = Intra-Unit Development | Normal = Post-Unit Development

This overview is coded using differing font faces to give a sense of the sequence in which each component primarily took place. The next section opens up again at the pre-unit development phase and provides a perspective for how the literature reviews were used as data sources.

Pre-Unit Development Methods

The pre-unit development phase consisted of continually more specific layers of literature studies. Each was aimed at identifying more detailed strategies for improving relevance to the two majors in the course—the ultimate product of this being a fully developed, high quality set of unit materials. Also included are the survey and interview data collection components and the initial CCIT collaboration methods as outlined in Figure 20:



Figure 20 Pre-Unit Development Methods Contributors

Initial Literature Review

This review contributed greatly to the development of the design principles and helped add content to the resulting Waves and Periodicity unit. From a nuts and bolts perspective, the literature informed my choice of instructional design framework with which to present my unit as an educative and high-quality, readily-adoptable resource. The initial literature study was also necessary to inform the development of survey questions and interview protocol. A visual summary of the initial literature review findings as they informed the overall unit reframing is provided in Figure 21. The underlying relationship to the human body theme and kinesthetic teaching and Energyfirst supporting strands is shown situated within the three identified realms of human experience.



Figure 21 Literature Review Findings across Three Realms of Human Experience

Movement in the classroom as a pedagogical approach is more than just a matter of cognition, just as the human experience is understood to extend beyond the cognitive realm. With the view of kinesthetic teaching as engaging the learner on these deeper levels (generalized as falling within the cognitive, social, and physical realms), activities were identified that engage the learner physically towards improving the guided inquiry approach adopted through this study. While many existing examples, again, focus on standard force and

motion (dynamics and kinematics) activities, this study holds up wave behavior and periodic motion as an obvious link to Sonography majors while also taking on the challenge of helping future educators see connections between what for many is an abstract topic and their future careers. While part of meeting this challenge was to make clear that the standards on which both majors are based depend on an understanding of these concepts, another major component was to model for students activities they could bring into the classroom that would highly engage their own future students.

The examples that I pulled in directly from the literature were adapted to fit my own units' needs just as I intend the unit materials from this study to be adapted as needed in other classrooms and even (by way of modeling) other courses. Among those kinesthetic teaching resources which influenced my own activities are, most prominently: the ACTION Physics curriculum (Schwartz, 1997), the inquiry-based approaches to kinesthetic learning by Whitworth, Chiu, and Bell (2014), the "Kinesthesia-1" activities showcased by Hans Pfister and Priscilla Laws (1995), and an adaptation of a game on acting out waves with your body meant to encourage students "to explain their own actions and thoughts" (Pantidos & Patapis, 2005, p. 344). Each of

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these, along with the adoption of a pragmatic design aimed at supporting guided inquiry in physics employed by one of my colleagues (Hilton, 2016, personal correspondence), was influential in the overall design of the activities that comprise my reframed unit.

Already discussed is a central approach: Scaffolding of concepts through liferelevant, co-construction of a shared language. Taking this scaffolding into the plane of career readiness, there exist particular physics concepts—which either cause students (non-physics majors) the most difficulty (Schulte, 2012) or which are the most necessary to grasp from a knowledge and practice standpoint (see Kawamura et al., 2000, Briscoe & Prayaga, 2004, Korb et al., 2005).

The next section describes the methodology for the surveys and interviews which filled in the gaps in my study and allowed me to hone in on the career-relevance from the perspectives of professional stakeholders.

Surveys and Interviews

I employed three surveys to solicit feedback from various expert groups at the College. From the first two of these three surveys, three follow-up interviews were completed. The surveys were developed based on my own goals for the course and were also heavily informed by the pre-unit development literature reviews. Input from one of my Executive Position Paper Committee members with extensive surveying experience was solicited to refine the survey questions. In this way, the survey questions went through a series of revisions aimed at clarifying and separating out ideas into more distinct questions. Tabulated forms of these surveys are available in Tables 6, 7, and 8 over the next few pages (see *Appendix E* for expanded reproductions of each). For these tables, horizontal lines are used to distinguish between three types of questions: interval scale, free-response, and comments sections. The use of the

interviews was contingent on the responses I received from the surveys. Interviewees were chosen based on their indicated willingness to answer follow-up questions. Additional selection criteria are also described in this section.

One goal in my use of surveys and follow-up interviews was to solicit input from instructors who were identified as successful in teaching physics to similar populations. Data obtained from this physics instructor survey were used to inform and refine pedagogical content approaches in my design of the unit while clarifying the actual, fundamental need for course content reframing. I asked respondents to identify typical topic and conceptual weak points along with other areas in the profession which might be supported by the learning objectives. As outlined in Table 6 on the following page, these questions included identifying typical difficulties students face in the course, connections between socially-, personally, and career-relevant issues, and descriptions of success strategies.

Additionally, other department leaders and program advisors were surveyed to determine specific means by which the Conceptual Physics course might best support students' program and career readiness. This survey included questions on typical difficulties students have throughout the program and also challenges faced in early field experience. The survey was aimed at two populations: Elementary Education advisors and Sonography advisors. In it, I also asked respondents about trends in the field for which their potential graduates must be prepared—including certification or competency exams on which physics-related questions appear and areas of primary difficulty. These questions are reproduced in Table 7. Again, for each survey, the final question asked whether the respondents were willing to answer follow-up questions

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Table 6Physics Instructor Survey Questions

Q1: Have you taught a fundamental or conceptual physics course within the past five years? (YES | NO) For the following statements, choose whether you Strongly Agree (5), Agree (4), Neither Agree nor Disagree (3), Disagree (2), or Strongly Disagree (1): Q2: The students learned a lot in the course. Q3: The course incorporated material which would help the students in their careers. Q4: The students learned material which would help them in their careers. Q5: The students' majors had little noticeable effect on their approach to the course content. Q6: The students had difficulty with understanding vocabulary early on. Q7: The students had difficulty understanding vocabulary throughout the course. Q8: I taught this course in a traditional manner. Q9: It is or could be beneficial to teach this course using an overarching theme to tie concepts together. Q10: Most of the students seemed satisfied with the course. Q11: The students realized connections between their everyday lives and the course content. Q12: The students realized connections between course content and social issues. Q13: The students realized connections between course content and their future careers. Q14: Provide an example of one or more teaching strategies which you feel have/has been particularly successful: Q15: Provide an example of one or more major learning challenges your students have faced: Q16: In terms of physics vocabulary, which physics terms have your students had the most difficulty understanding and/or applying? (Please list and rank the top five) Q17: How will your Education students apply the course content to their careers? Q18: How will your Life Science (e.g., Diagnostic Medical Sonography) students apply the course content to their careers? Q19: The box below is provided for you to submit any other comments: Q20: Would you be willing to answer follow-up questions in the future? (YES | NO) [If yes, provide mode of communication preferred (interview, e-mail, phone call)]

(and, if so, to provide appropriate contact information). In this way, I was able to

identify potential interview respondents from both of the first two survey respondent

pools.

Table 7Elementary Education and Sonography Program Advisor Survey
Questions

Q1: How many years of experience in your field do you have?
Q2: Briefly describe your role at the College and expertise background:
For the following statements, choose whether you Strongly Agree (5), Agree (4), Neither Agree nor Disagree (3), Disagree (2), Strongly
Disagree (1), or Not Applicable (N/A):
Q3: My program(s)' students will apply conceptual physics concepts in other courses.
Q4: My program(s)' students will apply conceptual physics concepts in the career field.
Q5: My program(s)' students have difficulty completing conceptual physics.
Q6: The only reason my program(s)' students take conceptual physics is because it is a program or transfer requirement.
Q7: If conceptual physics were not a program or transfer requirement, my program(s)' students would not need to take the course for
program or career preparation.
Q8: My program(s)' students are required to apply physics concepts when sitting for certification examinations.
Q9: List some of the major difficulties reported by your program(s)' students, if any, regarding the conceptual physics course:
Q10: What, if any, are the major concepts your program(s)' students will apply in other program or transfer courses?
Q11: What, if any, are the major concepts your program(s)' students will apply in the career field?
Q12: What major challenges, in general, will your students face in the career field? (This may include trends for which they must be
particularly well-prepared, typical areas of difficulty for entry-level careers, &tc.)
Q13: The box below is provided for you to submit any other comments:
Q14: Would you be willing to answer follow-up questions in the future? (YES NO) [If yes, provide mode of communication preferred
(interview, e-mail, phone call)]

The final survey was aimed at revealing educational technology strategies and, importantly, to help me better understand the role CCIT could play in my data collection phase. This brief survey helped me to define the extent to which CCIT could inform my reframing, and whether this would be constrained to educational technology recommendations or if it might extend into the content dimension. Questions three through five, reproduced in Table 8, show the STEM education focus taken by this

probing survey.

Table 8 Center for Creative Instruction and Technology (CCIT) Survey Questions

Q2: Briefly describe your role at the College and expertise background:

Q3: Have you ever assisted in the design and/or delivery of a distance-learning (i.e., less than 100% face-to-face) laboratory-based STEM course?

Q4: What educational technology applications/software would you recommend for a hybrid, laboratory-based STEM course? Q5: Are you aware of any research on physics and/or other STEM education outlining best practices in the use of educational technology?

Q6: The box below is provided for you to submit any other comments:

Q7: Would you be willing to answer follow-up questions in the future? (YES | NO) [If yes, provide mode of communication preferred (interview, e-mail, phone call)]

Whereas the previous two surveys resulted in follow-up interviews—each with one survey population representative, this third survey resulted in the use of the Collaborative Course Review process where I worked with an educational technologist to find areas where improvements to the course could be made.

All surveys were administered through the Qualtrics® online system and distributed to the potential respondents via e-mail invitation along with a survey link for those who elected to participate. The survey window overlapped with a two-week holiday, so the surveys were made available a week prior to the holiday and kept open for a total of four weeks. Two reminders—one just before the break and one just following—were sent out automatically for potential respondents who had not begun the process, and a closing thank-you e-mail was programmed in for those who did complete the survey by the end of the fourth week.

In the case of the follow-up interviews, the associated interview protocols were developed through the identification of gaps or markers from the aggregate survey data. Of the three physics instructor respondents, I conducted an interview with one instructor whose population of students most closely mirrored my own. The major gaps I sought to address with this interview were an expansion on how to help make the course more relevant to Elementary Education and Sonography students and also to gain feedback on

Q1: How many years of experience in your field do you have?

instructional strategies such as guided-inquiry and theming. Since the interview protocols for each follow-up interview were constructed nearly simultaneously and with knowledge of the survey responses across the expert areas, each protocol also complemented the other. In this way, it was possible to triangulate strategies for improving relevance for the unit reframing. An example of this (evidenced in Table 9), is when I asked the physics interviewee about career connections for students.

Table 9Physics Instruction Interview Protocol

In the survey there were a number of questions on potential barriers to students' understanding of concepts.
One of these potential barriers was a lack of clear connections to students' career goals. How important do you
believe it is to make connections between course content and students' eventual careers?
As an instructor, do you have ideas on useful ways to make these connections to careers more obvious to your
students?
Another potential barrier from the survey was a lack of connection between concepts. I am already aware that
Conceptual Physics covers a broad range of topics. Will you please elaborate on how you help students make
connections between concepts throughout the semester?
Will you please describe any special dynamics of having two dominant majors (e.g., Elementary Education and
Sonography Pool majors) in the classroom? (In other words, do you feel that this situation affects student
behaviors, group dynamics, classroom atmosphere, or some other aspect of the learning experience)?
My initial review of the literature supports the incorporation of biology concepts and having students physically
engaged in multiple ways is an effective teaching method in fundamental physics courses. Based on your
experience as a physics instructor, what do you think might be some potential weaknesses and/or strengths of
using these "human body" connections as an overarching theme for the course?

Of the Education respondents, one stood out as particularly well-versed in and vocal on the needs of Elementary Education students and provided some initial ideas on how the course could be improved to be more relevant to their needs. I conducted an interview with this person to gain greater insight into those needs and potential solutions, which proved very fruitful. The interview questions employed—based again directly on the survey responses from the Elementary Education group—are provided in Table 10.

Table 10 Elementary Education Interview Protocol

It is my understanding that elementary education students enrolled in conceptual physics are all planning to transfer into a 4-year teacher certification program. Also, most elementary education students take this course near the end of their time at Delaware Tech. Is this accurate?

That said, do students only take the course because it is a transfer requirement, or are there other direct applications either in their future courses, teacher certification process, or eventual teaching?

Are the *Next Generation Science Standards* integrated into any of their courses at Delaware Tech? If not, would this benefit elementary education associate's degree students?

Do you believe that, in general, elementary education students are prepared to teach the science components by the time they enter the field?

Do you believe that, in general, your elementary education advisees look forward to taking conceptual physics (and why or why not)?

The primary thrust of my work in this study has been geared toward developing conceptual physics teaching methods and themes that work for both elementary education majors and diagnostic medical sonography majors (since they share conceptual physics as a course requirement). Short of making separate physics courses for each, do you have suggestions on how I can cater to the elementary education students' needs?

Out of the same survey I received insight from a Sonography program advisor. The resulting follow-up interview played a critical role in developing my understanding of the needs and special requirements of my Sonography students. This was especially important given the relative lack of literature on ultrasound physics education compared to that for pre-service Elementary Education teachers. As outlined in Table 11, I wanted to fully understand the orientation of my Sonography students in the Conceptual Physics course. I focused the interview questions on exploring their knowledge of the field, their goals, the requirements for entering and being successful in the field, and specific skills that should be exercised before entering the clinical environment.

Table 11 Diagnostic Medical Sonography Interview Protocol

It is my understanding that diagnostic medical sonography students enrolled in conceptual physics are all pool students who are working towards admission into the full program. Is this accurate? Based on your experience as an advisor to these students, how familiar are they with the field of sonography by the time they enter conceptual physics?

Are there any specific, fundamental skills sonographers need to develop to be proficient in the field? You mentioned in your survey response that students have expressed a need for more course offerings of Conceptual Physics. Do you as a primary program advisor consider this an actionable concern? (In other words, if an additional section of the course were offered, would your advisees be able to provide sufficient numbers for the class to run, and when might this course need to be offered: daytime, evening; weekend)?

I am aware of the ARDMS ultrasound physics requirements from past experience, exploration of the materials available on ARDMS' website, and a review of some limited literature on the subject. In your estimation as a primary program advisor for these students, would it be worth the effort if I included a document explaining the links between sonography students' goals and the conceptual physics course?

Given the low number of participants for each interview, coding was not done in a traditional sense. The interviews were each recorded and I transcribed each within one to four days after recording. During this time frame, connections were identified between each interviewee's responses, the survey data, and the pre-unit development literature review. Since each group saw only a piece of the puzzle, this was a true exercise in triangulation. As previously discussed, this was especially true between the physics instructors, program advisors, and my initial findings on best practices from the literature.

Curriculum Design and Educational Technology Collaboration

Delaware Technical Community College's Center for Creative Instruction & Technology (CCIT) employs three primary categories of personnel whose job it is to support the "design, development, and implementation of technology solutions in the learning environment" (DTCC, 2015a). These are *Instructional Designers, Learning Strategy Coordinators*, and *Educational Technologists*. Since I teach the Conceptual Physics course in a hybrid format, I consulted with CCIT to ensure that my content meets the core pedagogical needs of my students and the standards of the College. This was also a crucial step in ensuring proper fidelity to the eighth design principle, *Quality Curriculum*, in my theoretical framework. In an effort to map out the topography of assessments and Measurable Performance Objectives, CCIT also provides instructors with a Course Design Matrix which I employed (see *Appendix F*). Since the matrix was originally meant to map out an entire course, I adapted it to match the unit level. I employed this matrix to compare the distribution and coverage differences between my original approach to the course and that of my reframed Waves and Periodicity unit.

Beyond this, CCIT was very influential in shaping the overall unit activities and strategies. Discussed elsewhere are the insights gained by the limited data that were collected in survey form. Determined to gain further insight, I moved beyond this preliminary survey (meant more as a generator of next-steps in the case of CCIT) to take advantage of the other services and resources offered by this group of educational technology and learning strategies experts (i.e., Collaborative Course Review). Beyond this service, CCIT regularly puts out blog and e-mail articles on the use of educational technologies such as Kahoot!® and Zaption®. Both of these tools play key assessment roles in my reframed unit. The closely related Instructional Innovation Network also puts on one-on-one trainings on a volunteer basis. From these, I explored and adopted the Padlet® tool for very frequent use within the unit in support of the Word Banking exercises. These applications were external to the survey process which had pointed me in the direction of educational technologies of high instructional quality and helped me to make informed choices in their selection.

The data collection phase of this study was required to improve my awareness of student needs, the availability of resources to assist in my work, and potential

instructional and advisement strategies. This was completed just prior to the intra-unit development phase. The next section describes the methods employed during this phase.

Intra-Unit Development Methods

Data during the unit development phase came from several sources. The feedback gained from the survey and interview data was accompanied by a parallel process where my original course materials were reviewed by CCIT. This latter process was primarily aimed at encouraging fidelity to Design Principle 8, *Quality Curriculum*, while the former feedback was used to better understand how the unit materials could be written specifically to meet the relevancy needs of my students. At the same time, the other design principles were also influencing the selection and development of the unit materials. These touch points for the unit materials prior to expert review and final revisions are illustrated in Figure 22:



Figure 22 Intra-Unit Development Methods Contributors

Among these touch points was also the intra-unit development literature review. This yielded a wealth of examples on common misconceptions for students with waveconcepts as well as insight into assessment strategies. I have already described in detail the literature review that went into identifying these two highly influential components. For the activity mining process that included resources across both the pre- and intraunit development literature reviews, these provided strong representation across the majority of the design principles. That said, those that focused on *Quality Curriculum* and *Career Connections* were underrepresented (design principle numbers eight and nine, respectively). This underrepresentation was likely just an artifact from the basic nature of the resources. That is to say, these primarily focused on the activity and concept descriptions instead of going into great depth on how they were linked to curriculum design considerations and students' future careers. The resources were diverse across format (print books, articles, and web-based). They also spanned activity types-these concepts and activities were adapted as demonstrations, laboratory activities, whole class and small group activities, discussions, online research opportunities, and various assessments. The majority of these resources inspired activities across the lessons – primarily in those in the middle of the unit (where the lessons were very modularized and were composed of highly diverse and focused activities).

The next section offers a succinct overview of the unit reframing and development process. Since Chapter 5, *Unit Design*, goes into much greater detail on this point, I here provide only a brief overview.

Unit Reframing and Development

It is important to note that this study does not represent simple supplementation of existing course materials with the addition of new materials. On the contrary, previous course materials were instead first reviewed to determine how well they met the needs of my students (based on the Design Principles) and were modified or discarded as necessary. Certainly some of the content for my reframed Waves and Periodicity unit had its origins in existing activities. *Appendix G* outlines a number of the activities that are based on the theoretical framework – following the theme of the human physical experience (i.e., the human body) and supporting strands. These strategies were meant to meet the curricular objectives fully and did not necessitate a change in the course syllabus or typical grading structure. This collection of activities, the Course Design Matrix, and the unit and lesson outlines evolved to accommodate new findings.

In the online realm, through the use of collaborative tools, students enrolled in my course will be asked to take part in the development of online glossaries and "tool belts" (equation and physical-constants banks along with content-based resources and other artifacts). This co-construction of understandings (called "Word Banking" in my reframed unit) incorporates a number of 21st Century skills aimed at improving students' adaptability by requiring them to develop socially through unique and interconnected scenarios (see NRC, 2010). It also involves potential opportunities for argumentation and sharing of differing perspectives and experiences (towards empathy). Connections are made pervasively to the Energy-first approach as a commonly shared language and supporting strand alongside which the lived and socially relevant curriculum is compared. In effect, this unit was designed to allow students to build

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meaning together while I guide this construction. These artifacts are meant to be referenced throughout the unit activities—effectively making room for students to ask new questions when they find that they do not have enough information with what they have already constructed (inquiry learning). Taken together with kinesthetic teaching strategies, these approaches form a purposeful reinforcement threaded throughout the lessons that allows students to reflect on and practice concepts and skills in various ways and levels.

The post-unit development methods followed a simpler path, as the only touch points for the unit materials at this point were evaluative in nature. The following section provides an overview of these steps, and Figure 23 graphically represents these touch points.



Figure 23 Final Contributors to the Unit Development Process

Post-Unit Development Methods

The main feature of the post-unit development phase is the unit review process. The parameters for this process and basic descriptions of those involved are presented in this section. Taken overall, the purpose of this step was to gain feedback from science education experts who were tasked with determining the fidelity of the reframed unit to the ten design principles.

Unit Review Process

Three colleagues completed a review of the reframed unit independent of one another. They consisted of a physics Ph.D., a physics-specialist Ed.D., and another Ed.D. with a biology, physics, and microbiology background. Subjecting the reframed unit materials to expert review is the final data-collection process within my research methodology. It is in keeping with the expectations of the Evaluation phase of the *ADDIE* framework (IREC, 2010, p. 17), and for the purposes of this study acts as a type of quality control. The three reviewers had a working knowledge of the Conceptual Physics curriculum, had a proven record of innovation in the classroom, and were veteran instructors in the community college or university environment.

As previously explained, the method I employed to assist in this rating process was very similar to that used in Buoni's study (2012). In fact, the outline for the tool is nearly identical as I adapted it to fit my seven-lesson unit reframing. Buoni's original heuristics were removed and replaced with the ten design principles that formed the theoretical framework of the study (Chapter 2). Each design principle was fully described to provide guidance to the unit reviewers. This description was provided by pulling out principle descriptors (one or more per design principle). In this way, each component and nuance of the design principles could be scored and mapped out by the reviewers. For example, the fifth design principle was built on three main ideas: manageable chunking of content, scaffolding of ideas, and an inquiry-approach to learning where students are responsible for developing ideas and exploring concepts. These three main ideas became the principle descriptors for Design Principle Five, *Scaffolded Inquiry*. By extracting the principle descriptors in this manner, the rubric was used to determine to what extent the design principles were perceptible in the activities pertaining to the lessons designed under my reframed unit. Additionally, the reviewers were not required to interpret each design principle in order to apply the rubric to the reframed unit materials.

For this purpose, the heuristics are accompanied by scoring criteria, whereby a value of '0' meant that the rater found no evidence of that descriptor within the activity. A score of '1' indicated some evidence, while a score of '2' (the maximum score for any activity) indicated strong evidence of the principle descriptor within that activity. Reviewers were instructed to leave blank any cells for activities that they felt they could not accurately score (either due to lack of sufficient background, the need for content generation in the classroom setting, or any technical difficulties in accessing the content). In these cases, those cells were left out of the overall heuristics scores. I also reviewed the unit independently using this heuristic in order to provide a comparison dataset against which to consider the feedback of the raters. The outcome is discussed in full detail at the end of the next chapter.

A basic skeleton of this tool is provided as an example in Figure 24. The *Quality Curriculum* design principle was intentionally excluded from the unit review since the CCIT group was the recognized authority on the standards of content delivery

and design. The unit was divided into seven lessons—each based around main ideas and grouped activities. These activities were interconnected to build up to (and encourage the demand for) new concepts and experiments.

		LESS	ON #			
DUDDIC						t)
RUBRIC:						hes
$0 \equiv \text{No evidence supporting this heuristics}$	c in the activity				ж	ehig
$I \equiv$ Some evidence supporting this heur	istic in the activity			ALS	RAG	. (1₌
$2 \equiv$ Strong evidence supporting this heu	ristic in the activity			01/	VEI	NK
				ICT	IC⊳	E R/
		γ#1	·γ #2	RIST	RIST	1 VIT
UNIT: waves & Periodicity, Concept	ual Physics	ctivit	ctivii	EUI	EUI	ELA
Design Principle	Principle Descriptor	4	A			<u> </u>
	Unit materials and activities explicitly involve events and/or					
1: Content is directly related to students real life experience	objects which are encountered by humans independent of					
rear nje experience.	socioeconomic or cultural considerations.					
2: Students co-construct meaning through	Unit materials and activities provide opportunities for students to work together in small group and/or whole class settings					
the development of a shared language and	Unit materials and activities allow students to build and ravise a					
peer engagement.	shared record of concepts and terminology.					
3: Terminology is foundationally	Energy concepts and vocabulary are used throughout the course					
introduced with an Energy-first approach which is continued throughout the course.	materials to support the activities and inform materials.					
	Unit materials and activities provide opportunities for students to					
	engage in higher-order thinking.					
4: Students are actively engaged with the	Unit materials and activities have students engage the content in					
content cognitively, socially, and physically.	ways that require the input of others and/or encourage empathy.					
	The activities incorporate students' bodies as sources of data and			-		
	as laboratory objects/movers.					
	Concepts are introduced in small chunks as opposed to being					
	lumped together and front-loaded.					
5: Concepts are scaffolded by being	Unit materials and activities build on previous activities.					
mirounceu us ciuss inquiry uemunus.	Opportunities are given explicitly as part of the unit materials and					
	activities for students to ask questions and formulate ideas in an					
	online or in-class setting.					
6: Concepts are introduced contextually using a unifying relevant theme	Unit materials and activities are built on the theme of connections to the human body					
7. Biological applications are employed in	Biology and biophysics content is evolicitly a part of the unit					
conjunction with physics content.	materials and activities.					
8: Course adheres to high standards of	DO NOT EVALUATE	v	v			
content delivery and design.	DO NOT EVALUATE	^	^			
9: Course embeds opportunities to explore	Unit materials and activities incorporate career-relevant skills and applications for Education majors.					
and practice career-relevant skills for	Unit materials and activities incorporate career-relevant skills and					
sonography and/or education majors.	applications for Sonography majors.	l				
10: Applications beyond the unifying theme	Content includes references and activities that are not explicitly					
enrich the learning experience.	related to the theme of connections to the human body.					
ACTIVITY TOTAL SCORE	[activity relative strengths in overall hueristic]					

Figure 24 Example of the Heuristic Tool Adapted as a Rubric for Science Education Expert Review

Methodology Summary

The methodology included a detailed look at literature selected through increasingly more specific criteria. This literature review took place primarily across the pre- and intra-unit development phases and informed the survey instruments, unit activities, unit assessments, the overall design and reframing process, and the review process. The survey responses informed and necessitated follow-up interviews. The findings from each data source are explored in the next chapter. These findings helped shape the Waves and Periodicity unit reframing at all levels (from individual activity components all the way to refining the design principles). There were in fact multiple sources that contributed to the design principles and reframed unit materials. The final of these was the unit review process completed by science education experts.

Chapter 4

FINDINGS AND DISCUSSION

As investigated in the previous two chapters, extensive literature reviews were consulted in the methodology to identify strategies for teaching students across ever more specific characteristics, to identify misconceptions, compare curriculum design frameworks, and integrate assessment strategies across the reframed unit. These highly influential findings were integrated into the literature review section and discussed in detail. Three survey instruments were also used to further identify student characteristics and needs within each major, learn how other physics instructors at the College had met with success teaching these majors, and to lay the groundwork for later collaboration with the College's Center for Creative Instruction and Technology (CCIT). Interviews were conducted with select respondents following the analysis of the survey data. Findings from each of the data sets from the study are presented and discussed in this chapter.

Pre-Unit Development Findings

Each survey in this study was built based on the questions that came out of the early literature review and other gaps in my own understanding. The interview questions were born directly out of the survey findings, and were aimed at gaining insight into remaining gaps or specific markers left by the survey respondents. Of particular importance with the program advisor investigations was the need to identify potential areas of career relevance support.

Elementary Education Survey and Interview Data

The survey respondent pools were small for each of the surveys (and consequently the follow-up interviews). Of the three survey instruments employed, the Program and Career Readiness survey yielded the highest number of responses. In fact, I received a slightly higher-than-anticipated participation response (five of nine, 56%) from the potential Education advisor pool. The results obtained from this survey were mixed, but they held clues to the nature of the program and the Education advisees that were both useful in shaping my instructional approach and in the development of the interview protocol employed. A summary of the ordinal data collected from the five Education professionals who responded to the survey is provided in Table 12, below:

Table 12Program and Career Readiness (Education) Questions and Frequency
(n=5)

QUESTION	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Not Applicable
Students in my program will apply Conceptual Physics concepts in other courses.	0	0	4	0	0	1
Students in my program will apply Conceptual Physics concepts in the career field.	0	1	2	2	0	0
Students in my program currently have difficulty completing Conceptual Physics.	1	1	2	1	0	0
The only reason my program(s)' students take Conceptual Physics is because it is a program or transfer requirement.	0	0	1	1	3	0
If Conceptual Physics were not a program or transfer requirement, my program(s)' students would not need to take the course for program or career preparation.	0	1	1	1	1	1
My program(s)' students are required to apply physics concepts when sitting for certification examinations.	1	1	2	1	0	0

The survey results show that the Education advisors polled were very much focused on the transfer and career-preparation aspects of the program. There was in fact little consensus among advisors on the need for an understanding of physics concepts to either obtain certification or be successful in the classroom (i.e., the career field). The data led me to believe that the respondents did not know the content covered in the Conceptual Physics course enough to form connections to coursework, certifications, or classrooms. An interview protocol was developed based on these survey responses. This allowed me to gain clearer insights into career applications than those that came out of the survey data.

Of the open response questions, only the question on general challenges the Elementary Education students would face in the field yielded information that contributed to the unit's reframing. This feedback was primarily useful in better understanding the career expectations placed on Elementary Education pre-service teachers. Going down the list (reference Table 13), much of it is affirmation of the literature review findings: the importance of STEM-minded teachers, the fact that Elementary Education teachers are expected to teach across broad topics ("breadth of knowledge") with a changing landscape, and the importance of the *Next Generation Science Standards* (here referenced as Common Core). The challenge of classroom management could be a study in itself, but modeling engagement activities across learning styles as a means of student motivation (as accomplished in my reframed Waves and Periodicity unit) is also an attempt at addressing this concern.
Table 13General Challenges in Career Field (Education) Emergent Themes and
Frequency (n=5)

General Challenges in Career Field (Education) Categories and Frequency (n=5)							
"What major challenges, in general, will your students face in the career field?"							
EMERGENT THEMES	Frequency (%)						
Changing requirements - Legislation / Common Core	2 (40%)						
Changing requirements - Curriculum and Assessment	1 (20%)						
Call for science and mathematics teachers (STEM Education prevalence)	1 (20%)						
Breadth of concept knowledge required	1 (20%)						
Classroom Management	1 (20%)						

Since this (and the remaining questions) were open-ended, I coded the responses to form the *Emergent Themes*. Given the low number of respondents, this coding process was primarily basic summarization. Two of the five respondents (40%) did recognize that political mandates or professional expectations presented a challenge to Elementary Education instructors. Further, combining the "changing requirements" categories yields a frequency count of 3 (60%) for program advisors' recognition of the changing landscape their potential graduates will face. Judging by the literature review component on the professional needs of Elementary Education majors, I find it unlikely that training a pre-service teacher in a rigid, non-inquiry based environment will benefit them in their careers. There was no other theme recognized by more than one respondent. The presence of "classroom management" suggests that the survey did achieve a reasonable breadth in response, as this is easily recognizable as a basic component of classroom dynamics and instructional challenges.

The other questions (on difficulties experienced by advisees who take Conceptual Physics and the applicability of concepts to other program requirements, transfer options, certifications, and the career field) were either overwhelmingly considered irrelevant by the respondents or were used solely as markers in the writing of the Education interview protocol. The coding process was the same for these survey questions (as they were also open response). The additional responses are provided in *Appendix H* for reference, although again they held little to no direct bearing on the resulting unit reframing. That said, the results again lent credence to the idea of developing supplemental content for the course that relates content to professional standards (i.e., to use for program advisement and course introductions). The interview conducted post-survey further supported this conclusion. The responses given underscored the need for students to realize the connections between the Praxis Subject Assessments in Elementary Education (referred to as the "Praxis II" by the respondent), Common Core (i.e., the *Next Generation Science Standards*), and the physics course's content.

In addition to providing impetus to making these connections explicit, the interview with an Education advisor yielded some useful insights that influenced the development of my design principles and basic approach to activity designs. These included the use of students as peer-teachers (e.g., Sonography and Elementary Education majors working on content separately and then bringing their results together), preparation for the use of pre-packaged curricular materials (human body unit materials were given prevalence), and the recognition that the Elementary Education students are typically apprehensive of science (Quote: "…before they see you guys, and they're shaking in their boots because they are…not that strong in the science."). An additional idea that came out of the interview was of empathy—that is, encouraging students from both majors to see the content from each other's perspectives. This final point was highly influential in the use and design of the mini-teaching assignment near

the end of the unit (Quote: "Or you could throw out to the Elementary Education majors 'what would tie into Sonography' or 'how would you teach someone in ... sonography about this concept'...and vice versa to Sonography: 'how would you teach a young person that you're working with'?" The respondent also explained how explicit connections between course content and education standards might be beneficial to students, suggesting that, "It'd be somewhere they could go look over things—maybe feel a little more comfortable when they're going in there and they would know how some of these things do relate...to the coursework."

Returning to career relevance, the emphasis was placed on preparation for professional certifications and training for use of the Delaware Department of Education's curriculum materials, noting that Elementary Education advisees have reported "that material [I] covered is in the Praxis II for the State of Delaware." For the curriculum materials, the respondent emphasized the biology components, stating that "if you could tie these in what you're teaching with the physics that'd be really neat for the students at Delaware Tech."

The upcoming section presents the findings from the Diagnostic Medical Sonography survey and follow-up interview. Again, the emphasis was on career relevance. The interview also helped me better understand the mindset and orientation of the Sonography Pool students who typically take my class.

Diagnostic Medical Sonography Survey and Interview Data

The Sonography survey was limited to one participant (one of three potential respondents, 33%) who indicated that physics concepts were important through all stages (program progression, credentialing, and career) in the field of Diagnostic

Medical Sonography. A follow-up interview with this participant revealed several findings that influenced my understanding of Conceptual Physics' career relevance for these majors.

The interview revealed that students tend to hold some misconceptions about the Sonography program and the career field. First, although admission into the program is very competitive, program admission hopefuls do not necessarily need a 4.0 GPA to enter the program. That is, "…yes it is a competitive program, however many students have gotten into the program who did not have a 4.0 GPA…although that…obviously makes you the strongest candidate if you have it…" Given this, the students do tend to be very grade-motivated. Many potential Sonography students do not initially realize that Sonography entails much more than imaging for pregnancies. The respondent noted that "the students are very surprised when they learn everything that we look at and all the things that we're responsible for."

Two major skills were identified that support success in the sonography field: hand-eye coordination and spatial reasoning. Hand-eye coordination in important "...because they have to be able to have both hands function independently while looking in a completely different direction, so they're looking at the monitor while the right hand is scanning the patient and the left hand is operating the controls" ... "what they'll learn is that a small alteration in where they are with the transducer is gonna make a huge impact on their image." The *Biggest Hands, Smallest Hands* activity is a direct product of this feedback. Figure 25 shows the basic idea behind this activity, graphically. In this activity, students compare how small alterations in hand motion can have dramatically different results. The highly kinesthetic nature of the unit activities strongly supports this career-relevant skill requirement.



Figure 25 Hand-Eye Coordination Practice Application for Sonography Majors

For spatial reasoning, "...the ability to think three-dimensionally", ... "they're looking [at] a flat monitor, but what they're looking at is, obviously, a picture of the human anatomy, and they have to be able to think, you know, what's in front of what I see behind, above, below, to the right, to the left, so they're constantly having to think spatially while looking at a flat image." Given the crucial nature of this skill, my unit incorporates several opportunities for students to practice using probes simultaneously with on-screen use of computer programs. Further expansion of these skills in a fully reframed course would include practice across unit topics.

The interview also yielded the idea that students could benefit from reinforcement other than program advisement of the idea that they need Conceptual Physics content to succeed: "...if they could hear it from other people and get that reinforcement as to the significance of physics...in the field of sonography and why it's so important to have that basic knowledge...then maybe that'll help them understand why, and it's not that they're just in here 'because I have to get an A'." Also, students would benefit from these increased opportunities to decide if they really want to enter the Sonography field prior to acceptance into the program.

The next section explores the data resulting from the basic survey delivered to the Center for Creative Instruction & Technology (CCIT) team. This survey was administered as a lead-in to the integration of CCIT input and guidance for the course. The survey was followed by a detailed course review process. This process yielded recommendations for improvement for existing course materials which had direct bearing on the educational technology considerations of the newly developed unit.

Educational Technology Survey and Course Review Data

As with the survey conducted with Education advisors, the Educational Technology survey yielded some results that did not contribute to the unit's reframing and so are not discussed but are included along with the rest of the *Additional Data* records. Those results that were most influential I outline in this section. I received a response from three members of the Center for Creative Instruction & Technology team (3 of 12 potential respondents, 25%), which I considered an appropriate level given the typical division of labor by CCIT. The survey was short and yielded next-step guidance on the use of the services provided by the educational curriculum, strategies, and technologies group (i.e., CCIT). The following is a sample of the survey data and the one response that informed me on how I should proceed:

Table 14Recommendations for Hybrid Course Design Emergent Themes and
Frequency (n=3)

EMERGENT THEMES	Frequency (%)
More information or research needed to provide assistance in this area	3 (100%)
Lab-based applications (i.e., provide students with realistic, simulated lab	2 (66%)
Programs that provide opportunities for repeated practice (mastery learning)	
and immediate feedback	1 (33%)
Programs that are aesthetically pleasing and easy to use	1 (33%)

These emergent themes were developed through basic summarization coding of the open responses. As is evident, all three respondents (100%) noted that a narrower line of questioning was needed for them to best assist me. The remaining responses provided insight into the nature of the educational technology parameters I should employ when selecting programs. Additionally, the brief comments left by the respondents helped me understand more about the nature of their services in advance of this, as well, in that they are more typically focused on educational methods than subject-specific resources. Overall, I picked up important considerations that went into choosing digital resources for my unit reframing. Namely, these were as follows:

- Realistic, simulated lab experiences
- Opportunities for repeated practice
- Immediate feedback
- Ease of use and viewing

Each of these components went into the development of the eighth design principle, *Quality Curriculum*, and are reflected in the *ADDIE* framework lesson and unit reframing samples (*Appendix I* houses the full unit materials). They also acted as filters in my selection of programs such as Zaption®, Padlet®, and WebAssign®. For instance, WebAssign® is aimed at providing immediate feedback and opportunities for practice. Padlet® and Zaption® appeared highly intuitive in their ease of use and viewing. Physics simulations are readily available, but any used were screened for realism of the simulated laboratory experience.

Moving beyond this, CCIT reviewed my existing course materials (which included also the original Waves and Periodicity unit content). The resulting Collaborative Course Review form checked for the presence and quality of key educational technology components. This was conducted through the lens of hybrid course design, and although I have not reproduced the fully completed form, here, I have pulled out a summary of the findings and recommendations.

For an overall course reframing, I was asked to be more explicit in orienting students to the course (e.g., "Getting Started"). The information is covered initially in the course, as the review showed, but it may address longer-term confusion with the hybrid nature of the course. Given that this study is confined to a unit, I left this feedback alone for the time being. It was also suggested that my concept map should link to the lesson sequence (i.e., "Weeks"). I have reformatted the unit materials to make explicit the connection between concepts and lesson sequence.

One recommendation that had a sweeping impact on my unit reframing was that the content should be chunked into smaller pieces and made more visible in each folder. For my unit on Waves and Periodicity, this showed up as manageable instructional components to be included in the online learning management system. Utilizing this recommendation will help students stay on track with the online content and may also help when they return to study past material.

Three other recommendations also featured very strongly in the unit reframing. The first of these was that I should continue using the discussion board to have students reflect on what they have learned. I expanded this to include a guided inquiry group activity in the discussion board format. The second was that I should be more explicit in guidelines, expectations, and requirements (e.g., adding rubrics to labs). This shows up in this study as a more explicit and consistent use of guidelines for activities. At the same time, it had to be balanced by the guided-inquiry approach that was put in place (Design Principle 5). The need for clearly explained evaluation criteria was also identified in assessments and featured in the post-development unit reviewer recommendations.

Finally, in terms of accessibility for diverse learners, it was recommended that I incorporate equivalent alternatives for students with disabilities or different learning needs. This was accomplished as part of the educative curricular materials in the unit and *ADDIE* lesson outlines. Additionally, in terms of readability and accommodating assistive technologies (e.g., screen readers), the recommendation was given that more instructions (i.e., use of text-based activity descriptions and instructions) should be placed on the learning management system instead of simply attaching files. A review of the unit materials shows that this feature is used throughout the reframed unit. I was informed that screen readers and other adaptive equipment operate best when descriptions are included for each item. For this reason, I took special pains to include text descriptions of every link used in the learning management system. Along these lines of readability and accessibility, I also made use of the fact that YouTubeTM provides Closed-Captioning for its videos. When warranted, I wrote my own Closed-Captioning scripts to ensure accurate presentation of concepts.

The following section explores the results of the survey given to other Conceptual Physics instructors across the College. It covered a lot of ground and was focused on honing in on student perspectives, areas of greatest difficulty, and strategies for improving my own teaching to meet the needs of these majors.

Physics Teaching Strategies Survey and Interview Data

The physics teaching strategies survey results filled the most important gaps that existed in my previous findings. For this survey, my population was made up of nine potential respondents who had all taught the Conceptual Physics course within the previous five years. Of the nine, three (33%) responded to my survey. These had all taught the course for multiple semesters with diverse majors represented on their rosters. That said, these survey results were not without their own gaps. Fortunately, some of these weaker areas were also addressed with the program advisors' feedback. Additionally, a follow-up interview was conducted to address any deficiencies or areas that required clarification.

The ordinal data collected from the survey across a broad range of statements are provided in Table 15. A definite imbalance in respondents' perceptions toward Allied Health (e.g., Sonography) majors' penchant to form connections over that of their Education major peers was evident. Given the response to whether students seemed to have had difficulty understanding concepts, in general, I presumed that the instructors at least considered their course reasonably successful in meeting students' needs. There were mixed responses on many of the questions where I tried to get at the biggest barriers to students' learning. Overall, though, motivation won out as the greatest potential barrier to students' understanding of concepts. There were mixed results on whether students were able to see career relevance in the course content. The final three questions in the table showed that there was some activity in these areas—

namely that students did (at some point in the instructors' estimations) realize connections between the course content and their everyday lives, social issues, and their future careers. The results of the interview follow this analysis of the survey data.

Table 15	Teaching Concep	tual Physics (Questions and	Frequency	(n=3)
		2	•		· /

QUESTION	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Not Applicable
The Education majors in the course(s) made connections between course content and their careers.		1		1	1	
The Allied Health majors (e.g., Diagnostic Medical Sonography) in the course(s) made connections between course content and their careers.				1	2	
The students had difficulty with understanding concepts early on.*	-	-	-	-	-	-
The students had difficulty understanding concepts throughout the course.	1	1	1			
Vocabulary was a barrier to students' understanding of concepts.	1		2			
Mathematics was a barrier to students' understanding of concepts.	1		2			
Motivation was a barrier to students' understanding of concepts.			1	1	1	
Lack of a clear connection to their program was a barrier to students' understanding of concepts.		1	1	1		
Lack of a clear connection to career goals was a barrier to students' understanding of concepts.		2		1		
Lack of a clear connection between concepts was a barrier to students' learning.		2		1		
The students realized connections between their everyday lives and the course content.			1		2	
The students realized connections between course content and social issues.			1	1	1	
The students realized connections between course content and their future careers.			1	2		

* This question was omitted due to an error in the survey.

Additional questions resulted in very useful feedback. On a question asking respondents to identify the course delivery formats they have employed for Conceptual Physics, 100% of the respondents (n=3) acknowledged that they had taught the course in a face-to-face format while there was less representation in the blended learning styles. Two out of the three respondents had taught the course in a hybrid format while

only one had taught it in a web-enhanced format (a delivery format that includes more face-to-face time than a hybrid course). This served to orient me to the diversity of course delivery style experience, as clearly the respondents had taught across multiple methods, including the hybrid format in which my own course is offered.

 Table 16
 Successful Physics Teaching Strategies Emergent Themes and Frequency (n=3)

"Provide an example of one or more teaching strategies which you feel have/has been particularly successful:"							
EMERGENT THEMES	Frequency (%)						
Student-centered approaches	3 (100%)						
Students responsible for some aspect of instruction	2 (66%)						
Inquiry methods w/ followup discussions and instruction	1 (33%)						
Real-life, hands-on applications	1 (33%)						

When asked to identify at least one example of a successful teaching strategy for the course, each respondent clearly identified student-centered approaches. This is shown in Table 16 along with other emergent themes. The idea that students should be responsible for some aspect of instruction (evident in responses from two of the three respondents) resonates with the insights gained from the Education Advisor interview, and the single instance where real-life, hands-on applications was provided is a clear call for active learning strategies. Some general guidelines for my own use of inquiry were suggested, although there was a need for increased detail in many of these areas that was gained in the post-survey interview process. Each of these responses provided support for the earlier literature findings on strategies for teaching physics. This convergence between the literature and survey responses increased my confidence that I could trust these suggestions in reframing my unit. In another question, I asked the physics instructors to provide examples of major learning challenges faced by their students. One respondent noted that students were unused to inquiry practices. Another respondent said that students are typically inflexible when exposed to new mathematics formulas.

These results suggested a need to improve my own awareness of how mathematics instructors apply physics in the prerequisite class and subsequent mathematics courses. However, my study of the literature up to this point (and throughout the study period) did not support a great need for mathematics support. Taken with the relatively low identification in the ordinal data of mathematics as a barrier to student learning, I deemed more relevant to this study the caution that students are going to be typically unfamiliar with methods of inquiry. As I learned later in the follow-up interview (and as the literature on inquiry suggests), this warning directly supported the need for scaffolding of inquiry levels.

When asked to identify concepts which students generally have difficulty understanding or applying, respondents generated a broad list of terms (see Table 17). All three of the respondents identified *acceleration* as a problem area. The concept of acceleration is salient throughout all aspects of physics. That said, given the nature of the Waves and Periodicity unit, this is reflected only implicitly in the activities and would rather be emphasized earlier in the course sequence. In this way, the concept of acceleration can be brought into discussions and concept support strategies and does not warrant representation in the fundamental design principles of the course.

Table 17Physics Terms Posing the Greatest Difficulty to Students Terms and
Frequency (n=3)

"In terms of physics vocabulary, which physics terms have your students had the most difficulty understanding and/or applying? (Please list and rank the top five)"

TERMS	Frequency (%)
Acceleration	3 (100%)
Velocity	1 (33%)
Vectors	1 (33%)
Torque	1 (33%)
Inertia	1 (33%)
d=rt vs. x=½at ²	1 (33%)
Resonance of waves	1 (33%)
Constants (e.g., k or G)	1 (33%)
Electric Potential	1 (33%)

Beyond this, the topics provided (e.g., resonance of waves, inertia; velocity) only serve to paint a picture of the general landscape of the course in which the Waves and Periodicity unit is situated. This list practically circumscribes the full course minus extended applications. Moving beyond simple concepts and looking at the larger picture, respondents provided me with feedback on their use of themes through which to add relevance and tie concepts together. All of the respondents reported making use of some theme or themed topic, as evidenced in Table 18. This feedback supported the use of a theme, but some bounds were suggested. Among these were the need to ensure that the topic resonates with the students (which is the point of identifying career and other relevancies) and the use of diverse applications beyond the theme (Design Principle 10). Beyond "Life" as a theme, other themes were suggested that related to everyday or common experiences (see Table 19). Namely, these are the themes of "Energy," "Driving," and "Hobbies/Sports."

Table 18Potential for Teaching Conceptual Physics with a Theme Emergent
Themes and Frequency (n=3)

"What are your thoughts on teaching this course using an overarching theme to tie concepts together (e.g., teaching the course or a unit within it entirely around sports)?"

EMERGENT THEMES	Frequency (%)
Uses a theme or themed topics throughout course	3 (100%)
Theme viable or suggested	2 (66%)
Theme may not resonate with all students	1 (33%)
Life as a theme	1 (33%)
Prefer diverse applications over using a themed approach	1 (33%)

Table 19Themes Used for Conceptual Physics Emergent Themes and Frequency
(n=3)

"Do you have a theme that you use in this course which is particularly useful (e.g., is there a topic or group of scenarios which you consistently come back to for a particular unit or throughout the course)? If so, please elaborate."

EMERGENT THEMES	Frequency (%)
Driving scenarios	2 (66%)
Energy (as the ability to cause change in motion or position)	1 (33%)
Hobbies/Sports	1 (33%)

Taken as a whole, this data suggested that any theme chosen should also be moderated by supporting strands to make room for out-of-theme applications and ensure that the primary theme does not unnecessarily overpower the course content. All, however, should have some immediately relevant application—with the exception of those activities brought in specifically for broadening of the content (i.e., *Outside Applications*). Beyond the selection of themes related to everyday, physically-involved scenarios is the pervasive concept of Energy as the ability to cause a change in motion or position. This was elaborated on in a follow-up interview, and held strong implications to my prior approach to Energy as a supporting strand in physics education. In fact, this solidified what I termed the "Energy-first approach" as Design Principle 3.

The final two survey questions revealed the physics instructors' perceptions of how their course content would be applied in their students' programs of study and careers. The results made it clear that the physics instructors knew both their Education and Allied Health majors would need to know this material for their future careers. In terms of Education majors, two of the three instructors pointed out that their students would eventually need to teach the subject matter. One respondent noted that problem solving would be an additional application. Similar claims were made for their Allied Health (e.g., Sonography) majors. All three respondents stated that there would be direct applications to their major and careers, while two of the respondents explained their understanding that the use of waves, sound, and motion applications was linked to student motivation. A single respondent noted that the course would also support future interactions with students' patients. Taken as a whole, this feedback corresponds directly to the findings from the program advisor interviews for both of these majors.

Again, the physics instructors obviously expected their students to eventually have to teach some or all of these concepts at some point in their careers. At the very least, there were fundamental skills identified that they felt were supported by taking their course (e.g., problem solving and patient interaction). Although—as evidenced in the literature review—there was significantly less information on teaching physics to Sonography majors versus Elementary Education majors, Sonography students seem to have the most physics instructor recognized potential motivations to do well in the course. This is another area that parallels the feedback gained from the Sonography

interviewee and corresponds to the issues of motivation discussed throughout this chapter.

A follow-up interview was conducted with a physics instructor whose student population most closely resembled my own. From it, the instructor identified student motivation as linked to seeing a connection to their goals-stating that "students who seem to see a clear connection with how it fits in with where they're going...seem more motivated to actually understand"). This goes beyond grade motivation and is clearly a career relevant connection. The instructor also noted that scaffolding of guided inquiry techniques works well for the Sonography students. An in-depth view of what this approach looks like in practice was gained from the interview to supplement the literature on inquiry instruction. It was applied in the unit reframing process and is clearly represented as Design Principle 5. The interviewee offered the suggestion that improving relevance for the Elementary Education students seems to improve their willingness to try inquiry activities, stating that they become more "willing to accept different approaches such as a guided-inquiry approach as opposed to a traditional lecture...I've noticed it's important: I also personally believe that it's very important to connect it to where they're going." Along these lines, the interview revealed a deficit in career relevance awareness for my Elementary Education students. Namely, Education majors do not believe they will need to teach science in their future careers. The respondent said that a typical Elementary Education student viewpoint is "'I don't wanna teach science, so I'm not worried about it'...Which was a lot of their attitudes and most of them, when I did start asking them...'What're you planning on teaching?'...if you said 'Are you gonna teach math or science?' you'd get that deer in the headlight look..."

Another finding was that the Energy-first supporting strand really works well in the experience of this respondent. Additionally, the respondent noted that it has direct connections to human motion and biological processes (Quote: "it carries through the whole course, and everything we do, and any topic we do, ... can be about energy and I connect it to this position and motion" ... "I think by the end they really got that pretty well in terms of it's not a substance...it's a qualitative and quantitative model we use to really describe...everything. And it works..." The respondent noted that at the end of the course the majority of students did not seem to have any misconceptions on energy concepts. This approach to energy as a way to change an object's position and motion was eye-opening for me, as it offered a simple, easy-to-remember rule that I could employ with my students. Although this idea will be introduced well in advance of my Waves and Periodicity unit, the language of the strand should be carried through the discussions and Padlet® Word Banking activities.

The interviewee also made some other observations from the classroom and in terms of instruction. For one, students from the different majors tend to group within their own majors during activities which could be a positive phenomenon if used correctly (e.g., as support and a group realization of concept importance). As part of this, and with the emphasis on career-readiness from the survey data, came Design Principle #9 which focuses on relating career expectations and practices for Sonography and/or Education majors.

Furthermore, the respondent identified Biology as the one discipline where the students have some potential to bring useful background knowledge and experiences into the classroom (Quote: "But, biology I would say is the one where they have...at least some...fragments of stuff up to a pretty good understanding"). This provides

further support for the idea that students will bring something usable to the table (even beyond their own unavoidable physical experiences) that compliments the overarching theme of connections to the human body.

Finally, along those lines, the instructor supported the idea that a theme should be two-pronged between the theme, itself, and applications external to the theme to extend their potential for making connections (Quote: "...yeah a two-pronged approach—do that plus some of the then external things they could see..."). This, in conjunction with related survey responses from the other physics instructors, further informed Design Principle #10, *Outside Applications*.

The survey and interview data, then, provided the final key in the development of my theoretical framework. These were also the final components of my pre-unit development. What follows is a very brief discussion of my findings during unit development.

Intra-Unit Development Findings

In this phase of the study, I began writing my unit outline, making connections to the ten design principles, identifying potential activities (and brainstorming some of my own), pulling in assessment strategies and educational technologies, and identifying misconceptions to inform the development of each of these. I have already presented the tabulated findings for those areas that included expansive use of the literature. In the intra-unit development phase, this included taking a deeper look at the physics education literature through an activity mining process, assessment strategies, and also the highly influential and deeply represented findings on common misconceptions on wave behavior that I pulled from the existing literature that informed the development of my lesson activities and assessments.

Given that these findings have already been discussed in detail, I do not present them again here. The next section explores the findings after the unit materials were reframed. At this point, I had completed the unit based on the pre-unit and intra-unit reframing methods and findings. The data from this post-development phase were revisionary in nature, as I subjected the draft unit materials to expert review at two levels. The first was aimed at following up on the *Quality Curriculum* design principle (principle eight). The second expert review focused on the remaining design principles.

Post-Unit Development Findings

CCIT Post-Revision Feedback

After the unit was reframed around the ten design principles, CCIT conducted a review of the materials to see how well the recommendations had been implemented. Both suggestions were used in the final revision of the unit materials. The post-revision feedback was positive across the board. The unit was judged to contain a good variety of resources and activities (both in multimedia and text). The reviewer appreciated the addition of tutorials I employed when a lesson introduced a piece of technology (e.g., Padlet®) to students. The first suggestion was that I should simplify the lesson maps under each lesson folder before distributing for student use. This change will only be evident in the student version on the learning management system, as the public website version is meant for reviewers and adopters. The second (and final) suggestion was that

I should rename the discussion board link something simple like "Discussion Board" instead of "Access the Discussion Board".

Overall, the feedback verified for me that I had met the *Quality Curriculum* goals set out in the pre-unit development Collaborative Course Review. In the subsequent section, I present the findings from the unit review process. This was the final component in refining the newly reframed Waves and Periodicity unit, and it was critical in ensuring that the connections my course materials made for students between the content and (especially) career relevance was explicit. This need to make the components of the design principles (as individual *principle descriptors*) more explicit in the materials was evident throughout the science education expert unit review process.

Unit Review Process Summary and Discussion

The unit review process was an extensive, activity-by-activity look at the developed Waves and Periodicity unit materials. Three science education experts acted as reviewers for each activity within the seven lessons. Across these seven lessons there were 57 separate activities. With fifteen principle descriptors each, a maximum of 855 data points could be logged per rater. An example of a complete score sheet (a record of my own self-scoring of the pre-unit review materials) with calculated ranks is available in *Appendix H* (*Additional Data*).

Using this heuristics as a lesson review tool, the maximum possible score for each lesson (column totals) was 30 points. The maximum possible score for each principle descriptor (row totals) was 114 points. Using these latter values and

comparing principle descriptor totals, the totals were ranked from least to greatest (with a rank of '1' indicating the highest ranking item). This was done for each reviewer, and the resulting ranks are shared by reviewer background in Table 20. As an example, I ranked principle descriptor #5 (aimed at opportunities for higher-order thinking skills) highest while ranking connections between content and Education major career-relevant skills and applications (principle descriptor #13) lowest.

Principle Descriptor # 5 10 11 13 14 15 2 3 4 6 7 8 9 12 8.0 12.0 13.0 Mine 4.0 10.0 1.0 7.0 5.0 2.0 3.0 6.0 11.0 15.0 14.0 9.0 6.5 4.0 11.5 3.0 15.0 6.5 1.0 2.0 13.0 14.0 8.0 Physics EdD 10.0 11.5 5.0 9.0 Physics PhD 6 10 5 15 12 11 14 13 3 7 4 8 1 2 9 12.0 13.0 8.0 3.5 3.5 11.0 6.0 7.0 5.0 9.5 15.0 2.0 9.5 Bio/Phys/Micro EdD 1.0 14.0

13.7

8.8

3.0

6.2

10.3

11.7

8.0

9.2

3.0

 Table 20
 Rankings of Principle Descriptors by Reviewer Background

5.7

Expert AVG

8.2

4.2

10.0

8.7

There was a great variation in ranking across the board. In some cases, all raters were within a few ranks of each other (e.g., principle descriptor #7 on *Students' Bodies as Sources of Data*) or nearly identical (e.g., principle descriptor #15 pulling in *Applications Outside of the Main Theme*). In one case, the top score for a rater corresponded to the lowest score for another (which was in agreement with my own ranking) as in the case of principle descriptor #13—*Career Relevance to Education Majors*.

9.5

It is extremely important to note that my own self-scoring was consistently lower across all of the activities for any of the raters. That is, none of the raters scored any activity or principle descriptor as low as my own self-score, and all scored at least one activity at the perfect (30 points) level. The inter-raters' *overall* activity scores rarely varied from each other by more than five points. The Physics Ph.D. rater generally gave a higher score than the other raters whereas the Physics-focused Ed.D. rater generally scored the activities lower (although still higher than the self-score).

On the scale of individual data points, 43.8% (284 of 649 valid data points) of the average scores across raters deviated by 1 or more points from the self-score. In comparison, there was a 57.1% disagreement of this magnitude (428 of 750 valid data points) between my self-score and the Physics Ed.D., 52.6% (423 of 805 valid data points) with the Physic Ph.D., and 63.2% (493 of 780 valid data points) with the Biology/Physics/Microbiology-focused Ed.D. These differences are most likely due to a conservative approach to self-scoring rather than any systemic deficiencies. It is in fact reassuring that even my lowest ranking activities and principle descriptors (and, by extension, the underlying design principles) were rated more favorably by veteran science education experts.

There were yet certain clues in the data that pointed to the need for some final revisions of the Waves and Periodicity unit materials. This was done by identifying the principle descriptors exhibiting the greatest deviation in interpretation. While these might indicate a particular insight on the part of a single reviewer, it is certainly a strong indicator that there were mixed messages in the draft materials that demanded clarification. A basic analysis of the difference between the highest and lowest ranks from the three reviewers reveals which principle descriptors were most ambiguously represented. The results of this analysis are provided in Table 21, below:

Table 21Difference Between Max- and Min-Ranks by Raters Across Principle
Descriptors

Focusing on the top three deviations as the areas most likely to be improved

Principle Descriptor #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Δ Rank	9	4	2	12	9	6	3	7	4	8	10	6	14	3	1

through revision, it was evident that the principle descriptors on *Energy*, *Human Body Connections*, and *Education Major Career Relevance and Applications* were the most confused in the lessons. Expanded out fully, these descriptors were:

- **Principle Descriptor #4:** Energy concepts and vocabulary are used throughout the course materials to support the activities and inform materials. *[from Design Principle 3]*
- **Principle Descriptor #11:** Unit materials and activities are built on the theme of connections to the human body. [from Design Principle 6]
- **Principle Descriptor #13:** Unit materials and activities incorporate career-relevant skills and applications for Education majors. [from Design Principle 9]

Getting to the heart of the matter, there were specific comments that came out of

the review process which provided insight into how these areas might be addressed.

The suggestions from these comments are summarized, below; beyond these there were

no comments except on basic mechanics of accessing and locating activities:

- Add more emphasis to Design Principle 3 (the Energy-first approach)
 Principle Descriptor #4
- Provide assessment question examples that illustrate the human body theme

 Principle Descriptor #6
- Have students film their mini-teaching presentations as part of a portfolio

 Principle Descriptor #13
- Share/develop additional rubrics as appropriate

As illustrated in **blue font**, this represents a direct correlation between science education expert review suggestions and the problems of confusion and ambiguity in

the draft unit materials. In this way, the first three suggestions provided the solutions needed to address these problems. To meet these deficiencies, and to also address the fourth recommendation (focused on *Quality Curriculum*), the following revisions were made to the Waves and Periodicity unit reframing:

- Energy concept questions were added to the *vLog 1* concept introduction video (**Principle Descriptor #4**)
- A note is now featured in the Word Bank reminding students to call on their Energy concepts to make connections (**Principle Descriptor #4**)
- Activities were revised to help students reflect on how Energy concepts relate (e.g., identifying areas of higher and lower Energy when acting out the Electromagnetic Spectrum) (Principle Descriptor #4)
- Additional examination questions were included as examples of potential human body connected questions in the summative assessment portion of the online materials (**Principle Descriptor #11**)
- The Mini-Teaching Presentations activity now includes a written expectation that the presentations will be video recorded for inclusion in students' ePortfolios (Principle Descriptor #13)
- An additional rubric was developed to accompany the lab journal entries (Design Principle #8)

All of these changes are reflected in the unit materials. Taken together, the Waves and Periodicity unit was revised multiple times based on an extensive literature review and several layers of input and scrutiny from stakeholders and education experts. Quality, comprehensive curriculum materials make up the front-end of the unit materials while educative curriculum plans provide the underlayment for future adopters and adapters of the materials. The chapter that follows explores the overall organization of the unit and takes a detailed look at each individual lesson.

Chapter 5

UNIT DESIGN

The purpose of this chapter is to describe the basic structure and mechanics of the Waves and Periodicity unit. This is done by first providing a general orientation to the components of the unit reframing. In the process, I explain the relationship between the Unit Outline and the actual unit materials. The chapter goes on to provide a detailed discussion on each lesson and considers the supplemental materials that accompany the lesson materials.

Navigating the Unit Materials:

In this section, I provide a pictorial tour of the features of the unit materials. Lesson Three (discussed in full detail in the next section) was used as the exemplar for this tour. The user interface is designed to mimic a standard learning management system layout, as evidenced in Figure 26, below:



Figure 26 Unit Tour Graphic: Learning Materials View

The user-friendly design allows for ease of navigation. It was designed using basic hyper-text markup language (HTML) for ease of use with assistive devices. The written descriptions and linear flow are also aimed at better accommodating these technologies.



Figure 27 Unit Tour Graphic: Lesson Descriptions, Time Commitments, and Lesson Objectives

In order to assist instructors in implementing the lessons directly, an estimate of total time commitment is given for each lesson. This will vary depending on the depth achieved with each modularized activity. The lesson descriptions go into much greater detail than those required by students. Adopters should remove any information which they consider superfluous for their student populations. Connections are made directly to my own Conceptual Physics learning objectives, although these can be replaced with suitable standards or other objectives by adopters as needed.



Figure 28 Unit Tour Graphic: Concept and Inquiry Scaffolding

Across lessons, the levels of inquiry are scaffolded. In this unit, the vast majority of activities are at the guided-inquiry level. Concepts and skills are also scaffolded (and instructor-focused supports are gradually decreased to make way for an increase in student responsibility). The findings from the literature study on common misconceptions in wave behavior are integrated into discussions, assessments, and other activities.



Figure 29 Unit Tour Graphic: Artifacts Across Three Realms of Human Experience

The majority of the activities in each lesson are made up of strong strains of engagement across the three identified realms of the human experience: social, physical, and cognitive. It is during these activities that students are asked to challenge their prior conceptions and subject their own understandings (once they acknowledge them) to peer critique. The ten design principles each are represented across the lessons. Three examples of activities being directly mapped to activities and assessments are provided in Figure 30. Namely, the principles shown here are *Energy-First, Career Relevance*, and *Outside Applications*.



Figure 30 Unit Tour Graphic: Examples of Design Principle Applications

To close the visual orientation tour, Figure 31 on the next page explores the close of the third lesson. As the unit progresses, the activities demand more from the students by giving them more freedom (read: responsibility) for forming conceptions and explaining themselves. This increase in responsibility is also true of the feedback process. At the end of each lesson on the web-based version of the unit I have provided blank templates (see *Appendices J* and *K*) and also fully designed unit and lesson plans. These plans, along with a detailed look at every lesson, are covered in the next section.



Figure 31 Unit Tour Graphic: Increasing Student Responsibilities and Educative Materials

A Lesson-by-Lesson Overview:

As previously noted, I teach this course in a hybrid (50% online, 50% face-toface) format. Given the demands and scope of the course, the majority of the in-person interactions I have with my students are therefore laboratory based. Students in my Conceptual Physics course have historically expressed their appreciation for its handson nature and the fact that they feel continually engaged throughout and despite hours of instruction. This heavily interactive nature in a mix of online and face-to-face environments persisted (and was enhanced) through this study and is evident in the lesson outlines that follow. By moving towards kinesthetic teaching strategies with an emphasis on the human physical experience, I expect that my students will experience even fewer passive moments in the classroom, and that their activity will have much more meaning attached to it.

In what follows, I provide an overview of each lesson to orient the reader to the thinking behind each and to offer insight into how they interrelate to form a cohesive unit. Additional insights and relationships to common misconceptions, potential alternative assessments, and other educative curriculum notes are available in the *ADDIE* unit and lesson plans.

Lesson One

Lesson One is a short, introductory lesson which takes place online prior to our first face-to-face session. Temporally, it would be at the tale-end of materials for the preceding unit (which looks at atomic structures, temperature, and heating).

The first activity is a vLog (or video blog). In an overall course design, this would be one of a series of vLog entries aimed at either 1) supporting background building or re-compartmentalization (as in the case of this first vLog) or 2) providing a checkpoint mid-unit (as with the vLog entry from Lesson Four). In this case, the moderation of the human body connections theme through the integration of outside applications is epitomized by this vLog. The video file brings students through diverse scenarios linking to major themes in the unit. The level of abstraction is varied to provide students opportunities to think further, but the goal of the vLog is not specifically aimed at teaching students new content. Beyond priming students mentally for the unit, questions are embedded using the Zaption® tool (described in the previous section). Altogether, these questions are geared toward identifying misconceptions and

setting the stage for generative discussion (possibly even argumentation) during Lesson Two.

Figure 32 shows the short and simple introductory components of which Lesson One is comprised. The collaborative Word Bank (identified in Chapter Two as a support strategy for making meaning of concepts) is also first introduced online. Students are prompted to begin working in the Word Bank simply to become familiar with its function, although they are able to begin adding content immediately. This fusion of digital word-wall and open-collaboration blog is threaded throughout the entire unit, and is in fact picked up immediately at the start of Lesson Two.

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#]*	Assignments & Assessments
ONLINE		Thinking about Waves		Transition out of the previous unit (not reflected in unit or lesson outlines/plans)	
Unit					
Preparation	0:30 est'd	Word Bank Opens		<u>Vlog Notes</u> : Seeding initial thoughts on waves [closed- captioned] "Fun in the Kiddie Pool", "Echoes Between Buildings," "Musical Body Parts" experiments/demos [DP#'s 1, 6, 7, 8, 10] <u>Word Banking</u> : Waves & Periodicity Word Bank opened for class co-construction [DP#'s 2, 3, 4, 8]	

Figure 32 Lesson One Breakdown from Revised Unit Outline

Lesson Two

At the start of this first face-to-face session, the class will review the Word Banking process and my expectations for its use. During this time the class as a whole will decide on an overall format for the organization of ideas, definitions, and resources. The Word Bank is to be like a constant companion tool as the class completes activities and discussions, so it may be best for it to be open as an active link on all computers or devices during face-to-face class times. What follows are two inquiry activities (both adopted from a Physics Respondent) which require students to discuss and investigate the nature of waves. As with many of the activities, these are done in small groups. The first activity asks students to pull their experiences and knowledge to lay the groundwork for their understanding of wave nature and the relationship of waves to their own lives. The subsequent activity is based on physical experimentation where students are given the opportunity to review and revise their understandings.

From there, students strongly pick up the human body connections theme through an activity where they map out the representative frequencies of their own voices and discuss the similarities and differences between these samples—inspired by a section from their own textbook (Ostdiek & Bord, 2013, p. 239). Embedded within this activity are comparative frequency graphs for people with which they are familiar and also a video on vocal cords showing the vocal flap undulations through the use of a stroboscope.

Moving again out of the small scale, students are then engaged in a highly kinesthetic activity where they must form a human chain to represent a long spring (adapted from Pantidos & Patapis, 2005, p. 344). They just prior had already used an actual lab spring in small groups to investigate wave behavior. This activity is meant to have them work together to reproduce longitudinal and transverse wave forms and in the process come to a shared understanding of wave and medium behavior. They also are able to feel physically how stiffness and density (varied and controlled as the students see fit) affect wave propagation. This concept is foundational to ultrasound technologists, while the kinesthetic learning component will support pre-service teachers when they enter the field.

The remaining lesson includes two embedded checks-for-understanding which address typical misconceptions and are meant to provide feedback to students and provide an opportunity for them to voice any related questions. Between these are three activities meant to bridge the gap between wave shapes and periodic motion. In the first, students compare hand sizes to overall equivalent wave forms. This was inspired by feedback from a Sonography Respondent on the importance of understanding how small motions can have a significant effect in imaging. The next, the "Human Oscilloscope" (adapted from Pfister & Laws, 1995, p. 219), is again a highly kinesthetic activity where students create continuous wave forms of varying characteristics while sitting across a rolling board. The final main activity focuses directly on the human heart rate (both resting and elevated) wherein students graph out their equivalent wave forms and create a distribution for the whole class. This activity was adapted from the ACTION PHYSICS curriculum developed for non-science majors and pre-college teachers (Schwartz, 1997, p. 126). Each activity is intended to be used as guided inquiry and encourages the scaffolding (and oftentimes lamination, to revisit ideas from different perspectives) of concepts.

After the bookend check-for-understanding, Lesson Two ends with a poem of my own design aimed at reaching more artistically-minded learners. The official lesson also closes out with an overview of textbook sections from Ostdiek and Bord's *Inquiry into Physics* text (2013) for which students are responsible for studying. The reading assignments cross over multiple topics and chapter sections in order to provide both practice for current concepts and to act as a support for Lesson Three content.

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#]*	Assignments & Assessments
IN-CLASS Knowledge Building Wave Nature and Behavior Wave Applications	(h:m) 1:20	Wave Characteristics Wave Examples Pendulum Motion FFT	4.1, 4.4, 4.5, 4.6, 5.8, 6.3	Word Banking: Review and Revision of Word Bank [DP#'s 2, 3, 4, 8] Activity: "What is a Wave" thinking group activity; life without waves [adopted from a Physics Respondent, DP#'s 1, 2, 3, 4, 5, 6, 7, 10] <u>Activity</u> : "What is a Wave" spring, tuning forks, and human voice experiments [adopted from a Physics Respondent, DP#'s 1, 2, 3, 4, 5, 6, 7, 10] <u>Demonstration</u> : Fast Fourier Transform (mapping out the human voice, &tc.), vocal flaps/cords [inspired by Ostdiek & Bord, 2013, p. 239, DP#'s 4, 5, 6, 7] <u>Activity</u> : "Do the Wave" - waveform modeling student line- up (acting out transverse and longitudinal waves, and free- and fixed-end reflections) [adapted from Pantidos & Patapis, 2005, p. 344, DP#'s 2, 4, 5, 6] <u>Activity</u> : "Biggest Hands, Smallest Hands" period, amplitude, and frequency assessment (hand holding pencil wave form creation) [inspired by a Sonography Respondent, DP#'s 1, 2, 4, 6, 7] <u>Activity</u> : "The Human Oscilloscope" [adapted from Pfister & Laws, 1995, p. 219, DP#'s 1, 2, 4, 6, 7] <u>Activity</u> : Heart Rate measurements (class graphing and waveform equivalent) [adapted from Schwartz, 1997, p. 126, DP#'s 1, 4, 6, 7, 9]	Assessments <u>Reading Assignment</u> : Sections on basic wave characteristics <u>Check for</u> <u>Understanding</u> : Wave Pulse Superposition [based on Stepans, 1996, p. 173] <u>Check for</u> <u>Understanding</u> : Leg and Arm Pendula [inspired by Blanksby et al, 1981, p. 79] WebAssign and Exam representation
				Poem. O FFT: poem recitation [DP# 5 3, 10]	

Figure 33 Lesson Two Breakdown from Revised Unit Outline

Lesson Three

This lesson opens up with a look back at the previous unit. Using a thermal camera, students here reconsider their "Is a Blanket Warm" activity (adapted from Roseberry, et al., 2010, p. 334) in light of a new concept: the electromagnetic spectrum. From this develops a discussion on infrared and ultraviolet portions of the spectrum. A crucial connection is made, here, as students are asked to identify whether these light-based concepts have sound-based equivalents (i.e., infrasound and ultrasound) (see JRC-DMS, 2008).

Figure 34 provides an example of the educative nature of the *ADDIE* framework plans created for this unit. These are exhaustive materials that go into depth on all
aspects of the lesson components. Beyond the appendix housing the full unit materials, they are also available in editable spreadsheet format by following the directions from *Appendix L*.



Figure 34 Making Use of the *ADDIE* framework Educative Curriculum Materials

Taking another note from the class' Ostdiek and Bord textbook (2013, p. 315) and the Acoustical Physics course's textbook (Edelman, 2012, p. 408), this transitions into a discussion of the effects of ultraviolet radiation on our bodies (specifically, our skin). Students are first asked to review the concepts for which they have already built up understandings. Then, they are exposed to mathematical relationships to help them describe wave behavior (e.g., the wave-speed equation). This is coupled with a classled demonstration where students model their conception of human skin using ball-andspring components—after which they conduct basic experiments which relate to both ultraviolet radiation and ultrasound imaging technology (i.e., transducers).

I then extend this back into the realm of kinesthetic learning with an activity similar to the whole-class wave behavior simulation activity (inspired by Pantidos & Patapis, 2005, p. 344). In this scenario, however, I challenge students to act out physically the electromagnetic spectrum. There are also embedded opportunities to challenge typical student misconceptions (e.g., whether differing frequency light waves move at different speeds) and to relate these concepts to socially-relevant experiences (e.g., Austism Spectrum disorders). Following this challenge comes an activity where students directly experience the Doppler Effect using sound (inspired by JRC-DMS, 2008).

A discussion on chattering teeth (as examples of periodic motion) and a demonstration aimed at relating sound production, reflection, and introducing standing wave patterns (based on Stepans, 1996, p. 186) are set alongside a very ultrasound-focused activity on simulating sound-based scanning of the carotid artery (inspired by Lewis and Mohazzabi, 2014). This face-to-face lesson is rounded out with embedded checks-for-understanding and activities which build on the previous activities (e.g., identifying and predicting tuning fork beat frequencies for sound and understanding how light's path is altered based on media characteristics). Sources for these activities are noted in Figure 35. Some of these are very much examples of kinesthetic learning, while others simply relate to the human experience or uses of human physiology as lab equipment. As I like to put it to my students, laboratory microphones are nice, but we

already have built-in, highly sophisticated "microphones" right in our head which we should not ignore. The lesson ends with an Exit Ticket, and the stage is set for Lesson Four.

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#]*	Assignments & Assessments
IN-CLASS		E-M Radiation		Recall: "Is a Blanket Warm"? Thermal camera inquiry	WebAssign and Exam
				activities with human body radiation (circulation, radiation,	representation
Wave		Units and Formulas		conduction, &tc.) from previous unit [adapted from	
Applications		Used to Quantify		Roseberry et al, 2010, p. 334, DP#'s 1, 2, 3, 4, 5, 6, 7]	Check for
Continued		Wave		Discussion: What is infrared? (infrasound? ultraviolet?	Understanding: Closed
		Characteristics		ultrasound?) [inspired by JRC-DMS, 2008, DP#'s 2, 3, 4, 5, 9]	End Reflection
				Discussion: "UV – It Hertz Your Skin" (period, frequency,	standing wave
		Doppler Effect		wavelength; wavespeed – units and relationships for each)	patterns [based on
				[inspired by Ostdiek & Bord, 2013, p. 315, DP#'s 1, 2, 3, 4, 6,	Stepans, 1996, p. 174]
		Periodicity		7]	
				Demonstration: Excited Skin Particles simulation (spring	Check for
		Standing Waves		model) [inspired by Edelman, 2012, p. 408, DP#'s 1, 3, 6, 7]	Understanding: Glass
		Deate		Activity: E-IVI spectrum student line-up (acting out the E-IVI	or water with Arrow
		Beats		spectrum) (inspired by Pantidos & Patapis, 2005, p. 344,	images (adopted from
		Pay Diagramming	22.22	DP# 5 2, 3, 4, 0] Activity Discovering the Deppler Effect "Dep't run with	AIA, 2010j
		Kay Diagramming	2.2, 2.3,	<u>Activity</u> . Discovering the Doppler Effect – Don't run with soiscore, run with a tuning fork!" (run down ballway activity)	Evit Tickot
			3.5, 4.1,	lingning by IRC-DMS 2008 DP#'s 1 4 6	EXIL FICKEL
	1:30		4.2, 4.3,	Discussion: Chattering Teeth periodicity [DP#'s 1 2 6 7]	
			61 63	Demonstration: Electric Toothbrush in action [DP#'s 1, 3, 6,	
			65	71	
			0.0	Demonstration: "Your Beating Heart" (simulating ultrasound	
				scan of carotid artery) [Lewis & Mohazzabi, 2014, DP#'s 1, 3,	
				6, 7]	
				Demonstration: "Bottles of Coke" water music production	
				and wave tube apparatus calculations [based on Stepans,	
				1996, p. 186, DP#'s 1, 3, 6, 10]	
				Activity: Standing wave pattern student line-up (acting out	
				nodes and antinodes) [inspired by Pantidos & Patapis, 2005,	
				p. 344, DP#'s 2, 3, 4, 6]	
				Activity: "Beats, Beats: The Musical Fruit" tuning fork	
				hearing activity with spreadsheet support [DP#'s 4, 5, 10]	
				Activity: Ray Diagramming (simulated spear fishing!)	
				[inspired by Hewitt, 2008, p. 298, DP#'s 2, 4, 5, 10]	
				Exit Ticket: 1 thing you are confident on; 1 thing you have a	
				question on or want to learn more about [DP# 8]	

Figure 35 Lesson Three Breakdown from Revised Unit Outline

Lesson Four

Lesson Four, an intermediary online lesson within the unit, plays a key role. It purposefully employs nine of the ten design principles which form the foundation for this whole unit reframing and sets the stage for the remaining design principle's inclusion in the lesson that follows. Figure 36 outlines the lesson and provides initial insight into how each of these design principles (indicated within brackets after "DP #'s") shaped the lesson. Again, the lessons accessed through the instructions in *Appendix L* explain exactly how each design principle is represented.

It is here that the same guided inquiry approach adopted for the other primary activities finds a place on the discussion board, online. Preceding this is a mid-point vLog entry aimed at ensuring that students who are engaging in the online thinking group activity are all on the same page. This lesson works to reinforce previously explored concepts and give students the freedom to apply what they have learned both in small groups and also now as individuals. Beyond practice problems and the extended physics applications which broaden the scope of the lesson and balance out the human body connections theme is a key activity sequence: a visual acuity online activity (inspired by Crouch & Heller, 2011, p. 160) paired with a homework assignment requiring students (with much freedom in the interpretation of parameters) to design a "working" model of their own eye: either one; visual impairments and all (inspired by McGuigan, 2009). This key sequence, supported as always by student contributions to the ongoing Word Bank, lays the ground for the next lesson: Lesson Five.

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#]*	Assignments & Assessments
ONLINE		Sound		Vlog Notes: Summary of content and activities to-date	Reading Assignment:
		Characteristics		[closed-captioned] [DP#'s 1, 6, 7, 8]	Sections on advanced
Social				Video Clip: Lightning vs. Thunder [DP#'s 1, 10]	wave behaviors and
Construction		Doppler Effect		Discussion Board Activity: "Sound" thinking group activity	applications
of Sound		Revisited		[adapted from a Physics Respondent, DP#'s 1, 2, 4, 5, 7, 8,	
Concepts				10]	Discussion Board: post
		Bow waves, shock		Activity: Modes of transportation (plane, boat, and really	and responses
	1:45	waves, and sonic	4.1, 4.4,	fast car!) webquest/simulations [inspired by Edelman, 2012,	
	est'd	booms	4.6, 6.1	p. 403, DP#'s 5, 8, 10]	Homework: eye
				Activity: "How do your eyes measure up"? (visual acuity	physical simulation
		Ray Diagramming		online activity) [inspired by Crouch & Heller, 2011, p. 160,	[inspired by
		Revisited		DP#'s 1, 4, 6, 7, 8]	McGuigan, 2009]
				Homework: Create-your-Eye gel experiment [inspired by	-
				McGuigan, 2009, DP#'s 1, 4, 6, 7, 8]	WebAssign and Exam
				Practice: practice problems with solutions [DP#'s 8, 10]	representation
				Word Banking: Update of Word Bank [DP#'s 2, 3, 4, 8]	

Figure 36 Lesson Four Breakdown from Revised Unit Outline

Lesson Five

After the no-doubt revealing Exit Ticket and Word Bank reviews, students' homework (the Create-your-Eye activity) is now tested, under controlled conditions, in Lesson Five. This activity incorporates wave behavior, but specifically the behavior of light waves—especially in the form of a collimated beam. Given the expected imperfections of home-made eye models (particularly considering the diversity of materials which might be used to create each model), this activity deserves sufficient experimentation and discussion time to explore other phenomena such as light absorption, scattering, additional attenuation, and other behaviors which students most likely will not be expecting (but which are central to understanding real-world physics phenomena, especially in the clinical ultrasound setting). The next leg of this lesson offers a mirror to what was completed online just prior: a thinking group activity on "light" (adopted from a Physics Respondent) as opposed to the discussion board sound activity. Bending away from light and back into the sound arena, the next two activities ask students to perform basic (non-clinical) hearing tests (inspired by JRC-DMS, 2008) and investigate sound wave interference patterns (based on Lewis & Mohazzabi, 2014). Following these are dual-activities aimed first at pre-service teachers and then at future ultrasound technologists. This is a crucial step, since the lesson closes (excepting the Exit Ticket procedure) with the call for students from both majors to prepare to work together for a mini-teaching activity. This challenge is set to take place in Lesson Six and takes up the majority of that learning time.

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#]*	Assignments & Assessments
IN-CLASS		Light Characteristics		Discussion: Review of prior Exit Tickets [DP #8]	Check for
				Word Banking: Review and Revision of Word Bank [DP#'s 2,	Understanding: Nodes
Social		Doppler Effect		3, 4, 8]	& Antinodes [based on
Construction		Revisited		Discussion: Review of Create-your-Eye gel experiment	Stepans, 1996, p. 174]
of Light				homework and LASER testing [DP#'s 4, 6, 7]	
Concepts		Color Mixing		Activity: "Light" thinking group activity and experimentation	WebAssign and Exam
				[adopted from Physics Respondent, DP#'s 1, 2, 3, 4, 5, 10]	representation
Sound vs.		Refraction		Demonstration: Conducting a basic whole-class hearing test	
Light			4.1, 4.4,	(analyze class range-distribution) [inspired by JRC-DMS,	Exit Ticket
	1:30	Resonance	4.5, 4.6,	2008, DP#'s 1, 2, 4, 5, 6, 7]	
			4.7, 6.3	Activity: "Best place to Sit in the Theatre" (sound	
		Interference		interference pattern lab exercise) [inspired by Lewis &	
		Patterns with Light		Mohazzabi, 2014, DP#'s 1, 2, 4, 6, 10]	
				Activity: "Honing your Teacher Voice" – projection	
		Interference		microphone analysis [DP#'s 1, 4, 7, 9]	
		Patterns with Sound		Discussion: "Do you really see during an ultrasound scan"?	
				[DP#'s 2, 4, 7, 9]	
		Ultrasound		Exit Ticket: 1 thing you are confident on; 1 thing you have a	
		Revisited		question on or want to learn more about [DP# 8]	

Figure 37 Lesson Five Breakdown from Revised Unit Outline

Lesson Six

As foreshadowed from the previous lesson discussion, Lesson Six is primarily devoted to completion of the mini-teaching assignments following Exit Ticket reviews and the use of Kahoot!® formative assessment software as a final check for misconceptions and to serve as a warmup. The rubric spells out their primary goals, but they are given significant freedom in design. Although the activity is setup to reflect the *Next Generation Science Standards*—most specifically the core ideas in the first and fourth grades on *Waves: Light and Sound* (NRC, 2012), it is possible for students to also make relationships across disciplines to the JRC-DMS National Education Curriculum: Common Curricula standards (2008). This mini-teaching experience, which requires Sonography and Education majors to work together in a lesson design and delivery process, is based on feedback gained from an Education Respondent during the research process and is aimed at maximizing the benefits of a two-major mixed classroom environment.

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#]*	Assignments & Assessments
IN-CLASS		Student Group		Discussion: Review of prior Exit Tickets [DP #8]	Kahoot! Quiz
		Teaching Sessions		Activity: Kahoot! Quiz on Waves & Periodicity [DP# 4]	
Student	1.00		4.1, 4.2,	Activity: Student topic assignments and mini-teaching	Presentations: student
Teaching	1:20		4.4, 4.5,	sessions (Sonographer and Educator roles and perspectives)	involvement in group
Sessions			4.0	[inspired by an Education Respondent, DP#'s 2, 4, 9]	teaching sessions
					(rubric provided)

Figure 38 Lesson Six Breakdown from Revised Unit Outline

Lesson Seven

Lesson Seven is truly a *decrescendo* for the unit. In this lesson students have the opportunity to make any final revisions or additions to the co-constructed Word Bank,

they are given the opportunity to explore musical applications of many of these concepts, and a series of exam preparation questions are explored via video clips. As explored in a previous section, summative assessment is not limited to WebAssign® or exam questions, however. This is where the unit's journal entry features (discussed in detail in the *Assessment Strategies* section preceding this one). Alternatives to the final component of the journal-writing activity might include the use of Padlet® or the development of an infographic as opposed to the design of an exam question. Through this combination of end-of-unit assessments, significant feedback potential is provided: both immediate (as in the use of the WebAssign® online system) and detailed and protracted (as in the unit journaling requirement).

Looking forward, this lesson would transition into a unit on electricity and magnetism. This is a natural transition given the prior unit's atomic focus and this unit's waves and periodicity focus including significant foreshadowing of electromagnetism via the electromagnetic spectrum activities.

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#]*	Assignments & Assessments
ONLINE		Physics of Music		Word Banking: Concluding additions/revisions in Word Bank	Practice: periodicity
				[DP#'s 2, 3, 4, 8]	calculation examples
Extended		Exam Preparation		Activity: Online exploration of musical applications [inspired	with solutions
Thinking				by Ostdiek & Bord, 2013, p. 249, DP#'s 1, 4, 10]	
		Formal Assessment		Activity: Waves and Periodicity journal reflection entry	Journal Entry artifact
Exam			4.1, 4.2,	[inspired by Hwang et al, 2015, p. 114, DP#'s 4, 8, 9]	[inspired by Hwang et
Preparation	2:40		4.3, 4.4,	Practice and Video Clips: Exam preparation questions on	al, 2015, p. 114]
	3st'd		4.5, 4.6,	waves and periodicity with fully worked-out solutions and	
			4.7	sample student questions [DP#'s 8, 10]	WebAssign:
				WebAssign-ment: Waves and Periodicity problems [DP#'s 8,	WebAssign-ment on
				10]	waves and periodicity
					(immediate feedback
				Transition into the next unit (not reflected in unit or lesson	generated; mastery
				outlines/plans)	learning focused)

Figure 39 Lesson Seven Breakdown from Revised Unit Outline

Supplemental Course Materials

Moving beyond the lessons, themselves, I have developed some supplemental materials to accompany the unit. These are organized into three components. The first is a general description of some positive changes to the course, overall, that have been made and which support the design principles by which the unit was reframed. The second is a document showing connections between the unit content and career expectations for both majors. The third and final supplement explains an overall course outline which I developed to give starting points for the extension of this reframing to the remaining units within the Conceptual Physics course. Since these units will be very similar to other physics or physical science courses, the applicability of the whole-course outline would be high.

General Changes to the Course

Over the course of this study, some general improvements have already been implemented. Whereas these changes did not result directly from the study, they did nonetheless affect the landscape of the course (and therefore also the Waves & Periodicity unit). One of these changes was the switch over to a new textbook. The previous textbook employed is a popular text for fundamental physics courses. The new textbook, however, was organized with many supports that I found appealing and in-line with my own goals for the course. Three features of the text are especially useful for the reframed unit: the use of concept maps (a clear language of physics support strategy), a special emphasis on everyday connections, and the integration of the WebAssign® program for immediate feedback and opportunities for embedded practice.

Another fundamental change to the course that did directly come from this study was the transition in how laboratory activities were assessed. In early iterations of the course, I would individually grade lab activities. The analysis questions for these rarely elicited higher order thinking and certainly were not inquiry-based. I moved on to laboratory quizzes for further assessment, but these also had the limitation of requiring only low-level engagement (e.g., knowledge and recall questions, or basic calculations). In the comparison unit, I had moved to the keeping of a lab manual which was assessed at the end of the semester while the primary feedback for each formal lab activity was provided within the class. Students were leaving with their questions answered, and I had an artifact to explore for end of semester reflection. The issue, again, was that the analysis questions did not require deep learning and the activities were still not rigorous enough.

Now with the new activities, I have moved away from formally recognized laboratory exercises to, instead, a fluid view of course time spent as an experience. In this way, journaling as assessment is used for delayed feedback while in-class explorations of more open-ended but still guided-inquiry level problems provide more immediate feedback and opportunities for the development of an "ongoing scientific dialogue occurring over the course of the unit" (Banchi & Bell, 2008, p. 29). The freedom this approach provides also sets the stage for expansion of topics into the realm of career preparedness as students are exposed to questions of how the topics and concepts relate to their chosen majors.

Making Connections to Professional Standards

One key component of improving the relevance of the Conceptual Physics course that came out of my research study was the need to help students realize that the course content truly is relevant in the first place. At the same time, the survey results showed that the Education advisors polled were very much focused on the transfer and career-preparation aspects of the program. This of course was not an unexpected finding, but it served to underscore the idea that the advisors might also benefit from supplemental advisement material that helps make connections between Conceptual Physics content and career goals.

To answer these needs, I designed an advisement tool aimed at showing the basic connections between the professional standards guiding the Elementary Education and Sonography majors. The resource includes all of the Measurable Performance Objectives that correspond to my Waves & Periodicity unit (except for the laboratory activities objective, which is implied for all of these). I plan to make this document available digitally via the learning management system to Education and Sonography majors before the first day of the course to help them see how they can relate the content and activities to their future careers.

For Education majors, this documentation parallels the *Next Generation Science Standards* (NGSS Lead States, 2013) by providing examples and direct links on how the course content addresses (inasmuch as it does) the four Core Ideas in the physical sciences (p. 105). This is meant to act as a starting point for education majors as it is expected they are still becoming familiar with the *Next Generation Science Standards*. The integration of the *Next Generation Science Standards* is meant to introduce Education majors to their eventual roles as primary school science educators. My hope

is also that making these connections with the reframed unit material and activities will have the added benefit of supporting any future iterations of the Delaware Science Coalition physics and physical science kits (see Delaware Science Coalition, 2014) which, as explained in a previous section, is a foundational goal of the course.

To parallel this for the Sonography majors, I have included the Joint Review Committee on Education in Diagnostic Medical Sonography's (JRC-DMS) National Education Curriculum physics components to provide verification that professional goals are addressed for this second majority (JRC-DMS, 2008). My aim in this is to provide Sonography students with a clearer map emphasizing the course-to-career pipeline based on classroom and program competencies. This unfortunately only begins to mimic the awakening experience of the Physical Therapy Assistant group from Hilton's study (2011). In order to compensate for the fact that the Sonography Pool students are not immersed in their chosen major (e.g., in clinical settings) at all throughout their time in my course, specific opportunities to explore the nature of ultrasound technology—alongside of learning new physics concepts—were developed in the reframed unit. The next and final chapter of this study looks at the limitations of the study and opportunities for leadership and research extensions.

Chapter 6

LIMITATIONS, OPPORTUNITIES, AND FUTURE DIRECTIONS

This study resulted in the development of a unit on Waves and Periodicity reframed around a unifying theme of the human experience (primarily physical) and supported by instructional strands to varying degrees along with being built on identified best practices and strategies for a specific population of students. This was done to improve the relevance to this population: my own Conceptual Physics students. It does, in my opinion, represent an improvement over a traditional unit delivery style in the realms of content, engagement, and assessment. I also am confident that it fits my typical student population better than other approaches. Still, the study overall has several limitations that must be recognized. Beyond these, I describe an action plan to move the unit into eventual adoption and/or adaptation by other physics instructors. I also provide a summary of lessons learned and leadership opportunities which were directly related to my engagement in this study along with potential for extension of this study in the future.

Limitations of the Study and Opportunities for Evaluation and Reflective Practice

Although this single unit has been designed with great care and attention to best practices and needs of my specific group of students, there do exist limitations to the study. Even for my own typical student population, there are questions and extensions to this work that suggest themselves. For instance, there are several other connections that could be drawn between the NGSS and the JRC-DMS common curriculum outside of the Waves and Periodicity unit. The singular unit focus, itself, can be seen as a limitation. However, the design principles extend well outside of the confines of this single unit. Viewed from this perspective, the unit reframing process serves as a model and springboard for reframing future units and eventually the entire course.

In light of the apparent strengths of the lesson and unit materials, there remains room for the investigation and integration of additional support strategies for diverse learners and also hybrid course development. To address primarily accessibility-based concerns, I would suggest a post-unit revision layer of review. Buggey (2000) suggests that "[there] are several ways to determine if a Website of online course is accessible" (p. 45). The full unit could be subjected to analysis by "a software program that evaluates sites for accessibility" that would "include a line-by-line site analysis with recommendations for improvement" (p. 45). While there exist several software tools for this purpose (and many are extremely complex in the level and type of input needed by the user, let alone being somewhat expensive for individual use of the full programs), I suggest a start for basic accessibility assessment that is free and easy to interpret: Web Accessibility in Mind, or WebAIM (Center for Persons with Disabilities, 2016). WebAIM uses an easily accessed user interface and provides a simple "pass/fail" checklist for interpretation of Section 508 of the Rehabilitation Act (on accessibility).

A further layer of review could be completed by accessibility experts working within the learning management system as mock-students. Finally, I would recommend the use of a focus group made up of students and/or instructors who have direct, personal experience with disabilities and accommodations. The focus group would review the materials, discuss them step-by-step (perhaps completing some activities as needed), and work to identify gaps in or opportunities for accommodations. The inclusion of more than a few instructors in the focus group might prove challenging,

though, given the known limitation from this study on participants. That is, the overall pool of potential respondents was small, and few of these potential respondents elected to participate. It might prove equally difficult to enlist the help of instructors who have the desired accommodations experience.

Along these lines, another limitation is that the unit has not been field piloted, except in the case of natural inclusion of content and strategies out of familiarity while conducting classes and workshops over the course of the study. While the contribution of program advisors and other professional stakeholders helped identify strategies to support students' goals and needs, direct feedback from students would add another rich dimension to future reframing endeavors. Part of this might have been to move past the Hilton (2011) research to gain insight into students' perceptions of the relevance of the Waves and Periodicity unit materials before and after reframing.

Additionally, the reframed materials are only meant to extend to conceptual or fundamental physics classrooms. However, it is possible to extend the design process used in this study to other physics courses and even other science courses (e.g., biology with kinesthetic teaching, chemistry with biology). Five of the ten design principles (namely *Life Relevance #1, Social Construction #2, Active Learning #4, Scaffolded Inquiry #5*, and *Quality Curriculum #8*) are readily <u>adoptable</u> to other courses. The other five design principles (namely *Energy-First #3, Themed Approach #6, Physics with Biology #7, Career Relevance #9*, and *Outside Applications #10*) are easily <u>adaptable</u> to other courses or disciplines as illustrated in Table 22.

Table 22 Transferability of the Design Principles across Courses and Disciplines

1. Content is directly related to students' real life experience.
2. Students co-construct meaning through the development of a shared language and peer engagement.
3. Terminology is foundationally introduced with an Energy-first approach which is continued throughout the course.
[Replace "Energy-first" with a new central idea for the discipline]
4. Students are actively engaged with the content cognitively, socially, and physically.
5. Concepts are scaffolded by being introduced as class inquiry demands.
6. Concepts are introduced contextually using a unifying, relevant theme.
[Contingent on potential to identify an appropriate theme]
7. Biological applications are explored in conjunction with physics content.
[Replace as needed based on discipline-specific best practices: e.g., "Historical perspectives are explored in conjunction
with technology"]
8. Course adheres to high standards of content delivery and design.
9. Course embeds opportunities to explore and practice career-relevant skills for sonography and/or education majors.
[Replace these majors with representative majors based on situation]
10. Applications beyond the unifying theme enrich the learning experience.
[Dependent on identification and adoption of a theme: can be adapted to simply be a broadening of applications]

All but the ninth design principle, *Career Relevance*, can remain unchanged when transferring these principles to another conceptual or fundamental physics setting. This single principle can be easily tailored to address the career needs of the majors represented within each particular course. The comments illustrate how half of the design principles are fully transdisciplinary in nature. They could be applied in a biology class, a social science course, a computer skills course—any formal education setting.

The remaining five design principles each have their own analogous version that can be developed for each discipline by following a generic research study plan. For example, an adopter might instead replace Design Principle 3 (Energy-First) with their discipline's version of a central idea. Design Principle 7's integration of biology into physics would instead be replaced with another relevant, transdisciplinary pairing. The ADDIE framework templates, support strategies (e.g., Word Banking), and other components of the sample Waves and Periodicity unit are also highly useful across community college (and other) classrooms. A model for reproducing the steps used in this study in any disciplinary setting is provided in Figure 40 on the next page. This flowchart is a full expansion of the previous flowcharts used to illustrate each step of the pre-, intra-, and post-unit development literature reviews and methodologies. As is evident, the design principles, themselves, went through stages of revision and expansion as new phases of the study progressed. The unit materials were also touched by a number of informants and revised accordingly.



Define Majors

Conduct Literature Reviews



Figure 40 Generic Research Study Steps for Curriculum Developers

The final considerations at the terminus of the flowchart outline the need for reflection and evaluation of the materials. The future extension opportunities described later in this chapter would begin this process, while further reflective practice would include gaining feedback from students during potential pilot studies. This could also include artifact analysis of student work, focused assessments, and external evaluations of student presentations and mini-teaching experiences.

Leadership and Extension Opportunities

Engaging in this study resulted in many insights that served to inform my understanding of high quality curriculum design, the importance and nature of wholestudent engagement, and leadership potential. Over the following sections, I explore each of these areas and explain how I might use what I have learned to grow further as a leader (and community member) and to help others in their own growth as educators.

Lessons Learned

My research path required me to pull myself out of the corner of simply being a physics instructor. Although I have always been gregarious and engaged in some basic communication and collaboration across disciplines, this study was my first opportunity to practice leadership in a role that asked others for assistance in a task that would not benefit them directly (and for which they would ultimately receive no recognition). The participation of my survey and interview respondents, especially, fell into this category. In the process, then, this study helped lay the groundwork for future collaboration with my fellow physics instructors Collegewide. I found over the course of the process that my physics colleagues would express interest and excitement on the progress of my

study, and some have already mentioned interest in the adoption of some of my unit materials and strategies. In fact, if I were to go back in this study, I would have expanded engagement with my physics instructor peers in two ways. First, I would have formed a focus group to support generative discussion. Barring that, I would at least have attempted to increase the number of interview respondents. Second, I would have asked them to pilot one or two activities and provide me with feedback. This early evaluation from a less biased source could have proven very informative.

Beyond the physics instructors, my collaboration with program advisors from the Elementary Education and Sonography groups lays the groundwork for potential learning-community style collaboration in the future. Continuing the discussion with these stakeholders could lead to a better understanding of my own students, new research possibilities, and potential professional partnerships and leadership opportunities.

Furthermore, my ongoing collaboration with the Center for Creative Instruction & Technology (CCIT) did more than simply help keep me within the expectations of the College and up to date on the latest educational technology. It also helped me to gain deeper insight into the purpose, processes, and infrastructure of CCIT. That said, if I were to do this study over again I would have used the CCIT team more for specifics on identifying accommodations for diverse learners (of all kinds) instead of relying as much as I did on the literature. This may seem backwards, but the position and charge of the CCIT team at my institution gives them access to top instructional innovation methods to the point that new methods and educational or supportive technologies might be in their hands before researchers have reported on them. Regardless, this work expanded my experience with the CCIT team to a new level, and—given the importance

of this group and their services—will prove useful in any number of future leadership roles.

Opportunities to Share During the Study Period

Through the course of completing this study, a few opportunities for me to selectively apply certain design principles from the study arose. The most recent of these was when I participated in a community outreach event at a local afterschool program that provides homework help and programs targeting Hispanic and Latino children in the area. In my activity, where students of all ages came around in small groups, I gave them the opportunity to explore physics applications in common, "everyday" scenarios (e.g., friction while walking, bicycle wheel rotation, and refraction in shallow versus deep water, among others). These activities were directly born of Design Principles 1 (*Life Relevance*), 4 (*Active Learning*), 7 (*Physics with Biology*), and 10 (*Outside Applications*).

Another opportunity was with a program that involves high-school aged students who are traditionally underrepresented in postsecondary education in STEM-based activities. Figure 41 on the next page shows an artifact from the workshop I developed with this group. In the workshop, students explored various ways in which their bodies related to physics. Their bodies, in fact, were key components of the laboratory equipment as they experimented with dynamometers (for hand grip predictions and comparisons), force plates and scales, and motion detectors. This experience very deliberately was built with Design Principle 6 (*Themed Approach*) in mind (with the theme of the human body at its center). The students engaged in social construction of

concepts as they formed predictions, designed experiments, and explained their

findings.

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Introduction: You have been provided with a datalogger and some probes. With this equipment, your team is tasked to explore the following questions and ideas:

- Who has the strongest grip?
- What characteristics do you believe go into determining how strong a person's grip is? ٠
- Who is the most dense (physically speaking) person in your team? Justify your response by explaining how you came to this conclusion.

Distance vs. Time Distance-A (m) 0 Time (s) Distance vs. Time Distance vs. Time Distance vs. Time Distance-A (m) Distance-A (m) ance-A (m) 4 4 Dista 여 Time (s) Time (s) Time (s)

Describe the below graphs, and then re-create them using your motion detectors: .



The remainder of the time, if any, will be spent exploring selected topics in how Physics relates to the Human Body.

Figure 41 Human Body Activity from a Math and Science High School Student Event

One other notable opportunity was at an international convention for a prestigious honor society for two-year colleges. At this convention, I was granted the honor of being an educational forum presenter. In this one-hour workshop, honor society students and advisors from across the Nation (and elsewhere) explored how basic Force and Motion physics concepts related to reaching their goals and overcoming social and other barriers. Two example slides from this workshop are provided in Figure 42. They illustrate how I pulled concepts from a "physics toolbox" and helped participants form links to their personal, social, and professional goals.



Figure 42 Sample Slides from an Educational Forum on Goals and Physics

At the event, participants shared life experiences and crafted ways to use physics concepts to address problems, improve their leadership skills, and achieve their goals. This was a more socially-oriented workshop (focused on *science agency*), but it again engaged multiple design principles—most notably Design Principle 4 (*Active Learning*) where students are engaged across three realms of human experience (cognitively, socially, and physically).

The next section explores the potential for extension of the unit materials to other scenarios and also discusses the potential for future research avenues.

Future Research and Extension Possibilities

Now that the Design Principles from this study have been validated through multiple levels of review and revision at the unit scale, the next step is to extend these guiding principles to the whole course. Recall that *Appendix H* outlines a number of the activities of which reframed lessons outside of the Waves and Periodicity unit could be comprised. This collection looks at the course as a whole even though my focus for this study was on a single unit. A sampling of this for components within a Force and Motion unit is provided in Table 23.

For the whole course, as with the unit held up as an exemplar in this study, students would take everyday human functions (e.g., breathing, heart beats; climbing stairs) and from these work toward both individual and whole-class understandings of the conceptual physics concepts. It is plain from this outline that there is much additional work ahead to reframe the Conceptual Physics course as a whole. An example of how this work should develop is drawn from the literature on the fourth level of inquiry: open inquiry. For open inquiry, where the "[problems], solutions, and

methods are left to the [students]" (Bell et al., 2005, p. 32), students truly "act like scientists" (Banchi & Bell, 2008, p. 27). However, "[it] is only appropriate to have students [conduct] open inquiries when they have demonstrated that they can successfully design and carry out investigations when provided with the question" (p. 27).

Table 23Sample of Extended Activities for Force and Motion Content

<u>PHY111 Syllabus</u> Core Course and Measurable	Current	Proposed Methods
Performance Objectives	Methods and	and Materials
(CCPOs in <i>bold italics</i> and <i>MPOs in italics</i>)	Materials (based on Summer 2015 - HYBRID)	(additional activities are suggested based on Design Principles)
Integrate and differentiate the basic processes of classical kinematics and dynamics, with emphasis on linear motion, nonlinear motion, Newton's Laws, and energy.	Reading assignments and basic problem sets (not listed); Lab quiz results are reviewed at the start of each new class.	Reading assignments and basic problem sets (not listed), periodic instructional "vlog" notes with accompanying outlines; ongoing word bank co- construction and discussion board participation
Define speed, velocity and acceleration, and explain their interrelationship.	In-class and online notes and discussions, echo-location and the motion detector discussion, Road Rage video demonstration	Eyes Closed & Ears Open practicum, vlog-notes w/ outline
<i>List and identify units of measure for distance, time, speed, velocity, and acceleration.</i>	Online video review, in- class and online notes and discussions, Interactive Physics simulations, Road Rash video game demonstration	Student Height analysis*, Time calculations*, Time and Proportion estimations*, vlog- notes w/ outline, Human Reaction Time lab, Bubble Diameter lab
Calculate speed and acceleration from their definitions.	In-class and online notes and discussions, Interactive Physics simulations, graphical analysis, group examples	Basketball dribbling speed competition, integrated into lab activities
Distinguish uniform acceleration from other types of motion.	In-class and online notes and discussions, frame of reference discussion, student motion lab	Student Motion lab, Ping-Pong Clear Pipe acceleration practicum, vlog-notes w/ outline, Blind Pew challenge
State the uniform acceleration formulas and be able to apply them when initial velocity equals zero.	In-class and online notes and discussions, Interactive Physics simulations, Choose Your Own Adventure practicum, Moo Motion lab, Semi-Olympic Events video demonstration	Choose Your Own Adventure practicum, vlog-notes w/ outline
Define vector quantity, scalar quantity, resultant, projectile, linear speed, and rotational speed.	In-class and online notes and discussions, Interactive Physics simulations, Moving Man PhET simulation practicum, Vector Addition strategies	Walk-It-Out Vectors Treasure Hunt, vlog-notes w/ outline
List and identify units of measure for rotational speed.	In-class and online notes and discussions, check for understanding, Rolling Things video demonstrations	Oral B inquiry, vlog-notes w/ outline
Describe the motion of a projectile (velocity and position).	In-class and online notes and discussions, spit ball or dart gun demonstration, drop vs. roll practicum, Range vs. Angle lab, ball toss experiment, projectile motion video clips and online demonstrations	Hang-Time practicum*, Pool Diving scenarios, Playing Darts demonstration, critical eye on Olympic Events, Physics of a Sneeze discussion, vlog-notes w/ outline, Baseball Diamond practicum, Projectile Tubes Optimal Angle lab

To seed this work, the activities outlined provide a strong starting point for the reframing of each Conceptual Physics unit by learning objective. Extension of these

into the open inquiry level would require highly reflective practice and an ongoing assessment of student ability levels in guided inquiry. That is where careful use of the journal entry responses and other formative assessment strategies would prove crucial.

I reframed this unit with the understanding that the educational technologies and strategies I employed were to be a part of the classroom community by the time the Waves and Periodicity unit material was reached. The skeletal components of each unit include the use of Word Banking, vLog creation (at least one introductory vLog entry and one check-point entry), and end-of-unit assessments (WebAssign®, exam preparation materials, and unit journal entries). Building on these are activities that purposefully include redundancy through guided inquiry, kinesthetic engagement, and social construction. Adding in formative assessments generously is the final component. These components are shown in their relative placement within a generic unit in Figure 43.



Figure 43 Generic Unit Outline to Guide Adoption of Curriculum Design Principles and Support Strategies

Moving beyond the Conceptual Physics course, there are opportunities to experiment with extending this to other science courses and even other non-science disciplines. This could take the form of integrating physics concepts into a biology course (e.g., the biology course(s) within the Elementary Education or Sonography programs). Another approach would be to extend these Design Principles to a technical field. Since the *ADDIE* framework of instructional design is so well adapted to career and technical education, and given that these Design Principles were made with the goal of improving relevance to mixed-major classes, the possibilities at the community college level are broad. In terms of relating this back to program advisors, a start might be to pull the Elementary Education and Sonography instructors together to discuss cross-disciplinary education and advisement strategies. This learning community-style approach could open up new opportunities to extend and share the principles that went into my unit reframing.

Of course, communication within the College's physics departments across the campuses provides a concrete opportunity to promote adoption and adaptation of these materials and strategies. To get this started, I provided a brief overview of lessons learned and course-specific recommendations in the form of a memorandum (see *Appendix M*). This memo is addressed to the College's physics department leaders. These recommendations outline potential updates to the syllabus and instructional practices based on my research results and include the most foundational and crucial components of the resulting unit. Instead of recommending adoption of the unit materials, directly, I offer them for review as an opportunity to feed further discussion. Although not reflected in the memorandum, I am also aware of bioscience grant opportunities that seek to expand integration of biology into other disciplines. There is

the potential to work with some of the physics instructors who have become interested in my approach to teaching conceptual physics and pursue these grant opportunities.

Along those lines, there are numerous external stakeholders where workshops on kinesthetic teaching, science agency, and the other major components of this study could be readily adapted to help the community *get moving* and learn more about themselves and their role in their health and society. These range from teacher camps to STEM events to holding workshops at local gyms. One place to start would be the creation of an online blog or vlog aimed at chronicling my pilots of the curriculum and obtaining feedback from others who are interested in collaborating and contributing to this line of teaching and research. It is my hope that opportunities to continue investigating how making connections between these three realms of the human experience in physics will unfold and lead to the development of additional professional conference presentations, workshops, and community engagement.

Conclusion

The design principles and unit materials formed during this study are exceptionally well-adapted to improving the relevance of Waves and Periodicity physics content to Elementary Education and Sonography majors. These same materials and strategies have natural extensions outside of the constraints of the Waves and Periodicity content. By adhering to these guiding principles, classrooms can engage in ongoing dialogue based on activities that engage learners as cognitive, physical, and social beings. The reframed unit as an outcome of this research study provides examples of refined strategies to support students where they most need it and by meeting them where they are. The process of curriculum reframing opens up paths for leadership since it serves as a model for improving instruction and curriculum. In any case, I am ready to get my students *moving together for learning*!

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Appendix A

CONCEPTUAL PHYSICS SYLLABUS

<u>Note</u>: This version of the syllabus was last updated in the Spring of 2009 (note the "200952" semester stamp beneath the old logo). This is still the syllabus I use for the course, even for the reframed unit. The last semester I ran the course with no reframing considerations was the Summer of 2015. It is important to note that the learning objectives did not require updating in order to reframe the unit.



Delaware Technical & Community College Georgetown Dover Stanton Wilmington

200952

DELAWARE TECHNICAL & COMMUNITY COLLEGE CAMPUS COURSE SYLLABUS

Campus:	Owens
Department:	Math/Physics
Course Number and Title:	PHY 111 – Conceptual Physics
Instructor Name:	Telephone:
E-mail:	
Office Hours:	
Pre-requisites:	MAT 015
Co-requisites:	None
Course Credits and Hours:	4:3:2
Course Description:	Physics 111 takes into account the major Physics and Earth Science topics covered in the Delaware Science Coalition (grades 1-6) science modules (kits). The course will be taught with an emphasis on understanding the material as well as developing an idea for how the material could be taught in an elementary environment.
	Addison-Wesley

<u>Materials</u> :	Scientific Calculator, Notebook, Metric Ruler and Protractor
Method of Instruction:	Campus classroom and laboratory.
Manuals:	None
<u>Disclaimer</u> :	

Core Course Performance Objectives:

- 1. Demonstrate clear understanding of the organization and defining characteristics of a science. (CCC 2,7)
- 2. Integrate and differentiate the basic processes of classical kinematics and dynamics, with emphasis on linear motion, nonlinear motion, Newton's Laws, and energy. (CCC 2,7)
- 3. Analyze the atomic nature of matter. (CCC 2,7)
- 4. Integrate and differentiate the basic principles of the waves and sound. (CCC 2,7)
- 5. Analyze the basic principles of static electricity and current electricity. (CCC 2,7)
- 6. Integrate laboratory and didactic principles and experiences with emphasis on speed, forces, rotational motion, periodic motion, work and power, sound and circuits. (CCC 1,2,3)

2. <u>Measurable Performance Objectives:</u>

The student will be able to:

- 1. Demonstrate clear understanding of the organization and defining characteristics of a science.
 - 1.1 Define fact, hypothesis, law, scientific method.
 - 1.2 Outline the scientific method.
- 2. Integrate and differentiate the basic processes of classical kinematics and dynamics, with emphasis on linear motion, nonlinear motion, Newton's Laws, and energy.

- 2.1 Define speed, velocity and acceleration, and explain their interrelationship.
- 2.2 List and identify units of measure for distance, time, speed, velocity, and acceleration.
- 2.3 Calculate speed and acceleration from their definitions.
- 2.4 Distinguish uniform acceleration from other types of motion.
- 2.5 State the uniform acceleration formulas and be able to apply them when initial velocity equals zero.
- 2.6 Define vector quantity, scalar quantity, resultant, projectile, linear speed, and rotational speed.
- 2.7 List and identify units of measure for rotational speed.
- 2.8 Describe the motion of a projectile (velocity and position).
- 2.9 Explain why satellites "fall".
- 2.10 Explain how linear speed varies on a rotating object.
- 2.11 Define mass, weight, volume, force, mechanical equilibrium, and terminal speed.
- 2.12 List and identify units of measure for mass, weight, volume, and force.
- 2.13 State and apply Newton's Laws.
- 2.14 Calculate weight from mass and mass from weight.
- 2.15 Define work, energy, power, potential energy, kinetic energy, and efficiency.
- 2.16 List and identify units of measure for work, energy, power, potential energy, kinetic energy, and efficiency.
- 2.17 Calculate the above quantities from their definitions.
- 2.18 State and apply the principle of conservation of energy.
- 3. Analyze the atomic nature of matter.
 - 3.1 Define atom, molecule, compound mixture, chemical reaction.
 - 3.2 List and identify common examples of atoms, molecules, compounds, and mixtures.
 - 3.3 Describe the microscopic character of liquids, solids, and gases.
 - 3.4 Describe the basic structure of an atom.
- 4. Integrate and differentiate the basic principles of the waves and sound.
 - 4.1 Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave, sonic boom, standing wave, node and antinode.
 - 4.2 Explain how frequency, period, wavelength, and wavespeed are interrelated.
 - 4.3 List and identify units of measure for frequency, period, wavelength, and wavespeed.
 - 4.4 Explain the difference between longitudinal and transverse waves.
 - 4.5 Define infrasonic, ultrasonic, compression, rarefaction, natural frequency, forced vibration, and resonance.
 - 4.6 Explain how the above terms relate to sound waves and their production.
 - 4.7 Identify the typical frequency range of human hearing.

- 5. Analyze the basic principles of static electricity and current electricity.
 - Define charge, conductor, semiconductor, insulator, 5.1 superconductor, electric field, electric potential energy, voltage.
 - 5.2 List and identify the units of measure for charge, electric field, electric potential energy, and voltage.
 - State and apply Coulomb's Law. 5.3
 - 5.4 State and apply the principle of charge conservation.
 - List and describe three methods for charging objects. 5.5
 - List and identify common conductors and insulators. 5.6
 - 5.7 Explain the relationship among electric potential energy, charge, and voltage.
 - 5.8 Define current, alternating current (AC), direct current (DC) and resistance.
 - 5.9 List and identify the units of measure for current and resistance.
 - State and apply Ohm's Law. 5.10
 - Explain the dangers of current electricity. 5.11
 - Distinguish between parallel and series circuits. 5.12
 - Calculate the power consumed by an electrical circuit. 5.13
- 6. Integrate laboratory and didactic principles and experiences with emphasis on speed, forces, rotational motion, periodic motion, work and power, sound and circuits.
 - 6.1 Investigate and explain linear motion in the laboratory.
 - Investigate and explain uniform and non-uniform forces in the 6.2

laboratory.

- 6.3 Investigate and explain the properties of periodic motion in the laboratory.
- 6.4 Investigate and explain work and power in the laboratory.
- Investigate and explain the properties of heat in the laboratory. 6.5
- Investigate and explain the properties of electricity in the laboratory. 6.6

Evaluation Criteria / Policy:

In order to achieve the maximum benefit from this course of instruction, the student is responsible for attending scheduled classes, completing all readings and instructor handouts, and actively participating in class discussion and activities.

The instructor will announce the schedule for written tests and quizzes

Students will demonstrate proficiency on all measurable performance objectives at least to the 75% level to successfully complete the course. The grade will be determined using the College Grading System:

92-100 =	А
83-91 =	В
75-82 =	С

0 - 74 = R

Students should refer to the <u>DTCC Student Handbook</u> for information on Academic Standing Policy, Academic Honesty Policy, Student Responsibilities and Student Rights, and other policies relevant to their academic progress.

<u>Grading</u>: A student's grade will be the average of the exams, labs, and other activities. There is no final exam. All the exams must be passed with a 75% or higher. If a student does not pass one or more exams, he or she will be required to take a cumulative exam containing material from the exams not passed.

Scope & Sequence

Energy:

What is it? What are the different forms? Transformation and Transference

Changing an Object's Mechanical Energy:

Linear, Parabolic, & Circular Motion Force Work / Power / Simple Machines (mechanical advantage) Wave Motion

Revisit Motion in an Observable Context:

Weather Astronomy

Revisit Motion within Earth's Dynamic Systems

Water History of Solar System Nature of Plate Tectonics

Revisit Motion within Microscopic Systems

Properties of Matter Thermal Energy Kinetic Theory of Gasses (Gas Laws) Electricity Magnetism

Appendix B

UNIT OUTLINES COMPARISON

Description: This document outlines the older unit (using the Summer 2015 (201553) semester materials) around key parameters. It is a more detailed precursor to the lesson design process than that outlined in *Appendix G* (Full Course Suggestions for Total Reframing) and is a unit-level adaptation of the design matrix given in *Appendix F* (CCIT Course Design Matrix Sample). The newly developed unit is also provided as a contrast to the previously-utilized lessons and provided a starting point for the *ADDIE* framework unit and lesson plans (see *Appendix I*). Since the course is offered in varying time slots based on semester, the lessons are broken up into hour approximations. Multiple lessons may be delivered during the same day or week.

ORIGINAL UNIT

Course: Conceptual Physics **Unit:** Waves and Periodicity

Lesson	Time (h:m)	Topic (s)	MPOs	Activities, Materials; Resources	Assignments & Assessments
IN-CLASS		Wave Types		Discussion Notes: Transverse vs. Longitudinal waves, sound vs.	Lab Quiz and Exam
				light, graphing wave functions, period vs. frequency, deriving the	representation
Knowledge		Anatomy of	2.2, 2.3,	wave speed equation, speed of sound vs. light	
Building		Waves	4.1, 4.2,	Activity: Doppler Effect (running down hallway w/ tuning fork)	
	1:00		4.3, 4.4,	Discussion Notes: Reflection, Refraction, and Diffraction	
		Wave	4.5, 4.6,	Activity: Refraction with bowl of water and coin	
		Characteristics	5.8	Discussion: Safe harbor in a tsunami event?	
				Summary: Computer simulations (teacher led)	
		Wave Behavior			

IN-CLASS Wave Applications Standing Waves Reinforcing Knowledge Calculation Practice	1:10	Calculating Speed of Sound Fast Fourier Transforms (FFT) Superposition Standing Wave Patterns Practical Applications Periodicity Speed, Wavelength, Frequency; Period	4.1, 4.2, 4.4, 4.5, 4.6	<u>Activity</u> : Investigating the speed of sound while considering room temperature and humidity <u>Discussion</u> : Review of FFT use in crime investigations and comparison of known people's voices <u>Activity</u> : FFT breakdown on Touch Tone phones <u>Activity</u> : Creation of transverse and longitudinal pulses, amplitude changes, attenuation, altering wave speed, superposition scenarios, nodes + antinodes, open-ended vs. closed-ended reflection <u>Animation</u> : Reflection <u>Discussion</u> : Engineering applications (e.g., engine design) <u>Demonstration</u> : Standing waves in a metal plate <u>Video Clip</u> : examples of standing wave patterns <u>Activity</u> : Student attempts at wave-speed formula calculations for periodic motion scenarios	Check for Understanding: Wave Pulse Superposition <u>Practice</u> : periodicity calculation examples with solutions Lab Quiz and Exam representation
IN-CLASS Formal Laboratory Activities	2:00	Wave Interference	4.1, 4.2, 4.4, 4.5, 4.6, 4.7, 5.8, 6.3	Spreadsheet Experimentation: Superposition spreadsheet simulations Activity: Identifying beats audibly; confirming using microphone and sound data analysis software Lab Methods Discussion: Why is it important to know which way tuning fork prongs vibrate? Activity: Wave Tube Apparatus exploration (sound) Activity: Transverse Wave online simulation Supplemental Resource: video clip assistance on wave simulation use Activity: Interference Patterns with Speakers (tone generator experimentation, high and low ranges) Lab Quiz: Waves and Periodicity (solutions provided after submission)	Check for Understanding: Closed End Reflection standing wave patterns Check for Understanding: Nodes & Antinodes Lab Manual artifacts Lab Quiz and Exam representation
ONLINE Concept Reinforce-	4:00 est'd	Wave Characteristics	4.1, 4.2, 4.3, 4.4	<u>Video Clip</u> : calculating speed of sound through air <u>Activity</u> : NOAA.gov calculator experimentation <u>Activity</u> : Anatomy of a Wave simulations (w/ video lessons) Demonstrations: Wave demonstration video clips	Reading Assignment: sections on sound, light, and E-M extensions

ment and		Speed of		Video Clip: The Tacoma Narrows Bridge Disaster	Ask Yourself: Thunder vs.	
Practice		Sound		Activity: practice problems with review of laboratory activities	Lightning	
				Poem: "O FFT!"		
		Wave			Exam Representation	
		Applications			-	
		Practice				
		Problems				
ONLINE		Ray Diagrams		Video Clip: Review of Ray Diagrams and Lenses (light)	Ask Yourself: Which of the	
		, ,		Activity: Survey of Human Vision Impairment	images best represents your	
Review of		SONAR		Activity: Relating light behavior to Earth's atmosphere, bodies of	current visions?	
Applications			4.1, 4.2,	water, and light sources.		
	2:00		4.3, 4.4,	Activity: Relating SONAR to wave behaviors and characteristics	Ask Yourself: Which type of	
Exam	est'd		4.5, 4.6,	Practice and Video Clips: Exam preparation questions on waves	corrective lenses should you	
Preparation			4.7	and periodicity with fully worked-out solutions and sample	consider, if any?	
•				student questions		
				*	Ask Yourself: How might water	
					density affect SONAR function?	
Fundamental F	arameters:	Keep within appro	ximately elev	ven hours' worth of course time, expand Measurable Performance Ob	jectives (MPOs) covered as content	
becomes more	fluidly link	ed to other units; d	lesign around	I newly identified principles and make explicit in revision.		
Additional direct foreshadowing and reinforcement from other units: compare with Appendix N, "Instructor's						
Original C	Original Conceptualization of Course Sequence" – note that not all connections were made as explicitly as others and some were very					
underemphasiz	zed or unde	rrepresented in the	ir original a	ppearance in the content; in the newly developed unit, these connectio	ons are emphasized. Many of these	
connections we	ere in fact n	ever made but are	now include	d in the new unit as human body connections (e.g., the periodicity of b	pasketball dribbling is now	
practiced) and expanded applications (e.g., Drinking Bird motion).						
Optical Illusions (Science Methods Unit)						
• Ener	gy Brainsto	orming, Thermal Ca	amera radiati	on, Drinking Bird motion, Stirling Engine action, Basketball Energy t	ransformation, Pendulum Energy	
Tran	sformation.	Spring Energy Tra	ansformation	, Hydraulic Jack action (Energy Conservation and TOE Unit)		
 Parti 	cle-Model	of solids (Atomic N	Vature of Ma	tter Unit)		
• AC \	Voltage Ger	neration. E-M field	s and nature	(Electricity & Magnetism Unit)		
• Circular Motion (Force & Motion Unit)						

• Satellite and Planetary Motion, Supercontinent Cycle, Rotation vs. Revolution, Earth & Moon phases, Seismic Waves (Earth & Space Science Unit)

NEWLY DEVELOPED UNIT

Course: Conceptual Physics **Unit:** Waves and Periodicity

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#1*	Assignments & Assessments
ONLINE Unit	()	Thinking about Waves		Transition out of the previous unit (not reflected in unit or lesson outlines/plans)	
Preparation	0:30 est'd	Word Bank Opens		<u>Vlog Notes</u> : Seeding initial thoughts on waves [closed-captioned] "Fun in the Kiddie Pool", "Echoes Between Buildings," "Musical Body Parts" experiments/demos [DP#'s 1, 6, 7, 8, 10] <u>Word Banking</u> : Waves & Periodicity Word Bank opened for class co-construction [DP#'s 2, 3, 4, 8]	
IN-CLASS Knowledge Building Wave Nature and Behavior Wave Applications	1:20	Wave Characteristics Wave Examples Pendulum Motion FFT	4.1, 4.4, 4.5, 4.6, 5.8, 6.3	Word Banking: Review and Revision of Word Bank [DP#'s 2, 3, 4, 8] <u>Activity</u> : "What is a Wave" thinking group activity; life without waves [adopted from a Physics Respondent, DP#'s 1, 2, 3, 4, 5, 6, 7, 10] <u>Activity</u> : "What is a Wave" spring, tuning forks, and human voice experiments [adopted from a Physics Respondent, DP#'s 1, 2, 3, 4, 5, 6, 7, 10] <u>Demonstration</u> : Fast Fourier Transform (mapping out the human voice, &tc.), vocal flaps/cords [inspired by Ostdiek & Bord, 2013, p. 239, DP#'s 4, 5, 6, 7] <u>Activity</u> : "Do the Wave" - waveform modeling student line-up (acting out transverse and longitudinal waves, and free- and fixed- end reflections) [adapted from Pantidos & Patapis, 2005, p. 344, DP#'s 2, 4, 5, 6] <u>Activity</u> : "Biggest Hands, Smallest Hands" period, amplitude, and frequency assessment (hand holding pencil wave form creation) [inspired by a Sonography Respondent, DP#'s 1, 2, 4, 6, 7] <u>Activity</u> : "The Human Oscilloscope" [adapted from Pfister & Lago 1005 m 2100 DPW's 1, 2, 4, 6, 7]	Reading Assignment: Sections on basic wave characteristics Check for Understanding: Wave Pulse Superposition [based on Stepans, 1996, p. 173] Check for Understanding: Leg and Arm Pendula [inspired by Blanksby et al., 1981, p. 79] WebAssign® and Exam representation

IN-CLASS Wave Applications Continued		E-M Radiation Units and Formulas Used to Quantify Wave Characteristics Doppler Effect		<u>Activity</u> : Heart Rate measurements (class graphing and waveform equivalent) [adapted from Schwartz, 1997, p. 126, DP#'s 1, 4, 6, 7, 9] <u>Poem</u> : "O FFT!" poem recitation [DP#'s 3, 10] <u>Recall</u> : "Is a Blanket Warm"? Thermal camera inquiry activities with human body radiation (circulation, radiation, conduction, &tc.) from previous unit [adapted from Roseberry et al., 2010, p. 334, DP#'s 1, 2, 3, 4, 5, 6, 7] <u>Discussion</u> : What is infrared? (infrasound? ultraviolet? ultrasound?) [inspired by JRC-DMS, 2008, DP#'s 2, 3, 4, 5, 9] <u>Discussion</u> : "UV – It Hertz Your Skin" (period, frequency, wavelength; wavespeed – units and relationships for each) [inspired by Ostdiek & Bord, 2013, p. 315, DP#'s 1, 2, 3, 4, 6, 7]	WebAssign® and Exam representation <u>Check for Understanding</u> : Closed End Reflection standing wave patterns [based on Stepans, 1996, p. 174] <u>Check for Understanding</u> : Glass
	1:30	Doppler Effect Periodicity Standing Waves Beats Ray Diagramming	2.2, 2.3, 3.3, 4.1, 4.2, 4.3, 4.5, 4.6, 6.1, 6.3, 6.5	wavelength; wavespeed – units and relationships for each) [inspired by Ostdiek & Bord, 2013, p. 315, DP#'s 1, 2, 3, 4, 6, 7] <u>Demonstration</u> : Excited Skin Particles simulation (spring model) [inspired by Edelman, 2012, p. 408, DP#'s 1, 3, 6, 7] <u>Activity</u> : E-M spectrum student line-up (acting out the E-M spectrum) [inspired by Pantidos & Patapis, 2005, p. 344, DP#'s 2, 3, 4, 6] <u>Activity</u> : Discovering the Doppler Effect – "Don't run with scissors; run with a tuning fork!" (run down hallway activity) [inspired by JRC-DMS, 2008, DP#'s 1, 4, 6] <u>Discussion</u> : Chattering Teeth periodicity [DP#'s 1, 2, 6, 7] <u>Demonstration</u> : Electric Toothbrush in action [DP#'s 1, 3, 6, 7] <u>Demonstration</u> : "Your Beating Heart" (simulating ultrasound scan of carotid artery) [Lewis & Mohazzabi, 2014, DP#'s 1, 3, 6, 7] <u>Demonstration</u> : "Bottles of Coke" water music production and wave tube apparatus calculations [based on Stepans, 1996, p. 186, DP#'s 1, 3, 6, 10] <u>Activity</u> : Standing wave pattern student line-up (acting out nodes and antinodes) [inspired by Pantidos & Patapis, 2005, p. 344, DP#'s 2, 3, 4, 6] <u>Activity</u> : "Beats, Beats: The Musical Fruit" tuning fork hearing activity with spreadsheet support [DP#'s 4, 5, 10] <u>Activity</u> : Ray Diagramming (simulated spear fishing!) [inspired by Hewitt, 2008, p. 298, DP#'s 2, 4, 5, 10] <u>Exit Ticket</u> : 1 thing you are confident on; 1 thing you have a question on or want to learn more about [DP# 8]	p. 174j <u>Check for Understanding</u> : Glass of Water with Arrow Images [adopted from AIA, 2016] Exit Ticket
ONLINE	1:45 est'd	Sound Characteristics	4.1, 4.4, 4.6, 6.1	<u>Vlog Notes</u> : Summary of content and activities to-date [closed- captioned] [DP#'s 1, 6, 7, 8] Video Clip: Lightning vs. Thunder [DP#'s 1, 10]	<u>Reading Assignment</u> : Sections on advanced wave behaviors and applications

Social		Doppler Effect		Discussion Board Activity: "Sound" thinking group activity	
Construction		Revisited		[adapted from a Physics Respondent, DP#'s 1, 2, 4, 5, 7, 8, 10]	Discussion Board: post and
of Sound				Activity: Modes of transportation (plane, boat, and really fast car!)	responses
Concepts		Bow waves.		webguest/simulations [inspired by Edelman, 2012, p. 403, DP#'s	F
		shock waves.		5. 8. 10]	Homework: eve physical
		and sonic		Activity: "How do your eves measure up"? (visual acuity online	simulation [inspired by
		booms		activity) [inspired by Crouch & Heller, 2011, p. 160, DP#'s 1, 4,	McGuigan, 2009]
				6. 7. 8]	
		Ray		Homework: Create-your-Eye gel experiment [inspired by	WebAssign® and Exam
		Diagramming		McGuigan, 2009, DP#'s 1, 4, 6, 7, 8]	ropresentation
		Revisited		Practice: practice problems with solutions [DP#'s 8, 10]	representation
				Word Banking: Update of Word Bank [DP#'s 2, 3, 4, 8]	
IN-CLASS		Light		Discussion: Review of prior Exit Tickets [DP #8]	Check for Understanding: Nodes
		Characteristics		Word Banking: Review and Revision of Word Bank [DP#'s 2, 3,	& Antinodes [based on Stepans,
Social				4,8]	1996, p. 174]
Construction		Doppler Effect		Discussion: Review of Create-your-Eye gel experiment homework	
of Light		Revisited		and LASER testing [DP#'s 4, 6, 7]	WebAssign® and Exam
Concepts				Activity: "Light" thinking group activity and experimentation	representation
-		Color Mixing		[adopted from Physics Respondent, DP#'s 1, 2, 3, 4, 5, 10]	representation
Sound vs.		_		Demonstration: Conducting a basic whole-class hearing test	Fxit Ticket
Light		Refraction		(analyze class range-distribution) [inspired by JRC-DMS, 2008,	LAR TICKE
			4144	DP#'s 1, 2, 4, 5, 6, 7]	
	1.20	Resonance	4.1, 4.4,	Activity: "Best place to Sit in the Theatre" (sound interference	
	1.50		4.5, 4.0,	pattern lab exercise) [inspired by Lewis & Mohazzabi, 2014,	
		Interference	4.7, 0.5	DP#'s 1, 2, 4, 6, 10]	
		Patterns with		Activity: "Honing your Teacher Voice" - projection microphone	
		Light		analysis [DP#'s 1, 4, 7, 9]	
				Discussion: "Do you really see during an ultrasound scan"?	
		Interference		[DP#'s 2, 4, 7, 9]	
		Patterns with		Exit Ticket: 1 thing you are confident on; 1 thing you have a	
		Sound		question on or want to learn more about [DP# 8]	
		Ultrasound			
		Revisited			
IN-CLASS		Student Group		Discussion: Review of prior Exit Tickets [DP #8]	Kahoot! Quiz
G. 1		Teaching	4.1, 4.2,	Activity: Kanoot! Quiz on Waves & Periodicity [DP# 4]	
Student	1:20	Sessions	4.4, 4.5,	Activity: Student topic assignments and mini-teaching sessions	Presentations: student
Teaching			4.6	(Sonographer and Educator roles and perspectives) [inspired by an	involvement in group teaching
Sessions				Education Respondent, DP#'s 2, 4, 9]	sessions (rubric provided)

ONLINE		Physics of		Word Banking: Concluding additions/revisions in Word Bank	Practice: periodicity calculation	
		Music		[DP#'s 2, 3, 4, 8]	examples with solutions	
Extended				Activity: Online exploration of musical applications [inspired by		
Thinking		Exam		Ostdiek & Bord, 2013, p. 249, DP#'s 1, 4, 10]	Journal Entry artifact [inspired by	
		Preparation		Activity: Waves and Periodicity journal reflection entry [inspired	Hwang et al., 2015, p. 114]	
Exam			4.1, 4.2,	by Hwang et al., 2015, p. 114, DP#'s 4, 8, 9]		
Preparation	2:40	Formal	4.3, 4.4,	<u>Practice and Video Clips</u> : Exam preparation questions on waves	<u>WebAssign</u> ®: WebAssign®-	
	3st'd	Assessment	4.5, 4.6,	and periodicity with fully worked-out solutions and sample $\frac{1}{2}$	ment on waves and periodicity	
			4.7	student questions [DP# \$ 8, 10]	(immediate feedback generated;	
				<u>WebAssign</u> ® <u>-ment</u> : Waves and Periodicity problems [DP#'s 8,	mastery learning focused)	
				10]		
				I ransition into the next unit (not reflected in unit or lesson		
Fundamental	Paramatars	Paflaction: Was ka	nt within the	outlines/plans)	lso due to a longer base semester	
(16 weeks) ver	sus that for	the comparison se	mester (10 w	veeks). Content in the 10 week version of the course is basically identi	ical to previous 16 week iterations:	
when employe	d for summ	er iterations the se	quence woul	d be compressed without loss of content (although sequence alteration	s would occur) Expanded more	
solidly the use	of other-ur	it MPOs as bound	aries betweer	these other units were made more passable through the use of a com	mon theme. Larger "formal" lab	
exercises were	broken up	into smaller, "chur	nked" activiti	es with embedded formative assessments.		
Additional	Additional direct foreshadowing and reinforcement from other units: compare with Appendix O "Instructor's					
Reconcepti	ializatio	n of Course Se	equence"			
• Earth/Space connections: "A Day at the Beach" (solar and lunar tidal effects, wave characteristics, &tc.), periodicity of orbital motion						
Force	e & Motior	n: Muscles (pushup	s, stretching,	&tc.) as Hooke's Law (spring modeling) applications, blood pressure	(Pressure) tie-in, centripetal	
moti	on	4 1	, U.			
• Ener	gy concept	s: Solar panel scier	nce (biologic	al breakthroughs in synthesizing photosynthesis; biomimicry), radiatio	on (human heaters), pendula (e.g.,	
swin	gs)					
Ator	nic Nature	of Matter: vibration	nal motion (p	article-model of molecules + compounds)		
along with further tie-ins as described in the Original Unit Outline Matrix						
*[SOURCE] indicates primary inspiration for each activity when it was not one that I developed independently (whether or not the activity is unique). Citation-						
format is used where the source is included in the Bibliography, and "Respondent" is used where the source was among my research study participants. The [,						
DP#] marker d	DP#] marker denotes the design principle being applied through inclusion of each activity/material/resource. Note that activities for which the justification is					
made in the lit	erature revi	ews (e.g., Word Ba	anking) or w	nch were built up across multiple research artifacts (e.g., vLog Entries	s) do not include a research or	
bibliography re	elerence. E	basic summarization	n activities (e.g., EXIL LICKELS, POEMS) also do not include such references, or activity	reference Additional influential	
readings are re	c inspiratio	Annendix P	uerstand are	vased on the common misunderstandings interature and do include a	reference. Additional influential	
readings are referenced in Appendix 1.						

Appendix C

CONNECTIONS TO THE NGSS AND JRC-DMS STANDARDS

Syllabus Measurable	Next Generation Science Standards:	JRC-DMS National Education Curriculum
Performance Objectives:	Active Links Included (seeded from	
See Syllabus	http://www.nextgenscience.org/overview-	
	<u>topics</u> root directory)	
Integrate and differentiate the	1^{st} and 4^{th} grades explicitly list performance	"Identify the characteristics of sound and
basic principles of the waves	expectations in the Next Generation Science	wave properties of sound" (JRC-DMS, 2008,
and sound	Standards. Other connections with Waves and	<i>p.</i> 12)
	Periodicity may be made across additional	
	units and grade levels. Not all measurable	
	performance objectives are directly duplicated,	
	but an understanding of each undergirds the	
	content which will be taught.	
Define amplitude, frequency,	NGSS, Disciplinary Core Ideas: Waves: Light	JRC-DMS, General Education: Physics
period, wavelength, wavespeed,	and Sound	• 5A: Waves (Sound)
interference pattern, Doppler	• PS4.A: Wave Properties	• 6B: Reflection and Refraction
effect, bow wave, shock wave,	• PS4.B: Electromagnetic Radiation	
sonic boom, standing wave,		
node and antinode.		
Explain how frequency, period,	NGSS, Disciplinary Core Ideas: Waves: Light	JRC-DMS, General Education: Physics
wavelength, and wavespeed are	and Sound	• 5A: Waves (Sound)
interrelated.	• PS4.A: <u>Wave Properties</u>	• 6A: Color
	\circ 4-PS4-1: Modeling waves to	• 8A: Waves (Electromagnetic)
	describe amplitude, wavelength;	• 8B: Frequency Spectrum
	wave motion	
	• PS4.B: <u>Electromagnetic Radiation</u>	

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List and identify units of	NGSS, Disciplinary Core Ideas: Waves: Light	JRC-DMS, General Education: Physics
measure for frequency, period,	and Sound	• 5A: Waves (Sound)
wavelength, and wavespeed.	PS4.B: <u>Electromagnetic Radiation</u>	• 8A: Waves (Electromagnetic)
Explain the difference between	NGSS, Disciplinary Core Ideas: Waves: Light	JRC-DMS, General Education: Physics
longitudinal and transverse	and Sound	• 5A: Waves (Sound)
waves.	• PS4.A: <u>Wave Properties</u>	• 5C: Emission
	• PS4.B: <u>Electromagnetic Radiation</u>	• 8A: Waves (Electromagnetic)
	 1-PS4-2: Illumination of objects 	
	in darkness	
	\circ 1-PS4-3: Reflection,	
	transmission, refraction,	
	scattering, and absorption	
	experiments	
Define infrasonic, ultrasonic,	NGSS, Disciplinary Core Ideas: Waves: Light	JRC-DMS, General Education: Physics
compression, rarefaction,	and Sound	• 5A: Waves (Sound)
natural frequency, forced	• PS4.A: <u>Wave Properties</u>	• 5B: Frequency Ranges, 1: Infrasound
vibration, and resonance.	• 1-PS4-1: Vibrating materials can	• 5B: Frequency Ranges, 2: Audible
	make sound and vice versa	• 5B: Frequency Ranges, 3: Ultrasound
	(resonance)	
	• PS4.B: <u>Electromagnetic Radiation</u>	
Explain how the above terms	NGSS, Disciplinary Core Ideas: Waves: Light	JRC-DMS, General Education: Physics
relate to sound waves and their	and Sound	• 5A: Waves (Sound)
production.	• PS4.A: <u>Wave Properties</u>	• 5B: Frequency Ranges, 1: Infrasound
	\circ 1-PS4-1: Vibrating materials can	• 5B: Frequency Ranges, 2: Audible
	make sound and vice versa	• 5B: Frequency Ranges, 3: Ultrasound
	(sound production)	
	PS4.B: <u>Electromagnetic Radiation</u>	
	PS4.C: Information Technologies and	
	Instrumentation	

	 1-PS4-4: Designing and building a communication device using light or sound over a distance 4-PS4-3: Transfer of coded information through sound waves 	
Identify the typical frequency	NGSS, Disciplinary Core Ideas: Waves: Light	JRC-DMS, General Education: Physics
range of human hearing.	and Sound	• 5B: Frequency Ranges, 1: Infrasound
	• PS4.C: Information Technologies and	• 5B: Frequency Ranges, 2: Audible
	<u>Instrumentation</u>	• 5B: Frequency Ranges, 3: Ultrasound

CONSIDER ALSO:

Education Majors:

Educational Testing Service (2015a). *Delaware test requirements*. Retrieved from <u>https://www.ets.org/praxis/de/requirements</u>

Educational Testing Service (2015b). *Overview of Delaware testing requirements*. Retrieved from <u>https://www.ets.org/praxis/de</u>

Sonography Pool Students:

American Registry for Diagnostic Medical Sonography (2015). *Sonography principles & certification (SPI) examination*. Retrieved from <u>http://www.ardms.org/get-certified/Pages/SPI.aspx</u>

Joint Review Committee on Education in Diagnostic Medical Sonography (2008). *National Education Curriculum: Common Curricula*, i-57. Retrieved from <u>http://jrcdms.org/nec/NEC-Part-II-CommonCurricula.pdf</u>

Appendix D

INSTRUCTOR COLLABORATIVE COURSE REVIEW

Welcome & Orientation	F	NF	Recommendations	Comments
Orientation to course components and Getting				
Started (i.e. Getting Started tab, Welcome				
Video/Letter)				
Instructor contact information				
Course syllabus				
Explicitly stated Student course expectations				
Explicitly stated Instructor course expectations				
Course schedule/outline (pacing guide)				
Explicitly stated course grading policy				
Minimum technology requirements				
Student introduction activity				
Intuitive and consistent navigation throughout				
the course				
Learning objectives are listed and linked to				
instructional units				
Course content is "chunked" into manageable				
instructional units				
Interaction & Collaboration	F	NF	Recommendations	Comments
Opportunities for Learner to Learner				
interactions				

Opportunities for Learner to Instructor				
interactions				
Opportunities for Learner to Content				
interactions				
Explicitly stated expectations, requirements,				
and/or guidelines (rubric)				
Instructional Materials	F	NF	Recommendations	Comments
Instructional materials linked to stated learning				
objectives				
Clear explanation of how instructional				
materials are to be used				
Reference materials are cited (e.g. link to				
direct source)				
Use of current instructional materials				
Developmentally-appropriate instructional				
materials				
Formats of instructional material are varied				
Multiple perspectives provided in instructional				
materials				
Assessment	F	NF	Recommendations	Comments
Varied assessments are provided throughout				
the course				
Assessments are aligned with instructional				
materials				
Assessment are linked to stated learning				
objectives				
Assessments are conducted on an ongoing				
basis throughout the course				
Clearly explained evaluation criteria (rubric)				

Multiple opportunities for student self-					
assessment					
Course Technology		F	NF	Recommendations	Comments
The instructional technologies used rein	force				
the course learning objectives					
The instructional technologies employed	d				
promote active learning					
Technologies required for the course are	e				
readily available					
The course technologies are current					
Learner Support		F	NF	Recommendations	Comments
Link to DTCC's Student Help Center is					
provided (<u>http://ccit.dtcc.edu/student-he</u>	<u>elp-</u>				
<u>center</u>)					
Link to DTCC's Learner Support page i	is				
provided (<u>www.dtcc.edu/student-</u>					
resources/learning-support)					
Accessibility		F	NF	Recommendations	Comments
The course employs accessible technolo	ogies				
and provides guidance on how to obtain	1				
accommodation					
The course contains equivalent alternati	ves to				
meet the needs of diverse learners					
The course design facilitates readability and					
minimizes distractions					
The course design accommodates the us	se of				
assistive technologies					
Course	Instructo	r		Evaluator Initials	Evaluation Date

Appendix E

SURVEY INSTRUMENTS and INTERVIEW PROTOCOL

SURVEY INSTRUMENT ON TEACHING STRATEGIES

to be administered via Qualtrics® online software

1) Have you taught a fundamental or conceptual physics course within the past five years? YES | NO

If so, please describe the students which typically made up your class(es)—e.g., program major, age, &tc. [Insert Comment Box]

For the following statements, choose whether you Strongly Agree (5), Agree (4), Neither Agree nor Disagree (3), Disagree (2), or Strongly Disagree (1):

- 2) The students learned a lot in the course.
- 3) The course incorporated material which would help the students in their careers.
- 4) The students learned material which would help them in their careers.
- 5) The students' majors had little noticeable effect on their approach to the course content.
- 6) The students had difficulty with understanding vocabulary early on.
- 7) The students had difficulty understanding vocabulary throughout the course.
- 8) I taught this course in a traditional manner.
- 9) It is or could be beneficial to teach this course using an overarching theme to tie concepts together.
- 10) Most of the students seemed satisfied with the course.
- 11) The students realized connections between their everyday lives and the course content.
- 12) The students realized connections between course content and social issues.
- 13) The students realized connections between course content and their future careers.
- 14) Provide an example of one or more teaching strategies which you feel have/has been particularly successful: [Insert Comment Box]
- 15) Provide an example of one or more major learning challenges your students have faced: [Insert Comment Box]
- 16) In terms of physics vocabulary, which physics terms have your students had the most difficulty understanding and/or applying? (Please list and rank the top five) [Insert Comment Box along with 1-through-5 ranking input boxes]
- 17) How will your Education students apply the course content to their careers? [Insert Comment Box]
- 18) How will your Life Science (e.g., Diagnostic Medical Sonography) students apply the course content to their careers? [Insert Comment Box]

- 19) The box below is provided for you to submit any other comments: [Insert Comment Box]
- 20) Would you be willing to answer follow-up questions in the future?

YES | NO [If yes, include prompt on mode of communication preferred (interview, e-mail, phone call)].

FOLLOW-UP INTERVIEW PROTOCOL – PHYSICS INSTRUCTOR:

In the survey there were a number of questions on potential barriers to students' understanding of concepts. One of these potential barriers was a lack of clear connections to students' career goals. How important do you believe it is to make connections between course content and students' eventual careers?

As an instructor, do you have ideas on useful ways to make these connections to careers more obvious to your students?

Another potential barrier from the survey was a lack of connection between concepts. I am already aware that Conceptual Physics covers a broad range of topics. Will you please elaborate on how you help students make connections between concepts throughout the semester?

Will you please describe any special dynamics of having two dominant majors (e.g., Elementary Education and Sonography Pool majors) in the classroom? (In other words, do you feel that this situation affects student behaviors, group dynamics, classroom atmosphere, or some other aspect of the learning experience)?

My initial review of the literature supports the incorporation of biology concepts and having students physically engaged in multiple ways is an effective teaching method in fundamental physics courses. Based on your experience as a physics instructor, what do you think might be some potential weaknesses and/or strengths of using these "human body" connections as an overarching theme for the course?

SURVEY INSTRUMENT ON PROGRAM AND CAREER READINESS

to be administered via Qualtrics® online software

How many years of experience in your field do you have? [Insert Comment Box]

2) Briefly describe your role at the College and expertise background: [Insert Comment Box]

For the following statements, choose whether you Strongly Agree (5), Agree (4), Neither Agree nor Disagree (3), Disagree (2), Strongly Disagree (1), or Not Applicable (N/A):

- 3) My program(s)' students will apply conceptual physics concepts in other courses.
- 4) My program(s)' students will apply conceptual physics concepts in the career field.
- 5) My program(s)' students have difficulty completing conceptual physics.
- 6) The only reason my program(s)' students take conceptual physics is because it is a program or transfer requirement.
- 7) If conceptual physics were not a program or transfer requirement, my program(s)' students would not need to take the course for program or career preparation.
- 8) My program(s)' students are required to apply physics concepts when sitting for certification examinations.
- 9) List some of the major difficulties reported by your program(s)' students, if any, regarding the conceptual physics course: [Insert Comment Box]
- 10) What, if any, are the major concepts your program(s)' students will apply in other program or transfer courses? [Insert Comment Box]
- 11) What, if any, are the major concepts your program(s)' students will apply in the career field? [Insert Comment Box]
- 12) What major challenges, in general, will your students face in the career field? (This may include trends for which they must be particularly well-prepared, typical areas of difficulty for entry-level careers, &tc.) [Insert Comment Box]
- 13) The box below is provided for you to submit any other comments: [Insert Comment Box]
- 14) Would you be willing to answer follow-up questions in the future?

YES | NO [If yes, include prompt on mode of communication preferred (interview, e-mail, phone call)].

FOLLOW-UP INTERVIEW PROTOCOL – ELEMENTARY EDUCATION ADVISOR:

It is my understanding that elementary education students enrolled in conceptual physics are all planning to transfer into a 4-year teacher certification program. Also, most elementary education students take this course near the end of their time at Delaware Tech. Is this accurate?

That said, do students only take the course because it is a transfer requirement, or are there other direct applications either in their future courses, teacher certification process, or eventual teaching?

Are the *Next Generation Science Standards* integrated into any of their courses at Delaware Tech? If not, would this benefit elementary education associate's degree students?

Do you believe that, in general, elementary education students are prepared to teach the science components by the time they enter the field?

Do you believe that, in general, your elementary education advisees look forward to taking conceptual physics (and why or why not)?

The primary thrust of my work in this study has been geared toward developing conceptual physics teaching methods and themes that work for both elementary education majors and diagnostic medical sonography majors (since they share conceptual physics as a course requirement). Short of making separate physics courses for each, do you have suggestions on how I can cater to the elementary education students' needs?

FOLLOW-UP INTERVIEW PROTOCOL – SONOGRAPHY ADVISOR:

It is my understanding that diagnostic medical sonography students enrolled in conceptual physics are all pool students who are working towards admission into the full program. Is this accurate?

Based on your experience as an advisor to these students, how familiar are they with the field of sonography by the time they enter conceptual physics?

Are there any specific, fundamental skills sonographers need to develop to be proficient in the field?

You mentioned in your survey response that students have expressed a need for more course offerings of Conceptual Physics. Do you as a primary program advisor consider this an actionable concern? (In other words, if an additional section of the course were offered, would your advisees be able to provide sufficient numbers for the class to run, and when might this course need to be offered: daytime, evening; weekend)?

I am aware of the ARDMS ultrasound physics requirements from past experience, exploration of the materials available on ARDMS' website, and a review of some limited literature on the subject. In your estimation as a primary program advisor for these students, would it be worth the effort if I included a document explaining the links between sonography students' goals and the conceptual physics course?

SURVEY INSTRUMENT ON EDUCATIONAL TECHNOLOGY

to be administered via Qualtrics® online software [Respondents: CCIT Faculty & Staff]

- How many years of experience in your field do you have? [Insert Comment Box]
- 2) Briefly describe your role at the College and expertise/background: [Insert Comment Box]
- 3) Have you ever assisted in the design and/or delivery of a distance-learning (i.e., less than 100% face-to-face) laboratory-based STEM course?

YES | NO [Insert Comment Box for elaboration]

- What educational technology applications/software would you recommend for a hybrid, laboratory-based STEM course? [Insert Comment Box]
- 5) Are you aware of any research on physics and/or other STEM education outlining best practices in the use of educational technology?

YES | NO [If yes, include prompt for elaboration on recommended resources]

- 6) The box below is provided for you to submit any other comments: [Insert Comment Box]
- 7) Would you be willing to answer follow-up questions in the future?

YES | NO [If yes, include prompt on mode of communication preferred (interview, e-mail, phone call)].

Appendix F

CCIT COURSE DESIGN MATRIX SAMPLE

UNMODIFIED VERSION (Whole Course)

CCIT Course Design Matrix Department: Course Number and Title: Instructor Name: Course Credits and Hours: Method of Instruction:

Week	Mode	Topics	MPOs	Activities/Materials/Resources	Assignments
1					
2					
3					
4					
5					
6					
7					
8					

MODIFIED VERSION (Unit-Specific)

Course: Conceptual Physics **Unit:** Waves and Periodicity

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources	Assignments & Assessments
Fundamental Parameters: description of these parameters					
Additional direct foreshadowing and reinforcement from other units: - notes					
•					

Appendix G

FULL COURSE SUGGESTIONS FOR TOTAL REFRAMING

PHY111 Syllabus Core Course and	Current Methods	Proposed Methods
Measurable Performance Objectives (CCPOs in <i>bold italics</i> and <i>MPOs in italics</i>)	and Materials (based on Summer 2015 - HYBRID)	and Materials (additional activities are suggested based on Design Principles)
Demonstrate clear understanding of the organization and defining characteristics of a science.	Reading assignments and basic problem sets (not listed); Lab quiz results are reviewed at the start of each new class.	Reading assignments and basic problem sets (not listed), periodic instructional "vlog" notes with accompanying outlines; ongoing word bank co-construction and discussion board participation
Define fact, hypothesis, law, scientific method.	In-class notes, sharing of student past experiences with problems to solve using, "Methodically Scientific" poem	"Methodically Scientific" poem, baseline data review, Science Methods TED Talk
Outline the scientific method.	Comparing traditional Scientific Method to science methods and Nature of Science, Optical Illusions lab, curious object inquiries lab, crime scene investigation lab	Thumb Wars lab, Pulse Rate practicum*, Optical Illusions lab
↑ FORMAL ASSESSMENTS:	Multiple-choice lab quiz, exam essay representation; lab manual representation	Exam essay representation, WebAssign®-ments; Journal entries
Integrate and differentiate the basic processes of classical kinematics and dynamics, with emphasis on linear motion, nonlinear motion, Newton's Laws, and energy.	Reading assignments and basic problem sets (not listed); Lab quiz results are reviewed at the start of each new class.	Reading assignments and basic problem sets (not listed), periodic instructional "vlog" notes with accompanying outlines; ongoing word bank co-construction and discussion board participation
Define speed, velocity and acceleration, and explain their interrelationship.	In-class and online notes and discussions, echo-location and the motion detector discussion, Road Rage video demonstration	Eyes Closed & Ears Open practicum, vlog-notes w/ outline
<i>List and identify units of measure for distance, time, speed, velocity, and acceleration.</i>	Online video review, in-class and online notes and discussions, Interactive Physics simulations, Road Rash video game demonstration	Student Height analysis*, Time calculations*, Time and Proportion estimations*, vlog-notes w/ outline, Human Reaction Time lab, Bubble Diameter lab
Calculate speed and acceleration from their definitions.	In-class and online notes and discussions, Interactive Physics simulations, graphical analysis, group examples	Basketball dribbling speed competition, integrated into lab activities
<i>Distinguish uniform acceleration from other types of motion.</i>	In-class and online notes and discussions, frame of reference discussion, student motion lab	Student Motion lab, Ping-Pong Clear Pipe acceleration practicum, vlog- notes w/ outline, Blind Pew challenge
State the uniform acceleration formulas and be able to apply them when initial velocity equals zero.	In-class and online notes and discussions, Interactive Physics simulations, Choose Your Own Adventure practicum, Moo Motion lab, Semi-Olympic Events video demonstration	Choose Your Own Adventure practicum, vlog-notes w/ outline
Define vector quantity, scalar quantity, resultant, projectile, linear speed, and rotational speed.	In-class and online notes and discussions, Interactive Physics simulations, Moving Man PhET	Walk-It-Out Vectors Treasure Hunt, vlog-notes w/ outline

	simulation practicum, Vector	
	Addition strategies	Oral D in anima and a matter and partition
List and identify units of measure for	discussions, check for	Oral B inquiry, viog-notes w/ outline
rotational speed.	understanding, Rolling Things	
	video demonstrations	
Describe the motion of a projectile (velocity and	In-class and online notes and	Hang-Time practicum*, Pool Diving
position).	demonstration, drop vs. roll	demonstration, critical eve on
	practicum, Range vs. Angle lab,	Olympic Events, Physics of a Sneeze
	ball toss experiment, projectile	discussion, vlog-notes w/ outline,
	motion video clips and online	Baseball Diamond practicum,
Evenlain when a stalliton "fall"	Galileo Galilei experiments in-	Imagine Yourself as Galileo thought-
Explain why salellies Juli .	class and online notes and	lab, "An Arm and a Leg" pendulum
	discussions, Interactive Physics	lab, vlog-notes w/ outline, Drop vs.
	build-your-own-universe practicum	Roll practicum
Explain how linear speed varies on a rotating	discussions mass distribution	hallering demonstration Hula Hoop
object.	simulation, hoops vs. disks	practicum, Being a Drum Major
	demonstration	demonstration, Bicycle practicum,
		vlog-notes w/ outline, Tension in
	Galileo Galilei experiments Tree	Prior student's sky dive video
Define mass, weight, volume, jorce, mechanical	of Force Types students-as-	critical eye on Olympic Events,
equilibrium, and terminal speed.	teachers, in-class and online notes	Categorizing Force Types sorting
	and discussions, Free Body	practicum, Balloon-lift experiment,
	thought-lab Interactive Physics	displacement vlog-notes w/ outline
	simulations, prior student's sky	displacement, rieg notes in outline
	dive video	
List and identify units of measure for	"World's Roundest Object" online	Vlog-notes w/ outline
mass, weight, volume, and force.	discussions. Interactive Physics	
	simulations, vocabulary worksheet	
State and apply Newton's Laws.	In-class and online notes and	Tug of War (sneakers vs. socks)
	discussions, personal force	practicum*, Running and Momentum practicum* Changing
	Stick demonstration, Ping Pong	Direction while Running practicum*,
	Peace Pipe demonstration, Twist	Dragging Students practicum*, seat
	and Shout DC Motor	belt and air bag safety (internal
	demonstration, frictional forces lab, Discovering Newton's 2 nd I aw lab	bleeding) inquiry, Egg-on-Your- Face experiment Pressure on Your
	Hooke's Law lab, "Newton Stole	Feet lab, Moving a Dresser friction
	the Limelight" poem, "When Push	lab, Ping Pong Peace Pipe and lung
	Comes to Shove" poem, video clips	capacity whole-class comparison,
	on Inertia and friction, PhET Forces online lab seat belt and air	"When Push Comes to Shove"
	bag safety materials, Impulse and	poem, "Fresh Prince of Preshair"
	Momentum English-language	poem, "An Impulsive World" poem,
	usages, conservation of momentum	Push Up and Deep Knee Bend lab,
	notes, online demonstrations, and worked examples Egg-on-Your-	on a scale practicum. Stretching
	Face experiment, "An Impulsive	Regimen for Sonographers (and
	World" poem, pressure from feet	others!), rooftop friction
	topic	demonstration, shopping cart inertia
Calculate weight from mass and mass from	In-class and online notes and	Bathroom scales (American vs.
Calculate weight from mass and mass from	discussions, Interactive Physics	European) practicum, previous lab
weight.	simulations, previous lab work	work, integrated into calculations for
Define work energy power potential	Brainstorming, word bank	Rubber Bands as Muscles modeling
Define work, energy, power, potential	construction, online and in-class	brainstorming, basketball energy
energy, kinetic energy, and efficiency.	notes and examples, Interactive	

	Physics simulations, basketball energy transformation demo, Energy Song video, bowling ball video, supporting images, discussion board participation	transformation demonstration, vlog- notes w/ outline
List and identify units of measure for work, energy, power, potential energy, kinetic energy, and efficiency.	Online and in-class notes and examples, brainstorming, notes on Carnot efficiency and general efficiency	Brainstorming, Human Body as a Space Heater discussion (save money on your heating bill – invite a friend!), efficiency of body functions inquiry, vlog-notes w/ outline
<i>Calculate the above quantities from their definitions.</i>	Online and in-class notes and examples, check for understanding through small group application, Interactive Physics simulations, hydraulic jack online practicum	Muscle forces/mechanical-advantage calculations*, Jacking up a Car practicum, Stair Climbing calculations, Killen's Pond State Park exercise path analysis
State and apply the principle of conservation of energy.	"Total Energy is Boring" discussion, Drinking Bird apparatus practicum, Stirling Engine demo, can of air practicum, pendulum lab, spring 3-energy transformation lab, bow and arrow lab, calorimetry virtual lab, "Energy is Boring" poem, webquest, roller coaster exercises, online notes and worked examples, practice problems	Diet and exercise lab manual setup*, webquest, Drinking Bird vs. Sweating practicum, Warm vs. Cool breath demonstration with can of air demonstration, Counting Calories lab, Using a Bow and Arrow lab, "Energy is Boring" poem, Fact or Fiction: "Use all of your Muscles to Burn Fat?" discussion, Weight Loss Goal thought-lab and calculations, vlog-notes w/ outline
↑ FORMAL ASSESSMENTS:	Multiple-choice lab quiz, exam essay and calculations; lab manual representation	Exam essay representation, WebAssign [®] -ments; Journal entries
Analyze the atomic nature of matter.	Reading assignments and basic problem sets (not listed); Lab quiz results are reviewed at the start of each new class.	Reading assignments and basic problem sets (not listed), periodic instructional "vlog" notes with accompanying outlines; word bank co-construction, discussion boards
Define atom, molecule, compound mixture, chemical reaction.	"Energy of Earth" video, detailed animations, online notes and story- telling	"Energy of Earth" video, detailed animations and story-telling, Acting- Out: Atoms activity
<i>List and identify common examples of atoms, molecules, compounds, and mixtures.</i>	Online notes and story-telling	Fluoride treatments animation, digestion discussion, biochemistry of muscle contractions*, science of knuckle cracking inquiry, nitrogen poisoning and diving discussion
Describe the microscopic character of liquids, solids, and gases.	"World's Roundest Object" online video, thermal imaging camera use, random motion simulation, online notes and story-telling, density lab, equilibrium temperature lab	Thermal Imaging Camera use, random motion simulation, Human Sense of Hot vs. Cold water equilibrium lab, "Is a Coat/Blanket Warm" experiment, Methods of Heating from the Human Experience discussion, breath pressure testing (volume, composition, Kinetic Energy, and Temperature of air in respiration), vlog-notes w/ outline, Can a Gas Apply A Force? (breath capacity marble w/ straw challenge)
Describe the basic structure of an atom.	Online notes and story-telling	Story-telling, modeling atomic structure using students, vlog-notes w/ outline
↑ FORMAL ASSESSMENTS:	Multiple-choice lab quiz, exam essay and calculations; lab manual representation	Exam essay representation, WebAssign®-ments; Journal entries
Integrate and differentiate the basic principles of the wayes and sound	Reading assignments and basic problem sets (not listed);	Reading assignments and basic problem sets (not listed), periodic instructional "vlog" notes with

	Lab quiz results are reviewed at the start of each new class.	accompanying outlines; ongoing word bank co-construction and discussion board participation
Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave, sonic boom, standing wave, node and antinode.	In-class notes and discussion, Doppler running down hallway practicum, video clips and simulations on wave behavior, slinky practicum, ray diagramming, Interactive Physics simulations, PhET Wave on a String online lab, checks for understanding, Tacoma Narrows Bridge disaster	Doppler running down hallway practicum, Chattering Teeth inquiry, Modes of Transportation calculations, Ray Diagramming and the Human Eye, vlog-notes w/ outline, Acting Out: Waves activity
Explain how frequency, period, wavelength, and wavespeed are interrelated.	In-class notes and discussion, video clips and simulations on wave behavior, Interactive Physics simulations, group examples, support videos and practice problems	Your Beating Heart lab, fundamentals of sonography examples, vlog-notes w/ outline
<i>List and identify units of measure for frequency, period, wavelength, and wavespeed.</i>	In-class notes and discussion	"UV – It Hertz" discussion, vlog- notes w/ outline
<i>Explain the difference between longitudinal and transverse waves.</i>	In-class notes and discussion, video clips and simulations on wave behavior, slinky practicum, Interactive Physics simulations	Fun in the Kiddie Pool experiments, slinky standing waves manipulatives, vlog-notes w/ outline, do you really "See" in ultrasound?
Define infrasonic, ultrasonic, compression, rarefaction, natural frequency, forced vibration, and resonance.	Simulations on wave behavior, speed of sound practicum, Fast Fourier Transform demos on voices and touch tone phones, slinky practicum, standing waves demos, discussions, and checks for understanding, water tube lab	FFT Your Voice practicum, Bottle of Coke water tube lab, Between Brick Buildings echo experiment, making sound with your cheeks and other body parts! discussion and practicum, vlog-notes w/ outline
Explain how the above terms relate to sound waves and their production.	In-class notes and discussion, slinky practicum, Interactive Physics simulations, beat frequency lab, NOAA.gov speed of sound calculator, lightning vs. thunder consideration, "O FFT!" poem, musically inclined brass acoustics online resource, SONAR use discussion	"O FFT!" poem, Discordant Choir Beat Frequency lab, Lightning: See it / Heat it calculation, Physics of Music and the Human Voice analyses and demonstrations, Building Clap-Echo experiment
<i>Identify the typical frequency range of human hearing.</i>	Speaker interference pattern lab	Conduct basic hearing test – students record and analyze class ranges, Best Place to Sit in the Theatre interference pattern lab
↑ FORMAL ASSESSMENTS:	Multiple-choice lab quiz, exam essay and calculations; lab manual representation	Exam essay representation, WebAssign®-ments; Journal entries
Analyze the basic principles of static electricity and current electricity.	Reading assignments and basic problem sets (not listed); Lab quiz results are reviewed at the start of each new class.	Reading assignments and basic problem sets (not listed), periodic instructional "vlog" notes with accompanying outlines; ongoing word bank co-construction and discussion board participation
Define charge, conductor, semiconductor, insulator, superconductor, electric field, electric potential energy, voltage.	Online scavenger hunt, Van de Graff online video clips, online simulations	Vlog-notes w/ outline

<i>List and identify the units of measure for charge, electric field, electric potential energy, and voltage.</i>	In-class notes and examples, vocabulary practice, 2D and 3D views of Electric and Magnetic fields, mini electromagnet creation	Electric Fields: Human hairs under the influence, vlog-notes w/ outline
State and apply Coulomb's Law.	In-class notes and examples, charge-by-induction experiments, E&M worksheet, online simulations	Storytelling, vlog-notes w/ outline, integrated into methods of charging content
<i>State and apply the principle of charge conservation.</i>	In-class notes and examples, online simulations, online Physlets, past student's work on residential application	Past student's work on residential application, vlog-notes w/ outline, Acting Out: Charges activity
<i>List and describe three methods for charging objects.</i>	Online notes and story-telling, demonstrations on charging and charge generation, online simulations	Methods of Charging from the Human Experience, vlog-notes w/ outline
List and identify common conductors and insulators.	Integrated into demonstrations, E&M worksheet, online simulations	Changing Body Resistances practicum, vlog-notes w/ outline
<i>Explain the relationship among electric potential energy, charge, and voltage.</i>	Battery discussion, online scavenger hunt, online simulations, Electricity and Magnetism online demonstrations	Marbles as Charges lab, Teacher on a Ladder Voltage-Level demonstration, Batteries/Circuits vs. Going down Niagara Falls in a Barrel, vlog-notes w/ outline
<i>Define current, alternating current (AC), direct current (DC) and resistance</i>	In-class notes, manipulatives (electronic components, online scavenger hunt, online Physlets, graphical analysis	"Clear!" heart inquiry, generating AC and DC by hand practicum, vlog-notes w/ outline
<i>List and identify the units of measure for current and resistance.</i>	In-class notes, vocabulary practice	Vlog-notes w/ outline
State and apply Ohm's Law.	In-class notes and examples, check for understanding, Circuits lab, online simulations, online Physlets	Humans synthesizing photosynthesis (solar panels) and Ohm's Law lab, vlog-notes w/ outline
Explain the dangers of current electricity.	"Why Hire Electricians" and student experiences discussion, "Simply Shocking" poem	"Simply Shocking" poem, "Why Hire Electricians" and student experiences discussion
Distinguish between parallel and series circuits.	Waterfall and breathing-through-a- straw illustrations, in-class notes on circuits with examples, online simulations, online Physlets	Breathing through a straw practicum, analysis of the human nervous system, vlog-notes w/ outline
<i>Calculate the power consumed by an electrical circuit.</i>	Online Physlets, worked examples, past student's work on residential application	Humans as power generators and power consumers, past student's work on residential application, vlog-notes w/ outline
↑ FORMAL ASSESSMENTS:	Multiple-choice lab quiz, exam essay and calculations; lab manual representation	Exam essay representation, WebAssign [®] -ments; Journal entries
Integrate laboratory and didactic principles and experiences with emphasis on speed, forces, rotational motion, periodic motion, work and power, sound and circuits.	Integrated into other MPOs	Integrated into other MPOs, Introduction to lab equipment and methods (first week)
Investigate and explain linear motion in the laboratory.	Integrated into other MPOs	Integrated into other MPOs, Introduction to lab equipment and methods (first week)
Investigate and explain uniform and non-	Integrated into other MPOs	Integrated into other MPOs, Introduction to lab equipment and

Investigate and explain the properties of	Integrated into other MPOs	<i>Integrated into other MPOs</i> , Introduction to lab equipment and
periodic motion in the laboratory.	Integrated into other MPOs	methods (first week)
Investigate and explain work and power in the	integrated and only in os	Introduction to lab equipment and
laboratory.		methods (first week)
Investigate and explain the properties of heat	Integrated into other MPOs	Integrated into other MPOs, Introduction to lab equipment and
in the laboratory.		methods (first week)
Investigate and explain the properties of	Integrated into other MPOs	Integrated into other MPOs,
electricity in the laboratory.		Introduction to lab equipment and methods (first week)
↑ FORMAL ASSESSMENTS:	Multiple-choice lab quizzes; lab	Exam essay representation,
	manual representation	WebAssign [®] -ments; Journal
		entries
Additional Syllabi Themes from Scope and Sequence not directly represented in the CCPOs/MPOs	See notes, below:	
Weather & Water	"Energy of Earth" video,	Wind in your Hair? & Riding the
	convection examples, renewable energy tie-ins, seasons topic	Currents discussions, Why Seasons? demonstration cooking rice vs. Air
	energy the ms, seasons topic	Conditioning? discussion
Solar System (Astronomy Connections)	Gravity Simulator lab, Universal	"Lunacy" poem, Universal
	creation Solar vs. Lunar eclipses	calculate our weight Star Gazers
	and predicting next eclipse activity,	history of human interaction and
	Planetary Motion History notes and	exploration of "the sky," effect of
	practice problems. Earth-Moon	microgravity on numans, dead star material discussion "A Day at the
	attraction, class check for	Beach" (Solar and Lunar tidal
	inaccuracies in common classroom	effects; E-M spectrum and the
	solar system posters, librations	science behind sun-block—"not all sun-blocks are created equal"
	participation, dead star material,	discussion), vlog-notes w/ outline,
	observable universe, seismic waves	Acting Out: Earth-Moon orbit
	& epicenters, and moon and earth	activity, Universal Gravitation
	and Solar System Evolution	gravitational attractive are you?
	discussions, video clips, and peer	-
	Interviews, "Lunacy" poem	"Continental Drift" noem webquest
Plate Tectonics (Earth Science Connections)	and discussion, plate boundaries	Our World: GoogleMaps quest,
	graphics, University of Bristol	"Does the Earth have a Rear End?"
	earth science overview of concepts,	inquiry, Magnetic Declination lab,
	"Continental Drift" poem,	Tectonic Titans activity
	discussion board participation,	
	Coke vs. Lava video experiment,	Included in Electricity material
Electricity & Magnetism	Earth Science connections	Astronomy, and Earth Science
		connections
Simple Machines (mechanical advantage)	Included in Work & Energy	Included in Work & Energy and
+ FORMAL ACCECCMENTS.	Multiple-choice lab quiz, exam	Exam essay representation.
FUNVIAL ASSESSIVIEN 15:	essay and calculations; lab	WebAssign®-ments: Journal
	manual representation	entries

Appendix H

ADDITIONAL DATA

EDUCATION RESPONDENTS

Difficulties w/ Conceptual Physics (Education) Categories and Frequency (n=5)

CATEGORY	Frequency (%)
Lack understanding of how the course applies [to their program]	1 (20%)
None reported	4 (80%)
Concepts Applied in Other Classwork (Education) Categories and Frequency (n=5)	
CATEGORY	Frequency (%)
None or Not Relevant	3 (60%)
Elementary Education connections	1 (20%)
Certification Exam preparation	1 (20%)
Mathematics connections	1 (20%)
Desired Changes in Conceptual Physics (Education) Categories and Frequency $(n=5)$	
CATEGORY	Frequency (%)
Offering a course section aimed specifically at Education majors	1 (20%)

None or Not Relevant

4 (80%)
EDUCATIONAL TECHNOLOGY (CCIT) RESPONDENTS

Tast Experience w/ Design of Distance-Learning course categories	and frequency (II=3)
CATEGORY	Frequency (%)
Specific distance learning course design experience	1 (33%)
None Reported	2 (66%)
Awareness of Research on Best Practices in STEM/Physics Categori	es and Frequency (n=3)
CATEGORY	Frequency (%)
Not aware of existing research in this area	3 (100%)

Past Experience w/ Design of Distance-Learning Course Categories and Frequency (n=3)

SELF-ASSESSMENT SCORING FOR UNIT MATERIALS PRE-REVIEWER DISTRIBUTION

		ESS	DN C				LESS	SON 0	2									LES	SON	03							LE	SON	04					LES	SON	05			LES	SON	J6	LES	SON	07				
RUBRIC: 0 = No evidence supporting this here 1 = Some evidence supporting this 2 = Strong evidence supporting this UNII: Waves & Periodicity, Concept	nistic in the activity euristic in the activity heuristic in the activity ptual Physics	Log Notes	/ord Banking	vora banking What is a Wave" thought otivitu	What is a Vave" xperimentation	wave Pulse Superposition heckup	ast router transform demo Do the Wave" activity	Biggest Hands, Smallest lands" activity	l he Human Usoilloscope ctivitu	Leg and Arm Pendula heckup Bart Hate Measurements	ativitu D FFT1" Poem	leading Assignment	is a Blanket Warm" tie−in	frared/Ultrasound Discussion	iscussion volted skin particles simulation	-M speatrum student line-up	liscovering the Loppler Effect ativity	Chattering Leeth" discussion	Your Beating Heart	Bottles of Loke" emonstration	losed-End Reflection Checkup Standing Wave Pattern" line-	p activity Beats: The Musical Fruit" orivity	lay Diagramming activity	heckup xit Ticket	Log Notes (Summary)	lip	Isoussion Doard group activity leading Assignment -	lodes of Transportation activity	fisual Impairment activity Create-your-Eye" Homework	ab hactice Problems w/ solutions	/ord Banking xit Tickets - Heview of	kubmissions Vord Banking	Create-your-Eye" LASEH	Light" thinking group activity learing Test demonstration	Best place in Theatre" activity	Nodes & Antinodes" checkup	otivity otivity Heally see ultrasound?	isoussion At Ticket	sit lickets - Heview of Abmissions	Lahoot Quiz	Intra reacting Freese water to	lusical Applications - web suboration	ournal Reflection	xa m Prep praotice /ebÅssign	EURISTIC TOTALS	EURISTICAVERAGE		ELATIVE RANK (1=highest)
Design Principle	Principle Descriptor	2	2 2	> 1 4	at of			F 4	9	- 04	90	ш	F	100	ЧШ	ш			1.4	91.0	υr	3 1	u p			- q เ	ч µ с	2	2 -	3 11	μ	01 >	- 2					90	μи	X 2	÷	12 q	7 4	2	Ŧ	Ŧ		<u>~</u>
1: Content is directly related to students' real life experience.	Unit materials and activities explicitly involve events and/or objects which are encountered by humans independent of socioeconomic or cultural considerations.	2	1	1 2	2	0	1 0	2	2	0	2 0	0	2	1	2 2	0	2	2 2	2 2	2	0	0 0	1	0 0	2	2	2 0	1	2 2	2 0	1	0 1	2	2 2	2 2	0	2 0	0 0	0	0 0) 1	2	1	0 0	60	1.0)5	4
2: Students co-construct meaning	Unit materials and activities provide opportunities for students to work together in small group and/or whole class	0	2 2	2 2	2	0	1 2	2	2	0	1 0	0	0	2	2 1	2	1	2 1	. 1	1	0 2	2 1	2	0 0	0	0	2 0	0	0 0	0	2	2 2	0	2 2	2 2	0	1 2	2 0	0	1 2	2 2	0	0 (0 0	54	0.9	95	8
language and peer engagement.	Unit materials and activities allow students to build and revise a shared record of concepts and terminology.	0	2 2	2 1	1	0	0 1	1	1	0	1 1	0	2	2	2 1	2	1	2 1	. 1	1	0 1	l 1	2	0 0	0	0	2 0	1	0	0	2	1 2	0	2 1	L 1	0	12	2 0	1	1 2	2 2	1	0	0 0	52	0.9	91	10
 Terminology is foundationally introduced with an Energy-first approach which is continued throughout 	Energy concepts and vocabulary are used throughout the course materials to support the activities and inform materials.	0	2 2	2 2	2	0	1 1	0	1	0	2	1	2	2	2 2	2	0	0 2	2 2	2	0 2	2 0	0	0 0	1	0	1 1	1	0	0	2	2 2	0	2 0	0 0	0	1 (o c	0	1 (2 כ	1	0	1 1	49	0.8	36	12
	Unit materials and activities provide opportunities for students to engage in higher-order thinking.	1	2 2	2 2	2	2	2 1	2	1	2	1	0	2	0	2 1	2	1	1 1	. 1	1	2 1	1 2	1	2 0	0	1	2 0	1	2 2	2 0	2	2 0	2	2 1	L 1	2	2 2	2 0	0	2 2	2 2	1	2 (0 0	73	1.2	28	1
 Students are actively engaged with the content cognitively, socially, and physically. 	Unit materials and activities have students engage the content in ways that require the input of others and/or encourage empathy.	0	2 2	2 2	2	0	2 2	1	2	0	2 0	0	0	2	2 1	1	2	0 0	0	0	0	2 2	1	0 0	0	0	2 0	0	1 1	L O	2	2 2	1	2 2	2 2	0	2 2	2 0	0	1	2 2	2	0	0 0	56	0.9	8	7
	The activities incorporate students' bodies as sources of data and as laboratory objects/movers.	0	0	0 1	2	0	2 2	2	2	0	2 0	0	1	1	0 0	2	2	0 0) 1	1	0	2 2	2	0 0	0	0	2 0	0	1 1	0	0	0 0	1	2 2	2 2	0	2	<mark>) 0</mark>	0	0	1 0	1	0	0 0	42	0.7	74	13
	Concepts are introduced in small chunks as opposed to being lumped together and front-loaded.	1	1 1	1 2	2	1	2 2	1	1	1	1 0	0	2	2	1 1	1	1	1 1	. 1	1	11	1 2	2	1 0	1	1	2 0	2	1 1	1	1	0 1	1	2 2	2 1	1	11	1 0	0	0	1	1	1 (0 0	59	1.0)4	5
5: Concepts are scaffolded by being introduced as class inquiry demands.	Unit materials and activities build on previous activities.	0	1 1	1 2	2	1	2 2	1	1	1	1 1	1	2	1	1 1	1	0	1 1	. 1	1	1 2	2 2	2	1 0	1	1	2 1	2	1 1	1	1	0 1	1	2 2	2 1	1	11	1 0	0	1	1	1	1	1 1	63	1.1	1	2
	Opportunities are given explicitly as part of the unit materials and activities for students to ask questions and formulate ideas in an online or in-class setting.	0	1	1 2	2	2	2 2	1	1	2	1	0	2	2	1	1	1	1	1	1	2	1 2	2	2 1	0	0	2 0	2	0	0	1	1 1	1	2 2	2 1	2	1	1 1	1	0 1	1	0	1	0 0	61	1.0)7	3
 Concepts are introduced contextually using a unifying, relevant theme. 	Unit materials and activities are built on the theme of connections to the human body.	2	0	2	2	0	2 2	2	2	2	2 1	0	2	1	2 2	2	2	2 2	2 2	2	0 2	2 0	0	0 0	2	0	1 1	0	2 2	2 0	0	0 0	2	0 2	2 2	0	1 1	1 0	0	1	0 (0	0	0 0	57	1.0	00	6
 Biological applications are explored in conjunction with physics content. 	Biology and biophysics content is explicitly a part of the unit materials and activities.	2	0	2	2	0	2 1	2	2	2	2 0	0	2	1	2 2	0	0	2 2	2 2	0	01	L 0	0	0 0	2	0	2 1	0	2 2	2 0	0	0 0	2	0 2	2 1	0	2 2	2 0	0	1	0 (0	0	0 0	50	0.8	38	11
 Course adheres to high standards of content delivery and design. 	DO NOT EVALUATE	X	X	K X	X	X	K X	X	Х	X	< X	X	Х	X	ХХ	X	X	ХХ	(X	X	X	< X	X	ХХ	X	X	x x	X	x	X	X	ΧХ	Х	ХХ	< X	Х	X	x x	X	X)	< X	. X	X)	x x	0		‡	ŧN∕A
9: Course embeds opportunities to explore and practice career-relevant	Unit materials and activities incorporate career-relevant skills and applications for Education majors.	0	0	01	1	0) 1	1	1	1	D	0	0	0	1 1	0	0	1 1	. 0	1	0	L 0	1	0 0	1	1	1 1	0	0	0	0	0 0	1	10) 1	0	2	סכ	0	1	2 0	0	2	1 1	29	0.5	51	15
skills for sonography and/or education majors.	Unit materials and activities incorporate career-relevant skills and applications for Sonography majors.	0	0	0 0	0	0	1 0	1	1	0	2 0	0	0	2	1 0	0	1	0 0) 1	0	01	10	1	0 0	1	0	1 1	1	1 1	1	0	0 0	1	1 1	1	0	12	2 0	0	12	2 0	1	2	1 1	34	0.6	50	14
 Applications beyond the unifying theme enrich the learning experience. 	Content includes references and activities that are not explicitly related to the theme of connections to the human	2	1 1	1 2	2	1	1 0	0	0	0	2 2	2	0	1	0 0	1	1	0 0	0	2	1 1	1 2	2	1 0	1	2	2 1	2	0	2	1	0 1	0	2 0	2	1	0	0 כ	0	1	1	2	1	2 2	53	0.9	93	9
ACTIVITY TOTAL SCORE	[activity relative strengths in overall hueristic]	10	15 1	5 25	26	7 2	1 19	19	20	11 :	8 7	4	19	20	21 16	17	15 1	15 15	5 16	16	7 2	0 16	19	7 1	12	8 2	6 7	13	13 1	3 5	15	2 15	15	24 2	1 20	7	20 1	16 1	2	12 1	7 15	13	11 (6 6				

Appendix I

FULL UNIT MATERIALS

This appendix houses a full record of the online unit materials. Where digital materials cannot be reproduced in this format, they are referenced as fully as possible. In many cases the materials have been condensed to suit this format. The borders were kept rough in the web-based images to remind the viewer of the online origins and navigation. These are all available at http://www.mrlafazia.com/PHY111/.



Conceptual Physics
Waves and Periodicity Unit
Return to Learning Materials View
es and Periodicity Unit
Lesson 01
Lesson Time (h:m) Topic(s) MPOs Activities, Materials; Resources [SOURCE, DP#]* Assignments & Assessments ONLINE Thinking about Waves Transition out of the previous unit (not reflected in unit or lesson outlines/plans) Assignments & Assessments
Unit Word Bank Opens Vlog Notes: Seeding initial thoughts on waves [closed-captioned] "Fun in the Kiddie Pool", "Echoes Between Buildings," "Musical Body Parts" experiments/demos [DP#'s 1, 6, 7, 8, 10] Word Bank Opens Word Bank Opens Vlog Notes: Seeding initial thoughts on waves [closed-captioned] "Fun in the Kiddie Pool", "Echoes Between Buildings," "Musical Body Parts" experiments/demos [DP#'s 1, 6, 7, 8, 10] Word Bank Opens Word Bank Opens Vlog Notes: Seeding initial thoughts on waves [closed-captioned] "Fun in the Kiddie Pool", "Echoes Between Buildings," "Musical Body Parts" experiments/demos [DP#'s 1, 6, 7, 8, 10]
Conceptual Physics Waves and Periodicity Unit
Return to Unit View
son 01
Watch this vLog introduction to Waves & Periodicity! This is an introductory video aimed at exposing you to some common wave and periodic motion applications. An emphasis is placed on the human experience while connections are also made to other phenomena. Many of the topics are left open-ended for you to reflect on prior to formally seeing this in class. Among these are "Treadmill Periodicity," "The Physics Playground," and other scenarios. Closed-captioning is provided, and there are quiz questions embedded into the video as you go. When you access the video, sign-in under your first name and last initial.

VIDEO FILE: http://zapt.io/txnkh4vb



Word Bank Orientation

- · Open up the Word Bank link. The password to this Padlet is: phy111-waves1
- · Read the description at the top and the two small text boxes which I have placed there.
- Experiment with adding a weblink, photo, or other attachment to the Word Bank. We can prune these as needed when we first open this file in class!
- If you feel you need a tutorial on the use of Padlet, please visit this link: Click here for a tutorial!
- We will begin adding physics content to this next class, but if you have ideas which you gleaned from the introductory vLog or from other pre-class sources, feel free to begin populating the page! Again, we can make edits as we go.

Proceed to Lesson02

Return to Unit View

Would you like to review the actual lesson plans? They are included, below: <u>Unit Plan | Lesson01 | Lesson02 | Lesson03 | Lesson04 | Lesson05 | Lesson06 | Lesson07</u> <u>Unit Template | Lesson Template</u>

WORD BANK URL: <u>http://padlet.com/dlafazia/waves1</u>

TUTORIAL URL: https://www.youtube.com/watch?v=bVLtOYQtbdo

Wave Characteristics Wave Examples Pendulum Motion FFT		<u>Word Banking</u> : Review and Revision of Word Bank [DP#'s 2, 3, 4, 8] <u>Activity</u> : "What is a Wave" thinking group activity; life without waves [adopted from a Physics Respondent, DP#'s 1, 2, 3, 4, 5, 6, 7, 10] <u>Activity</u> : "What is a Wave" spring, tuning forks, and human voice experiments [adopted from a Physics Respondent, DP#'s 1, 2, 3, 4, 5, 6, 7, 10] <u>Demonstration</u> : Fast Fourier Transform (mapping out the human voice, &tc.), vocal flaps/cords [inspired by Ostdiek & Bord 2013, p. 230. DPE's 4, 5, 6.	Reading Assignment Sections on basic wave characteristics <u>Check for</u> <u>Understanding</u> : Wav Pulse Superposition [based on Stepans, 1996, p. 173]
Wave Examples Pendulum Motion FFT		Activity: "What is a Wave" thinking group activity; life without waves [adopted from a Physics Respondent, DP#'s 1, 2, 3, 4, 5, 6, 7, 10] <u>Activity</u> : "What is a Wave" spring, tuning forks, and human voice experiments [adopted from a Physics Respondent, DP#'s 1, 2, 3, 4, 5, 6, 7, 10] <u>Demonstration</u> : Fast Fourier Transform (mapping out the human voice, &t.), vocal flaps/cords [inspired by Ostdiek & Read 2012, n, 230. DBF's 4, 5, 6, 7]	wave characteristics <u>Check for</u> <u>Understanding</u> : Wav Pulse Superposition [based on Stepans, 1996, p. 173]
Pendulum Motion		1, 2, 3, 4, 5, 6, 7, 10] <u>Activity</u> : "What is a Wave" spring, tuning forks, and human voice experiments [adopted from a Physics Respondent, DP#'s 1, 2, 3, 4, 5, 6, 7, 10] <u>Demonstration</u> : Fast Fourier Transform (mapping out the human voice, &tc.), vocal flaps/cords [inspired by Ostdiek & Bord 2013, p. 230. DPB's 4, 5, 6, 7]	Check for Understanding: Wav Pulse Superposition [based on Stepans, 1996, p. 173]
Pendulum Motion		Activity: "What is a Wave" spring, tuning forks, and human voice experiments (adopted from a Physics Respondent, DP#'s 1, 2, 3, 4, 5, 6, 7, 10] <u>Demonstration</u> : Fast Fourier Transform (mapping out the human voice, &tc.), vocal flaps/cords [inspired by Ostdiek & Bord 2013 p. 230. DB#'s 4, 5, 6, 7]	Understanding: Wav Pulse Superposition [based on Stepans, 1996, p. 173]
FFT		voice experiments (adopted from a Physics Respondent, DP#'s 1, 2, 3, 4, 5, 6, 7, 10) <u>Demonstration</u> : Fast Fourier Transform (mapping out the human voice, Etc.), vocal flaps/cords [inspired by Ostdiek & Read 2013 p. 230. DB#'s 4, 5, 6, 7]	Pulse Superposition [based on Stepans, 1996, p. 173]
FFT		DP#'s 1, 2, 3, 4, 5, 6, 7, 10] <u>Demonstration</u> : Fast Fourier Transform (mapping out the human voice, &tc.), vocal flaps/cords [inspired by Ostdiek & Bord 2013 p. 230. DB#'s 4, 5, 6, 7]	[based on Stepans, 1996, p. 173]
		human voice, &tc.), vocal flaps/cords [inspired by Ostdiek & Bord 2013 p. 239, DBE' 4 5 6 7]	1990, p. 173)
		Bord 2013 p 229 DB#'s 4 5 6 71	
		DUIU, 2013, U. 233, UF# 34, 3, 0, 7]	Check for
1	4.1, 4.4,	Activity: "Do the Wave" - waveform modeling student line-	Understanding: Leg
	4.5, 4.6,	up (acting out transverse and longitudinal waves, and free-	and Arm Pendula
	5.8, 6.3	and fixed-end reflections) [adapted from Pantidos & Patapis,	[inspired by Blanksby
		2005, p. 344, DP#'s 2, 4, 5, 6]	et al, 1981, p. 79]
		Activity: "Biggest Hands, Smallest Hands" period, amplitude, and frequency assessment (hand holding pencil wave form creation) [inspired by a Sonography Respondent, DP#'s 1, 2, 4, 6, 7] <u>Activity</u> : "The Human Oscilloscope" [adapted from Pfister & Laws, 1995, p. 219, DP#'s 1, 2, 4, 6, 7] <u>Activity</u> : Heart Rate measurements (class graphing and waveform equivalent) [adapted from Schwartz, 1997, p. 126,	WebAssign and Exan representation
		5.8, 6.3	 5.8, 6.3 and fixed-end reflections) [adapted from Pantidos & Patapis, 2005, p. 344, DP#'s 2, 4, 5, 6] <u>Activity</u>: "Biggest Hands, Smallest Hands" period, amplitude, and frequency assessment (hand holding pencil wave form creation) [inspired by a Sonography Respondent, DP#'s 1, 2, 4, 6, 7] <u>Activity</u>: "The Human Oscilloscope" [adapted from Pfister & Laws, 1995, p. 219, DP#'s 1, 2, 4, 6, 7] <u>Activity</u>: Heart Rate measurements (class graphing and waveform equivalent) [adapted from Schwartz, 1997, p. 126, DP#'s 1, 4, 6, 7, 9] Ponem: "O EFTI" noem recitation [DP#'s 3, 10]

Conceptual Physics

Waves and Periodicity Unit

Return to Unit View

Return to Lesson01

Lesson 02



Word Banking

At the start of class, we will review the Word Banking <u>process</u> and <u>expectations</u>. We will also decide on an overall format for organization of ideas, definitions, and resources.

WORD BANKING URL: http://padlet.com/dlafazia/waves1



What is a Wave? - Thinking Activity

In small groups, complete this thinking activity where you will consider the nature of waves and their relationship to our own lives.

- 1: In your group's opinion, what is a wave?
- 2: What does a wave do? In other words, does it transport something, or does it serve a purpose?

3: Where can you find waves (give a number of locations)? What is necessary for a wave to exist, can a wave exist in a vacuum (space)?

4: Are there different types of waves? If so, what are some of the different types? If not, what are the characteristics of the one type of wave you believe exists?

5: How do you describe waves? In other words, what distinguishes one wave from another? Do waves have characteristics? Can they be described in relation to our understanding of energy?

6: How do you think our lives would be different if there weren't any waves?



What is a Wave? - Exploration

You will now experiment with mechanical waves! Use this opportunity to review and revise your understandings built up from the previous activity. You will be using a long spring, tuning forks, and a microphone with data-logging capabilities.

Our objectives for this activity are to investigate waves in two different contexts in order to construct ideas about what waves are and what they do.

1: With the big spring, investigate and give your thoughts on the following (<u>remember to cite</u> <u>evidence</u>)

- What is a wave
- What does a wave do
- What affects the speed of a pulse on the spring
- Explain the role of the spring

2: Using the tuning forks and the microphone, give your thoughts and rationale on the following:

- To what is the microphone actually sensitive? In other words, what is it picking up? (Hint, don't answer sound)?
- Why do the different tuning forks produce different patterns, what's different about the pattern and what's different about the sound?
- Is there a way to change the size of the pattern vertically (on the Y-axis)? Explain how, and what is different about the sound.
- Sometimes, the pattern is a nice clean looking "sine" wave and sometimes it is jagged or messy. Explain why you think this happens.
- What kind of pattern do you observe when you play two or more tuning forks at the same time? Try random forks, then try two that are close to each other in frequency. Can you explain your observation?
- Do you think it would be easy to produce a clean looking "sine" wave with your voice? Explain why or why not.



Mapping out the Human Voice - Demonstration

Using the microphone and data-logger, we will run an FFT (Fast Fourier Transform) on the voice recordings of three or four people in the classroom. Select people with differing voice characteristics.

- Now discuss the similarities and differences between the FFT graphs.
- Review the following data and consider whether your conclusions are still supported: <u>Comparative FFTs</u>
- Consider now also this clip on <u>Video Stroboscopy of Vocal Cords</u> (discuss)



VIDEO CLIP URL: <u>https://www.youtube.com/watch?v=mJedwz_r2Pc</u>



Do the Wave - Physical Activity

Now it is your turn to act out these concepts!

In your previous explorations, you investigated the motion of a wave through a length of spring. Before we begin this activity, I will need two student volunteers to help me demonstrate the following:

Longitudinal waves (wave pulse and continuous wave)

Transverse waves (wave pulse and continuous wave)

Fixed-end reflection

Free-end reflection

Two single pulses adding together (change signs and amplitudes)

Now that we have reviewed these phenomena and understand how they are formed using a long spring, form a human chain.

The class will represent the long spring. Now as a group recreate each of the previous phenomena.

- 1. Which were the easiest to reproduce?
- 2. Which were the hardest, and why? Are your selections at all related to our Energy concepts?
- **3.** In terms of stiffness and density, how is the human chain different from or similar to the spring?
- 4. Can stiffness and/or density be adjusted in the human chain? How? In the long spring? How?



Group yourself with at least two other students, preferably ones whose hand characteristics (length, width, wrist circumference, &tc.) differ from your own.

Your task is to take a piece of chalk or dry-erase marker and drag it from one side of your lab desk to the other. Each person should use a different color. As you drag the writing utensil and walk along the length of the desk, pivot your wrist all the way up and down once per second (such that after "one Mississippi" passes, your hand would be at its original position). This is illustrated, below:



The exact timing is not important, so long as it is kept consistent within a group. Continue until you have multiple "wave forms."

Was there a difference between how each continuous wave looked between your partners? Who in your group expended the most energy in this process? Justify your decision and support with measurements as needed.

Is there any relationship between one of the many characteristics of a person's hand and one of the wave parameters (e.g., frequency, amplitude, wavelength)? If so, describe this in words and make an attempt to describe it mathematically.

Were there other factors that you believe influenced the results?

Compare your results with others in the class and share your findings: Did your understanding change?



The Human Oscilloscope - Activity

In this activity you will be creating continuous waves on a much larger scale using the white board (while atop a skate board or cart!).

Discuss as a class: What is an oscilloscope and how is it used?

Using the skateboard (or cart) provided, some classroom volunteers, and different-colored dry erase markers, the class must guide the volunteers on how to produce the following continuous wave forms (while riding the board/cart!) *Safety precautions should be taken during this activity*. Tasks:

Create a continuous wave of wavelength 30 cm and frequency 0.5 Hz

Create a continuous wave of wavelength 30 cm and frequency 2 Hz

Create a continuous wave of wavelength 30 cm, frequency 0.5 Hz, at twice the amplitude of the original wave

Of these three wave forms, which exhibits the greatest Energy? Justify your response. Questions:

How did your approach two completing the second task differ from the first? Did this change affect more than one wave parameter?

What can we call this difference (or these differences)?

Did doubling the amplitude have any effect on the other parameters? If so, how and why? Would this still hold true if the wave was produced by a sound source like a speaker?



Heart Rate Measurements

In this activity we will map out the resting and elevated heart rates of the class. You will graph out your own heart rate numbers as if your heart were producing a continuous wave form.

We will be looking at resting heart rate and also compare these to post-exercise rates. If a thermal imaging camera is available, compare before and after images of at least one volunteer (shoulders-and-up).

Create a basic STEM-and-LEAF Plot for heart rates of everyone in the classroom. Discuss the results.

Now each person (as able) should exercise to get their heart rate up (e.g., jumping jacks). Take the new heart rates and repeat: What has changed? If a thermal imaging camera is available, place the camera lens in contact with the chest wall and locate a volunteer's heart. Is there evidence of elevated work being by the heart on the body system? Support your reasoning. For your own numbers, graph out the equivalent wave form for both of your heart rates:





Check for Understanding

Kwadwo's leg is 120 cm long. George's leg is 70 cm long. Otherwise, the two students have comparable physical characteristics.

1) If they are both walking at the a rate of 3 m/s, what might you conclude about the frequency with which they move their legs?

2) Is it possible to have their frequencies be the same while still having them move at a rate of 3 m/s? If yes, what would need to change to accommodate this?

3) If their arms are similarly mismatched, how do their relaxed motions likely compare?





Reading Assignment

You are responsible for knowing the content in the following sections:

- 6.1: Waves Types and Properties
 6.2: Aspects of Wave Propagation
- 6.3: Sound
- 8.5: Electromagnetic Waves
- 9.1: Light Waves
- 9.2: Mirrors: Plane and Not So Simple
- 9.3: Refraction

Proceed to Lesson03

Return to Unit View

Would you like to review the actual lesson plans? They are included, below:

<u>Unit Plan | Lesson01 | Lesson02 | Lesson03 | Lesson04 | Lesson05 | Lesson06 | Lesson07</u> <u>Unit Template | Lesson Template</u>

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#]*	Assignments & Assessments
IN-CLASS Wave Applications Continued	1:30	E-M Radiation Units and Formulas Used to Quantify Wave Characteristics Doppler Effect Periodicity Standing Waves Beats Ray Diagramming	2.2, 2.3, 3.3, 4.1, 4.2, 4.3, 4.5, 4.6, 6.1, 6.3, 6.5	Recall: "Is a Blanket Warm"? Thermal camera inquiry activities with human body radiation (circulation, radiation, conduction, &tc.) from previous unit [adapted from Roseberry et al, 2010, p. 334, DP#'s 1, 2, 3, 4, 5, 6, 7] <u>Discussion</u> : "UV – It Hertz Your Skin" (period, frequency, wavelength; wavespeed – units and relationships for each) [inspired by Ostdiek & Bord, 2013, p. 315, DP#'s 1, 2, 3, 4, 5, 9] <u>Demonstration</u> : Excited Skin Particles simulation (spring model) [inspired by Edelman, 2012, p. 408, DP#'s 1, 3, 6, 7] <u>Activity</u> : E-M spectrum student line-up (acting out the E-M spectrum) [inspired by Pantidos & Patapis, 2005, p. 344, DP#'s 2, 3, 4, 6] <u>Activity</u> : Discovering the Doppler Effect – "Don't run with scissors; run with a tuning fork!" (run down hallway activity) [inspired by JRC-DMS, 2008, DP#'s 1, 4, 6] <u>Discussion</u> : Electric Toothbrush in action [DP#'s 1, 3, 6, 7] <u>Demonstration</u> : Electric Toothbrush in action [DP#'s 1, 3, 6, 7] <u>Demonstration</u> : "Your Beating Heart" (simulating ultrasound scan of carotid artery) [Lewis & Mohazzabi, 2014, DP#'s 1, 3, 6, 7] <u>Demonstration</u> : "Bottles of Coke" water music production and wave tube apparatus calculations [based on Stepans, 1996, p. 186, DP#'s 1, 3, 6, 10] <u>Activity</u> : Reats, Beats: The Musical Fruit" tuning fork hearing activity with spreadsheet support [DP#'s 4, 5, 10] <u>Activity</u> : Reats, Beats: The Musical Fruit" tuning fork hearing activity with spreadsheet support [DP#'s 4, 5, 10] <u>Activity</u> : Ray Diagramming (simulated spear fishing!) [inspired by Hewitt, 2008, p. 298, DP#'s 2, 4, 5, 10] <u>Activity</u> : Ray Diagramming (simulated spear fishing!) [inspired by Hewitt, 2008, p. 298, DP#'s 2, 4, 5, 10]	WebAssign and Exam representation <u>Check for</u> <u>Understanding</u> : Closed End Reflection standing wave patterns [based on Stepans, 1996, p. 174] <u>Check for</u> <u>Understanding</u> : Glass of Water with Arrow Images [adopted from AIA, 2016] Exit Ticket

Conceptual Physics

Waves and Periodicity Unit

Return to Unit View

Return to Lesson02

Lesson 03

Recall: "Is a Blanket Warm?"

Recall back in a previous unit where we explored the idea of whether or not a "blanket was warm."

- · What were our conclusions?
- · How did we use the thermal camera to explore radiation and conduction?
- · How did this tie into waves?

 - Consider what is meant by the "Electromagnetic Spectrum"
 Can you find a good graphic online to help explain this spectrum and how it relates to the thermal camera?



- · What effect, if any, does this have on the deeper layers?
- Does it matter if you disturb the outer layer more or less violently?
- · How does this relate to ultrasound imaging technology?



E-M Spectrum Line-up - Activity

Here you are going to work together to act-out the Electromagnetic Spectrum!

Recall the Electromagnetic spectrum graphic you found earlier in the lesson. As a group, line-up (all except one person with a video capture device) in a row. Your task is to recreate the E-M spectrum using your bodies to illustrate each major component.

Once you have figured out your "final solution" to this problem, act out the E-M spectrum while your camera-holding classmate records you. We will then review the video immediately after so that you can respond to the below questions:

How did you show the difference between one extreme and the other of the spectrum? What was your greatest difficulty in completing this task?

Was there any disagreement on how you needed to act out the E-M spectrum? If so, describe the main points of the disagreement and how it was resolved.

Is what you acted out an accurate portrayal of a single type of wave?

How is this analogous to other types of spectra with which you might be familiar? (e.g., Autism Spectrum)?

Does sound have an equivalent spectrum?

What moves faster: Gamma Rays or Microwaves? What do you need to know about Gamma Rays or Microwaves in order to compare them in terms of total Energy?



All but two of your peers will line up in a row in the hallway or other open space. Close your eyes. The two peers will both have identical tuning forks and strike them hard. One will be told to run and the other to jog, but with quiet footfalls. Then, on the return trip, they will both run at the same pace. Which of your peers was running? How do you know?

Did the tuning fork sound different when it was coming towards you versus moving away from you? If so, what is your explanation for this?

What would you need to know to decide which of the two runners expended the most Energy? Does this affect the Energy of the sound wave produced by the tuning fork? If so, in which way(s)? Draw out your conception of the sound waves in both situations.

Ask the runners what they heard. Find out (experimentally) whether it was different from what you heard. Explain any difference.

Cha	ttering Teeth Periodicity - Discussion
:	 What happens when your teeth chatter? Is this an example of "periodic motion"? If so, what might it look like in graphical format? How would you define parameters such as period, amplitude, and frequency? Could you experimentally find these? If so, what would these experiments require?
	"Electric Toothbrush in Action" - demonstration
	I have here an electric toothbrush and a standard toothbrush. Also available is a microphone with datalogging capabilities.
	- How might I use this equipment to investigate the motion of the toothbrush bristles?
	- How does the motion of the bristles compare to a standard toothbrush's, during use? Is this effective? Is it efficient?
	- Design a brief energy flow diagram for the electric toothbrush. How does this differ for the standard toothbrush?





Standing Wave Pattern - Activity

Get ready to act out a standing wave pattern! It may prove more difficult than you might think!!

Recall the E-M Spectrum Student Line-up Activity we completed earlier. As a group, line-up (all except one person with a video capture device) in a row. Your task is to model with your bodies a standing wave pattern.

Once you have figured out your "final solution" to this problem, act out the standing wave while your camera-holding classmate records you. We will then review the video immediately after so that you can respond to the below questions:

Did you take into account what was happening at the ends of your configuration? (e.g., did you have forced nodes or open-ended reflections?)

What was your greatest difficulty in completing this task? Are your selections at all related to our Energy concepts?

Was there any disagreement on how you needed to act out the standing wave pattern? If so, describe the main points of the disagreement and how it was resolved.

What is necessary to keep this type of wave phenomena going? How could you eliminate it? What conditions are necessary to get this type of wave phenomena to appear in the first place?



"Beats, Beats: The Musical Fruit!" - activity

Have you ever tried to tune an instrument? Or, have you ever been between two musicians trying to play exactly the same note, but they were just slightly off from one another? If you've never had the opportunity to experience these two scenarios, then you will be able to get a chance to experience something similar, now -- with tuning forks!

To prepare for this activity, experiment with the functions of this spreadsheet program: http://mrlafazia.com/labs/SUPERPOS.XLS

Part 1: Identifying Beats

Choose two tuning forks which are close to each other in frequency

Strike them both on the tabletop (lightly) and hold them close enough together that you can (safely) hear the sounds using the same ear. [If you are sensitive to sound, take this into consideration].

Do you notice anything different versus striking a single tuning fork? How would you describe it? Draw out a basic sketch of what you are hearing, over time.

Part 2: Experimentation

Take these two tuning forks and use the microphone setup at your station. Record the sound they make together (just as you heard it from Part 1). Zoom in on the sound little by little.

What do you notice about the interference pattern as you zoom in?

Is there evidence of superposition occurring?

Can you identify how many "beats" are occurring per second? This is what we call the "beat frequency."

Does it match your expectations based on the frequencies of the two tuning forks?

Which of the two tuning forks, if either, is exhibiting more energy? Justify your response using your senses and the sensor data.

Ray Diagramming - Activity

Have you had trouble gauging how deep a lack, pond, pool, or even puddle is before taking a dip? Ever seen the classic "broken pen" trick in a glass of water? Here we study some of the optics involved in these phenomena.

Pre-activity discussion:

- What types of wave reflect?
- What happens to a sound or light wave as it travels into (or out of) water?
- Besides reflection (and now "refraction,") how else do waves act?

Part One: Simulated Spear Fishing

There is a large, empty basin in front of you. You have two colors of string available. The toy fish is at the bottom of the basin. Using one string, show the path light is taking to reach your eye. Note the exact location of this string and arrange to keep it in place.

Are your group mates seeing exactly what you are seeing? Defend your conclusion.

Now fill the basin ³/₄ full with water. Using the second color of string, show the path the light is now taking to reach your eye. **Has it changed? If so, how, and why?**

Sketch out the situation:

Part Two: Submerged Coin

Take an empty bowl and place the coin at the bottom of it, in the middle. Step back until you can only just see the far edge of the penny. Mark this place with a piece of tape on the floor in front of your feet.

Predict where you will need to stand in order to see the penny when a group-mate fills the bowl ³/₄ of the way up:

After testing, was your prediction correct? Explain.

Has anything else about the penny appeared to have changed? If so, what?

Check for Understanding

Explain the results of this experiment...! Use ray diagramming to defend your explanation.

ONLINE RESOURCE URL: https://twitter.com/AIAVision/status/705397318217031681



Complete your Exit Ticket!

Don't forget to put up your Exit Ticket!

Using a Sticky Note, write down one thing you are feeling **confident** about from the lesson and one thing you still have a **question** about.



Put these up on the board on your way out!

No name necessary – these are anonymous.

Proceed to Lesson04

Return to Unit View

 Would you like to review the actual lesson plans? They are included, below:

 Unit Plan | Lesson01 | Lesson02 | Lesson03 | Lesson04 | Lesson05 | Lesson06 | Lesson07 | Unit Template | Lesson Template



Lesson 04

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#]*	Assignments & Assessments
ONLINE Social Construction of Sound Concepts	1:45 est'd	Sound Characteristics Doppler Effect Revisited Bow waves, shock waves, and sonic booms Ray Diagramming Revisited	4.1, 4.4, 4.6, 6.1	Viog Notes: Summary of content and activities to-date [closed-captioned] [DP#'s 1, 6, 7, 8] Video Clip: Lightning vs. Thunder [DP#'s 1, 10] Discussion Board Activity: "Sound" thinking group activity [adapted from a Physics Respondent, DP#'s 1, 2, 4, 5, 7, 8, 10] Activity: Modes of transportation (plane, boat, and really fast carl) webquest/simulations [inspired by Edelman, 2012, p. 403, DP#'s 5, 8, 10] Activity: "How do your eyes measure up"? (visual acuity online activity) [inspired by Crouch & Heller, 2011, p. 160, DP#'s 1, 4, 6, 7, 8] Homework: Create-your-Eye gel experiment [inspired by McGuigan, 2009, DP#'s 1, 4, 6, 7, 8] Practice: practice problems with solutions [DP#'s 8, 10] Word Banking: Update of Word Bank [DP#'s 2, 3, 4, 8]	Reading Assignment: Sections on advanced wave behaviors and applications <u>Discussion Board</u> : post and responses <u>Homework</u> : eye physical simulation [inspired by McGuigan, 2009] WebAssign and Exam representation

	Conceptual Physics
	Waves and Periodicity Unit
	Return to Unit View
	Return to Lesson03
Less	son 04
**	Waves & Periodicity vLog 2
	Waves & Periodicity vLog 2 User: David LaFazia - Added: 3/27/16 Watch Video
	This vLog entry is to make sure that everyone is on the same page with the content. In it, I share my expectations for the upcoming lessons and the underlying activities (e.g., Word Banking, Discussion Board, homework).
	[Please be sure you enable Closed-Captioning [CC] if you require auditory assistance].
	VIDEO CLID UDI a http://www.accentralia.com/accentralia.com/accentralia.com/



VIDEO CLIP URL: http://www.youtube.com/watch?v=Xd8i6d-N7J8



Sound - Thinking Activity (Discussion Board)

Using our Discussion Board, complete this thought-activity in your pre-assigned groups. (In the Discussion Board, these group are assigned in the title of the thread: e.g., "John M., Louisa G-H., Mah'mud A., Group 1" would indicate that those three students were assigned to that thread as "Group 1".

You will need to contribute to your group's thread early and often in order to produce a record of collaboration comparable to an in-class activity. Feel free to apply other technologies to support your use of the Discussion Board, if you are so inclined.

We now know that waves transmit energy, typically through a medium. We also know that waves possess certain characteristics such as wavelength, frequency, amplitude, and wave speed. Keeping these general "wave" ideas in mind, let us consider two important examples of waves, sound and light.

First, let's investigate sound ...

Sound:

1: What is the energy being transmitted via sound waves? In other words, what is vibrating or "wiggling" that we perceive as sound? Can you think of some examples?

2: Do sound waves need a medium? Can you think of some examples?

3: Do sound waves reflect? Can you think of some examples?

4: How do the frequency, wavelength, and amplitude affect how we perceive sound? Can you think of some examples?

5: What is the Doppler Effect?

In your assigned groups on the Discussion Board, carry out a detailed discussion of each question. This is not a webquest. In other words, you are not attempting to pull together resources to answer these questions "correctly." This is a discussion where you are investigating each other's understandings. You <u>may</u> bring in other resources to *support your ideas*, however.

Transportation WebQuest

This webquest is aimed at helping you explore what happens as objects move quickly through fluids/media (e.g., air or water), specifically as this relates to wave formations and wave speed.

Your task is to locate (and provide the active URL/link to) information leading to the answering of the following questions:

What is the fastest plane or jet speed achieved to-date?

What is the fastest boat or ship speed achieved to-date?

What is the fastest car speed (i.e., "ground speed") achieved to date?

What physical characteristics do the designs of the crafts which achieved these speeds have in common? Is there a trend, here? Explain.

Consider this webpage:

http://dev.physicslab.org/Document.aspx?doctype=3&filename=WavesSound_BarrierWaves.xml

Discover online an online simulation that compares bow waves, barrier waves, and shock waves (perhaps for a flying jet).

Consider also this question and its solution:

http://dev.physicslab.org/Document.aspx?doctype=5&filename=Compilations_NextTime_ShockCones.xml

How does this relate to the three ducks in the vLog 1 video from Lesson01?



In preparation, watch this video clip on Ray Diagrams and lenses:

https://www.youtube.com/watch?v=FVpPU4NIJh0

Do you have 20-20 vision? If not, join the club! While you may know how to correct a vision impairment, you might not know WHY you do not have perfect vision. Consider the images and explanations found on this webpage (you may ignore the videos):

http://www.cyberphysics.co.uk/topics/medical/Eye/sightCorrection.html

Which of the images best represents your current vision?

Which type of corrective lenses should you consider, if any?

If you do have corrective lenses, experiment with them as if they were a "magnifying glass" to see the effect they have (from either direction) on written text or images.

How might this phenomena relate to a larger picture? For example, how might these light behaviors and "lens-ing" relate to our atmosphere, energy transformation, bodies of water, and light sources?

Homework: Create-your-Eye

Using any appropriate types of material at your disposal (e.g., gelatin, clear plastics, &tc.), design a model of your eye! Consider how light travels through and to each component of your eye, and make accommodations for any vision problems you might have in your design.

We will be testing these (under controlled conditions) with a LASER beam during the next in-class session.

Note: there is no reason to break the bank -- stay low-budget -- if you can't find components around the house or in junk drawers, then hit the dollar store! Your eye model does not have to be perfect -- it just needs to carry out the basic function.



WORD BANKING URL: http://padlet.com/dlafazia/waves1



Reading Assignment

You are responsible for knowing the content in the following sections:

- 6.4: Production of Sound

- 6.4. Production of Sound
 6.5: Propagation of Sound
 6.6: Perception of Sound
 8.4: Applications to Sound Production
 8.6: Blackbody Radiation
 8.7: EM Waves and Earth's Atmosphere
 9.4: Lorgen and Lorgen Lorgen
- 9.4: Lenses and Images
- 9.5: The Human Eye
- 9.6: Dispersion and Color
- · 9.7: Atmospheric Optics: Rainbows, Halos, and Blue Skies

Proceed to Lesson05

Return to Unit View

Would you like to review the actual lesson plans? They are included, below:
 Unit Plan
 Lesson01
 Lesson02
 Lesson03
 Lesson04
 Lesson05
 Lesson06
 Lesson07

 Unit Template
 Lesson Template

TEXTBOOK ISBN: 9781133104681

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#]*	Assignments & Assessments
IN-CLASS Social Construction of Light Concepts Sound vs. Light	1:30	Light Characteristics Doppler Effect Revisited Color Mixing Refraction Resonance Interference Patterns with Light Interference Patterns with Sound Ultrasound Revisited	4.1, 4.4, 4.5, 4.6, 4.7, 6.3	Discussion: Review of prior Exit Tickets [DP #8] <u>Word Banking</u> : Review and Revision of Word Bank [DP#'s 2, 3, 4, 8] <u>Discussion</u> : Review of Create-your-Eye gel experiment homework and LASER testing [DP#'s 4, 6, 7] <u>Activity</u> : "Light" thinking group activity and experimentation [adopted from Physics Respondent, DP#'s 1, 2, 3, 4, 5, 10] <u>Demonstration</u> : Conducting a basic whole-class hearing test (analyze class range-distribution) [inspired by JRC-DMS, 2008, DP#'s 1, 2, 4, 5, 6, 7] <u>Activity</u> : "Best place to Sit in the Theatre" (sound interference pattern lab exercise) [inspired by Lewis & Mohazzabi, 2014, DP#'s 1, 2, 4, 6, 10] <u>Activity</u> : "Honing your Teacher Voice" – projection microphone analysis [DP#'s 1, 4, 7, 9] <u>Discussion</u> : "Do you really see during an ultrasound scan"? [DP#'s 2, 4, 7, 9] <u>Exit Ticket</u> : 1 thing you are confident on; 1 thing you have a guestion on or want to learn more about [DP# 8]	Check for Understanding: Nodes & Antinodes [based or Stepans, 1996, p. 174] WebAssign and Exam representation Exit Ticket

Conceptual Physics

Waves and Periodicity Unit

Return to Unit View

Return to Lesson04

Lesson 05



Let's review the previous Exit Ticket submissions

We will start out this lesson by reviewing the Exit Tickets you submitted previously. Did the online lesson activities help answer your questions before now?



Word Banking

Here we will take a moment to review all of the updates you have submitted for inclusion in our Word Bank.

WORD BANKING URL: http://padlet.com/dlafazia/waves1





LASER-Testing of your Eye Models!

Your homework will now be tested! Since the path of LASER light in your creations is uncertain, I will personally test these using protective measures. You will see the results of each test through the use of an overhead camera.



"Light" - thinking group activity

In this activity, you will be asked to reflect on three physical activities: color mixing, bending light, and light through a slit.

We now know that waves transmit energy through a medium. We also know that waves possess certain characteristics such as wavelength, frequency, amplitude, and wave speed. Keeping these general "wave" ideas in mind, let us consider an important example - light waves.

As we do the following three activities, we will answer the questions below:

- Color mixing
- Bending light
- Through the slit

Light:

1: What is the energy being transmitted via light waves?

2: Do light waves need a medium? Can you think of some examples?

3: Do light waves reflect, refract, & diffract? Can you think of some examples?

4: How do the frequency, wavelength, and amplitude affect how we perceive light? Can you think of some examples?

5: Do light waves experience the Doppler Effect?



ONLINE RESOURCE URL: http://onlinetonegenerator.com/



"Best place to sit in the Theatre" - activity

What happens when you have two wave sources interacting with one another? Does the dynamic change when you're within an enclosed space? Let's explore these and other questions!

Think: Have you ever been in a theatre (e.g., at a concert) and experienced "dead spots"? What about in a car – particularly one with a custom sound system? If so, keep these experiences in mind as you conduct the following exploration:

Using the online tone generator (from <u>onlinetonegenerator.com</u>) which you used previously for the hearing test, select a moderate (low frequency) tone at a tolerable volume which can still be heard throughout the room. Allow this to "ring" continuously.

With the speakers side-by-side about 30 cm apart, walk around the room. Map out any differences in volume that you might hear (e.g., against the walls, in the middle of the room, &tc.).

Describe the differences, if any, you perceive. Why do you believe these differences are occurring in those locations?

If you change the angle of the speakers, does this affect your map? What changed, if anything? If you change the distance between the speakers, what effect does this have, if any?

Does increasing or decreasing the frequency of the tone from the two sources have an effect? What happens to your perceived "differences" (if any previously) if you unplug the secondary speaker?



IMAGE URL: http://www.bestnursingdegree.com/img/florida-ultrasound-tech-with-patient.jpg



	Lesson 0	6				
	Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#]*	Assignments &
	IN-CLASS Student Teaching Sessions	1:20	Student Group Teaching Sessions	4.1, 4.2, 4.4, 4.5, 4.6	Discussion: Review of prior Exit Tickets [DP #8] <u>Activity</u> : Kahoot! Quiz on Waves & Periodicity [DP# 4] <u>Activity</u> : Student topic assignments and mini-teaching sessions (Sonographer and Educator roles and perspectives) [inspired by an Education Respondent, DP#'s 2, 4, 9]	Kahoot! Quiz <u>Presentations</u> : student involvement in group teaching sessions (rubric provided)
			Con	cep	otual Physics	
			И	/aves a	and Periodicity Unit	
				<u>Re</u>	eturn to Unit View	
				Re	<u>sturn to Lesson05</u>	
Les	son 06					
	Let's re We will st	view th art out t	he previous Ex	kit Tick	et submissions e Exit Tickets you submitted previously.	
	Kahoot! (Before we ç	Quiz or get into t	Waves and the mini-teaching	Periodi lessons	city , let's loosen up with this warm-up activity!	

QUIZ URL: https://play.kahoot.it/#/k/d26ab004-2e39-49f8-949e-24ad43989d16 (public URL for Kahoot!

users - obtain access at http://getkahoot.com



Mini-Teaching Assignment: Description + Rubric

This document outlines for you the parameters of the mini-teaching assignment. A copy of the rubric which will be used to grade your co-teaching performance is also provided.

Proceed to Lesson07

Return to Unit View

Would you like to review the actual lesson plans? They are included, below: <u>Unit Plan | Lesson01 | Lesson02 | Lesson03 | Lesson04 | Lesson05 | Lesson06 | Lesson07</u> <u>Unit Template | Lesson Template</u>

Mini-teaching Assignment:

The remainder of this lesson will now be spent with your own mini-teaching experiences! The unit topics have been broken up into the following lesson assignments:

- Wave Parameters (Amplitude, Frequency, and Period)
- Wave Parameters (Wave Speed)
- Wave Behavior (Reflection, Refraction, and Diffraction)
- Wave Behavior (Doppler and the Doppler Effect)
- Wave Behavior (Superposition, Standing Waves, and Beats)
- Periodic Motion
- Light vs. Sound
- Ray Diagramming and Applications of Waves

The topics have been assigned to you in pairs. I will give you some time to complete your preparations for the mini-teaching sessions. Each lesson should last between 5 and 8 minutes, including a question-answer session at the end. <u>You will video record your mini-lessons</u> so that they may be included in your ePortfolios (in preparation for entry into the career field and exhibition of work artifacts). Be sure to make explicit connections to the <u>Next Generation Science Standards</u>. Simple activity ideas can be found by grade level (e.g., see the "Clarification Statements" in red in this breakdown of <u>"Waves: Light and Sound"</u> at the 1st-grade level).

The lesson may be in any format you wish, but it should include some aspect of the following:

• Activity Title

- *Next Generation Science Standards* connections
- Learner Objective(s) or Learning Target(s)
- Resources used to Inform Lesson
- Materials Needed for the Lesson
- Methods of Engagement and Assessment

Again, this is a super-short lesson, so any activities and assessment strategies will be kept short (or more accurately: <u>focused</u>).

On the next page is included the rubric with which you will be graded. All co-teaching groups will be graded on the same rubric, but adjustments will be made for lack of or low participation on the individual scale.

Have fun! I look forward to your lessons!! I will provide feedback on the rubric which we can discuss after the fact.

CRITERION	0 – Missing	1 – Unsatisfactory	2 – Emerging	3 – Proficient	4 – Exemplary
Next Generation	No standards were	The standards identified to	The standards are	The standards are	The standards are
Science Standards	included in the plan.	not link to the lesson being	identified, but some do not	identified and appropriate	identified and appropriate
		taught.	link to the lesson being	to the lesson. Letters and	to the lesson. Letters and
			taught.	number of appropriate	numbers of appropriate
				benchmarks are missing.	benchmarks for each
					standard are included.
Objectives/Targets (1)	No learner objectives or	Does not clearly identify	Some objectives or targets	All objectives or targets	Clearly identifies the
	targets are identified.	the knowledge and skills	are listed but are	are listed but some are	knowledge and/or skills
		students will acquire.	incomplete.	incomplete.	students will acquire.
Objectives/Targets (2)	No learner objectives or	None of the objectives or	More than one objective	One objective or target is	All learner objectives
	targets are identified.	targets listed are	or target is not	not measurable	/learning targets are
		measurable.	measurable.		measurable.
Resources	No resources are	More than two resources	Two resources not listed	One resource is not listed	Lists all resources used to
	identified.	missing and/or not cited	and/or not cited correctly.	and/or not cited correctly.	create the lesson.
		correctly.			
Materials	No materials needed for	Four or more necessary	Two or three necessary	One necessary material	Lists all materials needed
	this lesson are identified.	materials needed by the	materials needed by the	needed by the students	by the students and the
		students and teachers are	students and teachers are	and teachers is missing.	teacher.
		missing.	missing.		
Engagement	Lesson includes no	Lesson minimally engages	Lesson engages students in	Lesson engages students	Lesson engages students
	engagement activity.	students.	discussion or questioning.	cognitively and physically.	cognitively, socially, and
					physically.
Assessment	No evaluation or	Employs very minimal	Employs basic components	Employs either formative	Employs either formative
	assessment is included.	formative or summative	of formative or summative	or summative assessment	or summative assessment
		assessment and these are	assessment which are only	strategies, but the	strategies and allows the
		not directly used to inform	minimally applied to	assessments do not help	feedback to appropriately
		the lesson.	inform the lesson.	measure the learning	inform the lesson.
				objectives or targets.	
Teaches the Lesson	Lesson is not taught.	Does not generally	Teaches from the lesson	Teaches from the lesson	Teaches the lesson
		following the lesson plan	plan but is unable to make	plan and is able to make	following the lesson plan
		or is unable to make	adjustments based on	some but not enough	and makes appropriate
		adjustments based on	student needs.	adjustments based on	adjustments needed to
		student needs.		student needs.	provide for student needs
					and understanding during
			1		the lesson.

OVERALL GRADE: _____/ 32 = _____%

Activity and rubric based on https://www.ben.edu/college-of-education-and-health-services/school-of-education/upload/Mini-Lesson-Plan-Assignment-Rubric.pdf

Lesson	Time (h:m)	Topic(s)	MPOs	Activities, Materials; Resources [SOURCE, DP#]*	Assignments & Assessments
ONLINE		Physics of Music		Word Banking: Concluding additions/revisions in Word Bank [DP#'s 2, 3, 4, 8]	Practice: periodicity calculation examples
Extended Thinking		Exam Preparation		Activity: Online exploration of musical applications [inspired by Ostdiek & Bord, 2013, p. 249, DP#'s 1, 4, 10]	with solutions
		Formal Assessment		Activity: Waves and Periodicity journal reflection entry	Journal Entry artifact
Exam			4.1, 4.2,	[inspired by Hwang et al, 2015, p. 114, DP#'s 4, 8, 9]	[inspired by Hwang e
Preparation	2:40 3st'd		4.3, 4.4, 4.5, 4.6,	Practice and Video Clips: Exam preparation questions on waves and periodicity with fully worked-out solutions and	al, 2015, p. 114]
	1993103230		4.7	sample student questions [DP#'s 8, 10]	WebAssign:
				WebAssign-ment: Waves and Periodicity problems [DP#'s 8, 10]	WebAssign-ment on waves and periodicity
					(immediate feedback
				Transition into the next unit (not reflected in unit or lesson	generated; mastery

 Would you like to review the actual lesson plans? They are included, below:

 Unit Plan | Lesson01 | Lesson02 | Lesson03 | Lesson04 | Lesson05 | Lesson06 | Lesson07 | Unit Template | Lesson Template

Conceptual Physics

Waves and Periodicity Unit

Return to Unit View

Return to Lesson06

Lesson 07



Word Banking

Now that we have reached the final lesson in this unit, take what you have learned and update the Word Bank! (Remember that the password is **phy111-waves1**).

It might be that you have something new to add, or you may have a revised understanding of a previous subject (e.g., ray diagramming).

Whatever the case, go ahead and make your revisions. For major revisions, I will approve these by the due date on the WebAssign-ment.

WORD BANKING URL: http://padlet.com/dlafazia/waves1



Explore these musical applications of acoustics!

Are you musically inclined, or musically curious? Follow the lesson an acoustics outlined on this webpage. It provides an excellent bit of immersion into musical applications of what we have learned, especially concerning sound waves.

ONLINE RESOURCE URL: http://www.phys.unsw.edu.au/jw/brassacoustics.html

Complete your Waves & Periodicity Unit Journal Entry

Here are the writing prompts to help guide your Journal Entry for this Unit: I have provided a rubric, here, to help guide your completion of this Journal Entry.

1) After having completed this unit, what skills do you have which you would not otherwise have developed?

2) Explain in detail what a wave is, in your own words.

3) Explain in detail what periodic motion is, in your words.

4) Are waves and periodic motion related? If you believe so, defend your position.

5) Review the Exam Practice questions and attempt to complete them on your own prior to viewing the video solutions. How do you rate your performance before viewing the videos? How do you rate your understanding after viewing the videos?

6) Write a new problem you would ask a student to complete on an exam for this content if you were the instructor.

Robite.					
CRITERION	0 – Missing	1 – Unsatisfactory	2 – Emerging	3 – Proficient	4 – Exemplary
Retrieval of Relevant Knowledge	No evidence of knowledge retrieval.	Definitions, explanations, and examples do not support the prompts and/or three or more inaccurate statements are present.	Definitions, explanations, and examples support the prompts, but two or more inaccurate statements are present.	Definitions, explanations, and examples support the prompts, but one inaccurate statement is present.	Definitions, explanations, and examples are all accurate.
Reflection	No evidence of reflection.	The skills or exam practice prompts are completed with minimal evidence of reflection.	The skills and exam practice prompts are completed with minimal evidence of reflection, or only one of the prompts is addressed at a basic or higher level.	The skills and exam practice prompts are completed with basic evidence of reflection.	The skills and exam practice prompts are completed with obvious evidence of reflection.
Content	No content provided.	Responses are loosely related to the topic; ideas are unsupported.	Entry responds to the basic prompts; ideas are supported minimally.	Entry responds to the prompts adequately; most ideas are supported by facts or examples.	Entry responds to the prompts fully and proper support is given for the ideas presented.
Idea Development	Responses are not explained.	Responses are explained; two or more components are missing.	Responses are explained; one component is missing or ideas are not original.	Responses are explained in detail with original ideas evident.	Responses are explained in detail with evidence of original idea development and the use of examples to support explanation.
Organization	Insufficient content is provided to make a determination of Organization.	Journal entry lacks structure.	Topics and ideas are presently randomly.	Ideas and conclusions are logically placed.	Responses are logically organized throughout.
Mechanics	Insufficient content is provided to make a determination of Mechanics.	Spelling and other grammatical errors are prevalent.	Several spelling and/or other grammatical errors occur throughout the entry.	There are few spelling and/or grammatical errors.	There are no spelling or grammar mistakes in the entry.
Creation / Synthesis	The creation task was not completed.	The creation artifact is completed but does not meet the guidelines of the prompt.	The creation artifact does not directly meet the guidelines of the prompt, but it relates to the topic.	The creation artifact relates to the topic but there is little evidence or originality.	The creation artifact relates to the topic and is an example of original work.

RUBRIC:

OVERALL GRADE: ____/ 28 = ____%



Exam Review Question 1

What two characteristics of sound are affected with moving sound sources?
 Is the effect the same if the listener is moving instead of the source?

Video Clip: https://youtu.be/LIC2HAi33xw

VIDEO CLIP URL: https://youtu.be/LIC2HAi33xw



VIDEO CLIP URL: https://youtu.be/nuCnrm93PaQ

IMAGE URL: http://olc.spsd.sk.ca/de/physics20/light/light_images/refrac_app_fish.gif



VIDEO CLIP URL: https://youtu.be/tg1VJzJ4VCw

IMAGE URL: http://www.ces.fau.edu/ces/nasa/images/Energy/VisibleLightSpectrum.jpg




ASSESSMENT PLATFORM URL: http://webassign.net



Exam Questions (for curriculum reviewers, only)

These questions are the formal Exam questions which relate to this unit's content. These will not be available to student viewers and is provided here only for the sake of those who wish to view and/or use these unit materials.

Return to Unit View

 Would you like to review the actual lesson plans? They are included, below:

 Unit Plan | Lesson01 | Lesson02 | Lesson03 | Lesson04 | Lesson05 | Lesson06 | Lesson07 | Unit Template | Lesson Template

Exam Questions for Waves & Periodicity Unit representation:

Blue Highlights = existing connections

Green Highlights = models for new exam questions

- A piano uses stretched metal strings of different thickness and length to produce different notes. A small
 hammer strikes the strings in the piano and the strings vibrate.
 - a. When an individual string is struck, it vibrates and we hear a sound. Assuming the tension in a string is constant while the person is playing, what does this tell us about the speed of the waves in the string (i.e., will the speed be constant, or will it vary)?
 - b. Different strings have different lengths, and this will result in different wavelengths and frequencies when the strings are struck. Suppose a string that vibrates at 256 Hertz is struck and then later a string that vibrates at 312 Hertz is struck. What wave characteristic causes the two sounds to sound different to a listener?
 - c. How hard you push the keys on the piano dictates how hard the hammer strikes the strings. What characteristic of the wave in the string will be different as you push the same key softly or more vigorously?
- 2) You are at sea on a research vessel using side-scan SONAR to take images of the ocean floor. Another person is curious why the researcher adjusts the frequency of the SONAR in order to achieve images that are more detailed. How would you help your colleague understand?
- Imagine being at a LASER show where different color LASERs are used in conjunction with music. Explain how the frequency and the amplitude of the light determines "how the LASER looks" to us.
- Look at the picture to the right. Is the pencil actually broken, or does it just look broken? Explain what wave behavior causes the pencil to look this way.
- 5) After cooking pasta you notice the burner on your stove is not red anymore, but you still feel heat when your hand is close to the burner. Using the idea of light - and the different types of light on the Electromagnetic Spectrum - discuss why you are still able to "feel" the heat with your hand. Is the burner still giving off a form of light we cannot see?



- 6) While at the NASCAR race in Dover, a single car speeds down a straight section of track toward your location in the stands. You and your friend notice the sound of the car <u>gets louder</u> as the car approaches and your friend says to you, "You see how the car <u>gets louder</u> as it gets closer? That's called the Doppler Effect—we learned about that in science class." Do you agree with your friend's statement? (Explain your thinking)
- 7) In class, we demonstrated waves by disturbing a long spring. This disturbance traveled or propagated away from the source through the spring (the medium). Earthquakes are called seismic waves or disturbances. Describe in simple, general terms what happens at the epicenter (where the Earthquake originates) to cause the seismic waves (in other words, what did the Earth "do" to cause seismic waves)? Describe the basic difference between "P" and "S" seismic waves. How is the Earth vibrating differently to create these different waves?
- 8) Look at the picture to the right. What wave behavior is being demonstrated as the water waves move through the gap in the rocks?
- 9) You are walking through a pond trying to spear bullfrogs for dinner. You look in front of you about 6 feet away and you see a nice bass "suspended" at what looks like a foot below the surface. You're about to throw your spear at the frog when you remember what you learned in physics class. Should you aim at the frog, below the frog, or above the frog? Explain your rationale and use a ray-diagram (draw the lines showing where the frog is versus where your eyes tell you it is!) to aide your explanation.



10) Below is a blank graph of Intensity versus Time for heart rates. A student, <u>Kwadwo</u>, measures his resting heart rate to be about 60 bpm. After some rigorous jumping jacks, his heart rate doubles. Graph this out using a simple sinusoidal wave to model the overall heart rate.



 11) The class has lined up to physically model the Electromagnetic Spectrum. Three of the students, Jorge, Belle, and Julia, are doing a particularly fine job. Jorge is oscillating up and down faster than Julia. Belle is oscillating up and down faster than Jorge. The students are representing Microwaves, Visible Light, and X-rays. Match each light category to their actors!

 Microwave
 Jorge

Visible Light	Belle
X-rays	Julia

12) While taking a test, you notice a sharp tone coming from a fellow students' cell phone. Several of the other students, especially the younger ones, are all looking in the direction of the cell phone. The instructor, who is several decades older, does not seem to notice, as is the case with several of the older students. How do you explain this phenomenon?

13) A friend of yours runs towards you screaming while being chased by a wasp. How does the sound volume change as she runs closer? Describe how the frequency you would perceive from her voice compares a) in front of her, b) behind her, and c) to her side. Is the speed of sound greater in front of her, behind her, to her side, or is there no difference?

fou and a renow student	are using a rope to exp	vel e se slitude de ti	s. Tou create a sing	ste transverse puis
(upward) and your peer (does the same at an eq	uai amplitude. In t	ne spaces provideo,	sketch the wave p
along the rope before, de	uring, and after superp	osition. Be sure to l	abel your wave "A"	and the other wa
in each sketch.				
Before pulses meet:				
During pulse meeting:				
During pulse meeting:				
During pulse meeting:				

- 15) What is sound? You may support your definition with labeled sketches. Be sure to explain sound in terms of the energy concepts we have explored. How do humans produce sound? How do we perceive sound? Does your definition of sound match your explanation of human sound production and perception?
- 16) What is light? You may support your definition with labeled sketches. Be sure to explain light in terms of the energy concepts we have explored. Do humans produce light? How do we perceive light? Does your definition of light match your responses to the questions of human light production and perception?

17) A 250 Hz tuning fork and a 500 Hz tuning fork are in your hands (one in each). If you strike both with the same force, what conclusions can you make on how their a) energy output, b) frequency, and c) speed of sound produced compare?

18) In an ultrasound clinic, a sonographer is scanning a patient. The patient remarks, "It is so amazing that we can see what's inside of me! It's so dark in there! How can you pick up the light when it's so dark inside me?" How should you respond?

19) Your record your voice while reading a textbook chapter. After you are done, you decide you would like to find out what frequency(-jes) make(s) up your voice. Explain how you would do this, and draw a prediction of what the resulting data would look like:



20) Draw what is happening with the particles of air when you speak. Your sketch may be simple, but it must be complete. Feel free to include labels and descriptions to help support your drawing.

Unit Plan: Conceptual Physics, "Waves & Periodicity"

ADDIE COMPONENT

Analysis Phase

1. Is training really necessary?

What are the performance goals of this lesson? (with syllabus and other objective references) Include

a general introduction to the unit. This unit explores periodic motion with an emphasis on wave forms. This is done by exploring observable and often common phenomena through a scaffolded inquiry approach. Key concepts in sound, light, and other wave applications are explored. The unit models teaching strategies for Education majors and incorporates instructional practice opportunities while also providing a foundation for ultrasound physics applications suitable for Sonography-bound students seeking to enter the Ultrasound Physics course. The concepts are applied broadly enough to meet the needs of all majors.

What knowledge, skills, and attitudes are required? Graphical analysis, basic algebraic skills, ability and willingness to participate in online discussions and activities, tolerance and skills for guided inquiry, physical self-awareness, awareness of applicability to career/major, ability to work in small teams and as an individual, ability to collaborate as a class; tolerance and discipline to complete a meaningful journal reflection entry for the unit.

2. Who are the students?

What knowledge, skills, and attitudes are already in place? What misconceptions may be present? Connections are made to prior classroom knowledge (e.g., forces, pressure, motion, radiation; &tc.) and common "everyday" experiences (e.g., electric tooth brush motion). Importantly, by this point in the course, the appropriate expectations for a guided inquiry approach should already be in place. It is expected that students have a working knowledge of basic variable manipulation. A number of studies have been completed on undergraduate physics misconceptions. These are discussed in greater detail in the parent-study, and the most prominent of these lessonspecific misconceptions are noted on each individual lesson plan.

What special needs or constraints exist for these students? Many of the students have trouble when asked to operate at higher order (synthesis) levels. An example approaching this is when students are asked to analyze a system where multiple phenomena are occurring together.

3. What equipment, resources, and facilities are available?

Is the lab space adequate for this unit? Since much of the "lab equipment" simply involves the use of the students' own bodies (e.g., arms and legs as pendulums), any lab space will be adequate provided it allows for the free movement of students. In my own lab space, both small group activities and whole-class discussions are well-supported.

Is additional support needed for course delivery? To run this unit as-written, access to typically free online resources is necessary. In addition to this and access to an appropriate text with WebAssign access, the unit is written with the assumption that lab equipment (e.g., dataloggers and probe technology + software) is readily available in the laboratory.

How can job conditions be mirrored in this unit (e.g., problem- or situation-based)? This unit embeds a student-as-teacher activity prior to the end-of-unit assessment. As outlined in the lesson plans, there are also opportunities for practicing computer-use (e.g., simulations and data-entry) and exploring ultrasound applications.

NOTES, ANECDOTES, and HELPFUL HINTS:

The exact "Measurable Performance Objectives" (MPOs) are provided on the overall Unit Outline and on the Course Syllabus.

Students typically have trouble with the algebra even at this point, so it is useful to provide examples and algebra guides. I found it particularly useful to have students design their own spreadsheets.

By exposing students early on to complex scenarios and acknowledging the complexity of everyday life examples, their "science sense" may be nurtured. If this is <u>not</u> done, you run the risk that students will become mistrustful of the science taught.

Applying the theme of Human Body Connections will likely prove a suitable support for low-budget and equipment-lite classrooms.

All data collection and graphing activities, along with assessment activities, may be modified to fit other- or lower-tech scenarios.

1. Is there a task analysis to guide the design process, or must it be created?

There is no single "Job Task Analysis" (JTA) to guide the design process. Instead, what takes the place of the JTA is the set of Design Principles developed from the parent-study.

2. What competencies and objectives must the student master? (audience, behavior/action, conditions, and

degree/standard components must be represented)

The student must master, to the satisfaction of the instructor (via the assessments provided), all of the Measurable Performance Objectives which go along with the overall unit and individual lessons.

3. What assessment, test items, and checklists can I use to determine whether students are competent? (must

match the learning objectives)

As outlined in the lesson plans, there are a number of formative and summative assessments which I have designed to accompany this unit. Specific assessments, test items, and checklists/rubrics are described in the individual lesson plans.

Development Phase [Greater detail for this phase is provided in the Lesson Template]

1. How should I create the lesson plans and organize content; what media will be used?

What is my overall delivery strategy (e.g., media, laboratory) The unit is delivered in a hybrid (or distributed) format. There is a short online introduction where students build a basic background of visuals and reminders on the commonplace existence of wave and periodic behaviors. The unit is heavily built around socially constructed understandings of concepts and terminology with a strong and consistent laboratory component. These hands-on activities build from less formal to moreso and are coupled with in-class and online opportunities for discussion and other supports for cognition.

Do I have examples of correct performance? For this unit, it would defeat the purpose to give students direct examples of exemplary work (e.g., for the student-as-teacher or lab exercise components). However, several opportunities exist (and are made explicit in the individual lesson plans) to model sound problem solving approaches, laboratory methods, and other performance standards prior to student assessment.

How will student performance be assessed for the learning objectives in this unit? As previously noted, there are summative assessments formally employed throughout the unit. In addition to these are formative assessments of varying types and other less-traditional summative assessments (e.g., end-of-unit journal entry; student-as-teacher experience).

2. What instructor and student activities should be included?

What forms of additional support are available (e.g., educational technology, current events) The textbook now employed provides students with WebAssign (online assignment software) access. A number of free online tools (e.g., simulations, Kahoot!, GoogleDrive) are available for use. YouTube-published videos and other online resources are readily available; while some of these I have created myself, there is a wealth of ever-updated material to be found online.

3. How do I provide practice and feedback for students?

What general strategies will be used to provide opportunities for students to practice the skills and concepts? In terms of general practice, example problems and strong inquiry methods encourage ongoing challenge and growth. The social components support socially-moderated opportunities for argumentation, empathy (towards consideration of diverse perspectives), and construction of shared understandings.

At what points and will confirming and corrective feedback be provided? All laboratory activities are verbally "graded" throughout the process. This culture of immediate feedback is mirrored online through the use of WebAssign for online practice and homework assignments. Beyond all other assessments, the reflective journal response for the unit should provide individualized insight into student conceptions and opportunities for feedback.

These Design Principles may be extended beyond the Conceptual Physics classroom and adapted for other applications with high fidelity.

These are reproduced on the Syllabus and are reflected in the lesson outlines. Other fundamental competencies (e.g., working in diverse groups, &tc.) are integrated into the existing Measurable Performance Objectives and are not explicited identified.

Feedback on assessments should be reflective and provide connections between where students have been and where they are going with the concepts.

It is important to continually update (or verify the validity of) the materials used in any course. Given the proliferation of materials available via the world wide web, carefully selected and regularly reviewed content can help support students in making relevant connections

to course content.

This "social moderation" must be bounded within a safe and supportive learning environment. Students take risks when they share their views and suppositions.

All feedback should, again, "look back" and "look forward." This is a

fundamental aspect of unit design since it is situated within a larger

Implementation Phase [Greater detail for this phase is provided in the Lesson Template]	curricular frame.
1. How do I motivate students?	
What about this unit may be the most interesting and attention-grabbing for students (i.e., less	son
introduction and sustaining motivation)? For Sonography students, this unit will be something they li	kely have
been looking forward to the most, as it represents the strongest connection to their chosen major. That in i should act as strong motivation for those students; and this connection should be made explicit from the st the Education majors, however, it is presumed that there will have been other opportunities (in prior units) teaching experiences. This connection on its own will then not retain any novelty. Nonetheless, the prospe student-as-teacher activity should serve as some sustaining motivation. In general (and for all majors), the begun with examples of wave behavior and periodicity in commonplace circumstances with the promise of applications in the laboratory setting.	tself tart. For for mini- ect of the e unit is novel
How are the learning objectives relevant to students' goals? In general students taking the course	are Education majors in particular may not realize that they could be
coming to get a broad view of many physics concepts which are often abstract. Understanding the set, and pi problem solving and other skills along the way, supports the development of students in ways they may not However, for their own goals (beyond program major requirements), the Education students will at some ler expected to teach these science concepts. Sonography students at this point in their studies know little ab true nature of ultrasound physics, so this unit serves as a strong introduction to their field and the science it. Since this same explanation is shared throughout the unit, this question is not asked in the lesson plan	texpect. vel be out the behind 15.
How do I facilitate confidence and ensure satisfaction? This is done by continuing the culture of imm	nediate
feedback while requiring students to get the most challenge (and growth) out of the guided inquiry process making direct connections between shared experiences, confidence in the subjects should be supported. Additionally, satisfaction is supported when connections are made explicit between career expectations ar material.	. By nd course
2. What opportunities will there be for higher order thinking?	
The inquiry activities adopted require students to make connections for themselves: both to build knowled apply it, and extend their thinking. For each lesson students are gradually asked to become more and more independent. In conjunction with this expectation is an increase in complexity often leading toward high thinking.	ige, e ier order
3. What logistical considerations are there in my use of presentation and activity media?	
Computer software and probe/data-logger hardware must be available and properly employed. In a hybrid format, students must have access to and the ability to effectively use the digital resources. This means the orientations to both the in-class equipment and online resources are required. Such orientations would ge take place during the first week of class unless a new, unexpected need is identified. Importantly, online simulations tend to lose their browser script support as new internet browser generations are released (of without notice and without direct alternatives).	delivery It is always beneficial to have low-tech backups for core activities. at This is where the Human Body Connections theme can be particular enerally useful, but also where traditional physics methods can save a lesse iten (e.g., in the event of a network outage).
4. What general summarization strategies will be employed at the end of lessons?	
The "Word Banking" activity will serve as a strong summarization method. Since online lessons are paired class activities, the word bank will also act as a transition between these. Throughout this unit other sumr strategies are more instructor-oriented. For example: reviewing simulations or recitation of a physics poer 5. What are the time considerations anticinated for this unit?	with in- mary m.
This unit is comprised of seven lessons which are divided up over roughly two and one-half weeks for a six	teen Originally, the unit saw only about a one and one-half week renre-
week semester. Given the central importance of the unit content to the Education and Sonography majors, e	even if
offered during the ten week summer semester this unit should not be compressed past less than two week	sentation in the overall course. The incorporation of the Human
Evaluation Phase	Body Connections theme and other modifications make this expan-
1. How do I know if my course has been successful?	sion to a two and one-half week period feasible.
How well did students perform on the summative assessments? This has yet to be determined. St	udent
performance is not a part of this study.	
What trends were noticed in student feedback at the end of the unit (or course)? This has yet to determined. Student performance is not a part of this study.	be
2. Which superior about the periormance is not a part of time study.	
2. which experts should review the induction experts (PbDs/EdDs), especially those with curriculum downloamont av	nerience Theorem is the ball of the second second
rivisios and other science coucation experts (rius/cous), especially those with controllum development exp	These responses are identical throughout the unit. I have left them
3. which changes should be made to improve the course after it is presented? This has not to be determined. Beflective are still around that this event is in the lange of the still around the still ar	in the actual Lesson Plan sheets, however, for use in my own
inis has yet to be determined. Reflective practice will ensure that this question is considered appropriate	ıy.
4. Do the results justify the time and effort spent developing the course?	

This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.

Lesson 1 of 7: Conceptual Physics, Waves and Periodicity Unit: "Unit Preparation"

ADDIE COMPONENT

Analysis Phase

1. Is training really necessary?

What are the performance goals of this lesson? (with syllabus and other objective references) Include a general introduction to the lesson. This online lesson acts as a lead-in to the main unit. It is aimed at laying a foundation of connectedness between the human experience (often literally "The Human Body") and wave phenomena. I do not assign any Measurable Performance Objectives at this point. This is also where students first gain access to their shared Waves & Periodicity Word Bank as they begin to make meaning of new concepts.

What knowledge, skills, and attitudes are required? At this point students are only being asked to build knowledge and perhaps dredge up past experiences (likely common ones, but this is never to be assumed). Since Word Bank contribution is a necessity, they should be able to access and contribute meaningfully to the online bank.

2. Who are the students?

What knowledge, skills, and attitudes are already in place? What misconceptions may be present? Potential students have experienced all of the "initial thoughts" that the video blog (i.e., vLog or Vlog) introduces. It is likely that they did not think much about the phenomena at the time, but it is difficult to say what conceptions each student may have internalized. The motion of media may be misunderstood as being the motion of the wave (Stepans, 1996, p. 174).

What special needs or constraints exist for these students? For this lesson there are little constraints beyond inhibitions in participation in the Word Banking activity. It is worth noting at this point, also, that students need to see the importance of the vLog notes (and any other videos or online, ungraded activities).

3. What equipment, resources, and facilities are available?

Is the lab space adequate for this lesson? As an online lesson, lab space is not an issue. Server space is also not important.

Is additional support needed for course delivery? That said, students need even more support when they are asked to complete online assignments. The use of virtual office hours is suggested, but perhaps better even are clear guidelines to which students can refer back for specific activities (e.g., instructions an expectations for use of the Word Banking system).

How can job conditions be mirrored in this lesson (e.g., problem- or situation-based)? Online collaboration and word processing skills are certainly mirrors of the 21st-century workplace.

NOTES, ANECDOTES, and HELPFUL HINTS:

It is assumed that students will have been exposed to Word Banking earlier in the semester.

This is why it is so important to allow the Word Banking activity to act as a type of formative assessment tool. Use it carefully to identify any potential misconceptions early on. They will be addressed at the start of the next class.

If students do not believe the online activities will contribute to their grade (at least in a strong, indirect way) then they may not complete the activities. One strategy if this becomes a problem is to incorpor-

ate vLog review quizzes and to grade the Word Banking components. Knowmia.com or Zaption.com are two educational technologies

by which basic assessments may be smoothly integrated with media.

1. What c	ompetencies and objectives must the student master? (pull learning objectives from Syllabus)
	For this introductory lesson, I have not explicitly pulled out learning objectives from the Syllabus.
2. What a	ssessment, test items, and checklists can I use to determine whether students are competent? (must
match the	e learning objectives)
	Basic reflection on student initial input for the Word Bank exercise should be employed to identify misconceptions
	and build off of students' prior knowledge.
3. What is	the overall lesson outline and concept progression for this lesson?
	See the lesson outline at the top of this lesson plan.
4. How do	pes this lesson relate to the previous and/or upcoming material?
	This introductory lesson relates to the previous unit's (Electricty & Magnetism) material through periodicity (e.g., "wiggling" charges) and wave nature (e.g., electromagnetic waves). The accompanying theme of "Energy first" is continued as waves are explained as a "way to transfer Energy." Force and Motion concepts (e.g., acceleration, inertia) are explicitly called on to explain wave phenomena (e.g., wave speed dependence on a medium's characteristics).
Development Phase	
1. How sh	ould I create the lesson and organize content; what media will be used?
	What is my overall delivery strategy (e.g., media, laboratory) YouTube is used to host the vLog entry (with
	comments enabled). GoogleDrive is used for the Word Bank.
	Do I have examples of correct performance for this lesson's learning objectives? Prior units will have
	included vLogs as resources and Word Banking. These prior experiences serve as the "examples of correct
	performance."
	How will student performance be assessed for the learning objectives in this lesson? There are no
	formal assessments setup for this short online lesson. However, see the previous notes on potential vLog quizzes and on the need to treat Word Bank contributions seriously.
2. What ir	nstructor and student activities should be included?
	What forms of additional support are available (e.g., educational technology, current events)
	Knowmia.com or Zaption.com may be used to incorporate quizzes alongside of vLogs if needed. Tsunami or other
	tectonic plate boundary phenomena are often available, or developments in physics (e.g., gravitational waves)
	which can be incorporated in this early phase of the unit.
3. How do	p provide practice and feedback for students?
	What opportunities will there be for students to check their understanding and practice skills or tasks?
	The Word Bank contributions will be addressed early on in the next lesson. YouTube comments may be used for
	students to check their understanding on vLog entries.
	At what points and will confirming and corrective feedback be provided? Primarily this will happen for
	this content in the face-to-face lesson which follows.

Again, if necessary to build participation and completion of vLog viewing, basic quiz questions may be constructed. For this first run, however, these "motivational quizzes" were not deemed necessary.

Imp	lementation Phase	
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1. How do	I motivate students?
	How will I introduce the lesson? The vLog entry is designed to be both interesting and entertaining. It is meant
	to draw students into the subject matter.
	How do I facilitate confidence and ensure satisfaction? Students shold be familiar with this pattern of
	introduction by this point. Word Banking is introduced at a basic level for each unit and students co-construct
	meaning for new vocabulary as it is presented.
2. What o	pportunities will there be for higher order thinking?
	Very little, at this point. The point of this lesson is knowledge-building, not higher order thinking.
3. What lo	ogistical considerations are there in my use of presentation and activity media?
	The vLog is to include English-language closed-captioning, which can be a challenge and is time-consuming to construct. It is important to have a method of participant-tracking in place for the Word Banking document. This can be done (at least on the honor system) by having students include their initials after their contributions or any changes (or by being fancy with fonts).
4. What s	ummarization strategy will be employed at the end of this lesson?
	The Word Banking is the student-centered summarization activity. They pull key ideas from the vLog content and begin to build definitions together.
5. What a	re the time considerations anticipated for each component of this lesson?
	All vLogs are kept as short as possible, and it is expected that students will spend about fifteen or twenty minutes
	engaged in the Word Bank summarization activity. Overall, this short introductory lesson should take approximately 30 minutes.
6. How ar	e each of the guiding principles for content design and delivery from the "Human Body Connections" Theo
Framewo	rk represented used to support instruction and lesson development?
	DP1 - Content is directly related to students' real life experience: human body parts as sound producers.
	wave phenomena as observed in a small pool, common echoes
	DP2 - Students co-construct meaning through the development of a shared language and peer
	engagement: Word Banking open for students to begin building shared definitions and resources
	DP3 - Terminology is foundationally introduced with an Energy-first approach which is continued
	throughout the course: terminology should take an on Energy flavor and/or be guided by prior Energy knowledge
	DP4 - Students are actively engaged with the content cognitively, socially, and physically: peer construction of knowledge through Word Banking
	DP6 - Concepts are introduced contextually using a unifying, relevant theme: human body applications are provided early on as examples of wave-involved phenomena
	DP7 - Biological applications are explored in conjunction with physics content: basics of biology of sound

DP8 - Course adheres to high standards of content delivery and design: use of online video-blogging

DP10 - Applications beyond the unifying theme enrich the learning experience: non-human body

production (e.g., voice) are laid out

software and asynchronous collaboration software

connections examples are employed in the vLog

This admittedly will not work for all students, but it should be more motivating than online notes!

	How well did students perform on the summative assessments? This has yet to be determined. Student performance is not a part of this study.	
	What trends were noticed in student feedback at the end of the unit (or course)? This has yet to be determined. Student performance is not a part of this study.	
2. Which	experts should review the materials before implementation?	
	Physics and other Science Education experts (PhDs/EdDs), especially those with curriculum development experience.	These are to be completed in post-implemenation as part o
3. Which	changes should be made to improve the course after it is presented?	deliberate reflective practice.
	This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.	
4. Do the	e results justify the time and effort spent developing the course?	
	This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.	

ADDIE COMPO	NENT	NOTES, ANECDOTES, and HELPFUL HINTS:
Analysis Phase		
1. Is	training really necessary?	
	What are the performance goals of this lesson? (with syllabus and other objective references) Include	
	a general introduction to the lesson. This face-to-face component builds on the foundational knowledge in place and asks students to engage in guided inquiry activities towards a deeper understanding of wave nature. Several wave phenomena are also explored along with opportunities for students to gauge their understanding. The following Measurable Performance Objectives are addressed: 4.1 - Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave, sonic boom, standing wave, node and antinode. 4.4 - Explain the difference between longitudinal and transverse waves. 4.5 - Define infrasonic, ultrasonic, compression, rarefaction, natural frequency, forced vibration, and resonance. 4.6 - Explain how the above terms relate to sound waves and their production. 5.8 - Define current, alternating current (AC), direct current (DC) and resistance. 6.3 - Investigate and explain the production.	
	What knowledge, skills, and attitudes are required? The greatest challenge for this lesson is that it asks	As you increase the inquiry requirement you should also increase th
	students to engage in guided inquiry. Students typically do not feel comfortable in inquiry learning.	checks for understanding. I model this in the lesson plan. Students
2. W	ho are the students?	crave affirmation that they are at least on the right track.
	Students will be very physically involved in much of this lesson. Potential misconceptions may be present? Students will be very physically involved in much of this lesson. Potential misconceptions include the idea that our voices are made up of single frequencies, that longer pendula swing faster, and that sound waves are transverse waves. When it comes to superposition, students may only add pulses together at the peak instead of at all points in the pulse (Kennedy & de Bruyn, 2011, p. 1159). Some students also hold to the misconception that wave intensity is related to wave speed instead of tension and mass density (p. 1160). They are also uncertain about what happens even when you complete a single "jerk" to a string (Caleon & Subramaniam, 2013, p. 659) which will become relevant during some of the hands-on inquiry activities. Students may also believe that waves permanently cancel each other out due to destructive interference (Stepans, 1996, p. 174). What special needs or constraints exist for these students? It is important to ask whether students are relevant during to the basis of the provision inquiry activities in the loberatory. I have had students whether students are relevant due to destructive interference (Stepans, 1996, p. 174).	
	sensitive to sound or flashing lights before investigating waves in the laboratory. I have had students who are either tone deaf or even who experience physical pain when exposed to louder sounds or certain frequencies. I tend to avoid strobe effects since students may not be aware of their own sensitivities (it is better to prevent seizures and skip the strobe light!).	
3. W	'hat equipment, resources, and facilities are available?	
	Is the lab space adequate for this lesson? There is adequate space for long-lines of students, and the white board at the front of the room allows for completion of Pfister & Laws' "The Human Oscilloscope" activity.	
	Is additional support needed for course delivery? There is the potential for student helpers in demonstrations of wave phenomena (e.g., standing wave patterns). The other activities also leng themselves to having students lead the class instead of being instructor-focused.	
	How can job conditions be mirrored in this lesson (e.g., problem- or situation-based)? Cardiography (e.g., "motion mode") is an important aspect of sonography. Also, the hands activity can be used to introduce future sonographers to the idea that small movements in the hand can result in wide sweeps of space (which effectively alters temporal resolution in ultrasound images).	

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Desi	gn.	۲ľ	iase

1. What competencies and objectives must the student master? (pull learning objectives from Syllabus)

4.1 - Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave, sonic boom, standing wave, node and antinode. **4.4** - Explain the difference between longitudinal and transverse waves. **4.5** - Define infrasonic, ultrasonic, compression, rarefaction, natural frequency, forced vibration, and resonance. **4.6** - Explain how the above terms relate to sound waves and their production. **5.8** - Define current, alternating current (AC), direct current (DC) and resistance. **6.3** - Investigate and explain the properties of periodic motion in the laboratory.

2. What assessment, test items, and checklists can I use to determine whether students are competent? (must match the learning objectives)

There are two "Check for Understanding" formative assessment opportunities in this lesson. Additionally, WebAssign and Exam questions have been selected for summative assessments. *(See the WebAssign and Exam questions documents which are matched to the Measurable Performance Objectives).*

3. What is the overall lesson outline and concept progression for this lesson? See the lesson outline at the top of this lesson plan.

4. How does this lesson relate to the previous and/or upcoming material?

Students are now asked to investigate through inquiry and other methods the basic characteristics of waves which they were introduced to in the previous lesson. Much of what students complete in this lesson is built on in the subsequent lesson (e.g., heart rate measurements foreshadow the carotid artery activity, and the "Do the Wave" activity sets the stage for the more complex, whole-class standing wave patterns).

Development Phase

1. How should I create the lesson and organize content; what media will be used?

What is my overall delivery strategy (e.g., media, laboratory) Students delve into the topic with guided inquiry and then are given very hands-on, whole-class, bodily-engaging activities to help them form even stronger **Do I have examples of correct performance for this lesson's learning objectives?** Online simulations (e.g., Interactive Physics or PhET Simulations) can act as very good examples of "ideal wave phenomena." However, this might prove more educational if kept in a confirming role after students have already explored and made their attempts and observations (and drawn their own conclusions about how waves act).

How will student performance be assessed for the learning objectives in this lesson? Formatively, there are two "Check for Understanding" activities aimed at key ideas (and typically confusing ones). These concepts also have summative representation in both Exam questions and WebAssign questions.

2. What instructor and student activities should be included?

What forms of additional support are available (e.g., educational technology, current events) There are numerous online simulations (mentioned previously) to help confirm or refine students' understandings. These also represent great opportunities to compare and contrast real-world vs. ideal-world environments. Some of the simulations do allow for real-world simulation (e.g., hysteresis).

3. How do I provide practice and feedback for students?

What opportunities will there be for students to check their understanding and practice skills or tasks? Two literal "checks for understanding" are provided in this lesson. The bulk of the activities are meant for students to experiment with their inquiry-drawn conclusions (literally putting them to the test and building on them in diverse applications).

At what points and will confirming and corrective feedback be provided? The formative assessment points that are integrated into the lesson are primarily meant for this purpose. However, depending on need and opportunity, I recommend some level of engagement with the educational technologies (i.e., computer simulations) previously discussed. The WebAssign activities linked to this content will provide corrective feedback prior to examlevel assessment.

Students should be coming up with their own questions during these experiments. If they are not being forthcoming, take the time to elicit questions and observations from them (e.g., what was difficult to do physically; how does this relate to actual wave media and

motion?) If you have students who are unable to perform certain

activities, identify alternatives (e.g., wheel-chair bound students can be a "forced node" or they can produce standing waves with ropes or springs).

Implementation Phase

1. How do I motivate students?	
How will l introduce the lesson? The Word Banking review + revision activity is meant to engage students socially and show how their contributions and ideas work into the whole picture. This is similar to the value of whole-class brainstorming, but with more structure and a potentially more obvious (to the student) purpose.	
How do I facilitate confidence and ensure satisfaction? Not only am I acknowledging the "whole student" by engaging them cognitively, socially, and physically, but the diversity of practice applications (devoid for the moment of grades) should help students feel more comfortable with their ideas.	The challenge here is to help students feel like their input is valid. Students will typically fear inquiry-based courses because they feel that they are not "being taught" the content. It is important for the
2. What opportunities will there be for higher order thinking? Beyond the Word Banking, students jump right into guided-inquiry activities. Out of these they will form their base	instructor to build up a classroom culture of inquiry (this is where the "scaffolded inquiry approach" is so crucial). If you have not made
3. What logistical considerations are there in my use of presentation and activity media?	students comfortable with inquiry, then you will continue to face kick-back by these points where they are being asked to contribute
Besides basic laboratory equipment, since the students' bodies make up much of the "equipment" needed for these activities room size must always be considered. Hallways may come in handy depending on the layout of the classroom! Preparation should include back-up plans and access to alternative forms of instruction (e.g., fall-back on traditional simulations or basic rope/spring activities as demonstrations if a particular student or group need to see the concept played out in a different way).	to a shared understanding. This is why practice, a clear goal, and opportunities for students to confirm that their understanding is in line with your expectations are so crucial. Much of that is dependent on how you, as a teacher, respond to student questions and how you
4. What summarization strategy will be employed at the end of this lesson?	tie their feedback into the overall unit/course. Now you begin to see
A poem recitation on Fast Fourier Transforms is given to help tie in this tool. A return to the Word Bank by the end of the lesson is always called-for, as this should be considered a "living document."	the power of the Word Bank!
5. What are the time considerations anticipated for each component of this lesson? By mixing a strong social component (review and revision of the Word Bank) with strong physical action and team- building exercises (quite literally), there is incredible opportunity for generative feedback and questioning. It will be important to keep the class moving through the activities, so logistically it may be good to ask the students to add new understandings to their Word Bank (recall: online shared document which can be modified by multiple users simultaneously) as they go through the activities.	
6. How are each of the guiding principles for content design and delivery from the "Human Body Connections" Theo Framework represented used to support instruction and lesson development?	pretical
DP1 - Content is directly related to students' real life experience: Life without waves is considered, human voice production is investigated, complete a comparison of how hand size affects wave creation; heart rates all based in the everday human experience, among other activities	
DP2 - Students co-construct meaning through the development of a shared language and peer	
DP3 - Terminology is foundationally introduced with an Energy-first approach which is continued	

throughout the course: Integrated into Word Banking and guided-inquiry activities. Students feel changes in

energy-requirements as they physically move their bodies to create wave forms.

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	DP4 - Students are actively engaged with the content cognitively, socially, and physically: Students are continually refining their understanding of wave formation and characteristics as they go through both thought-labs
	and physical activities to verify or revise these based on direct experience.
	DP5 - Concepts are scaffolded by being introduced as class inquiry demands: This is the heart of the Word Bank construction process (it grows as students need it to grow). Based on what students learn through their inquiry and physical activities, their shared documentation of this can grow organically.
	DP6 - Concepts are introduced contextually using a unifying, relevant theme: The Human Body Connections theme is salient throughout these activities.
	DP7 - Biological applications are explored in conjunction with physics content: Concepts such as heart rate, vocal "cords", and other aspects of human physiology are integral parts of the content. These often were inspired by typical biophysics topics.
	DP8 - Course adheres to high standards of content delivery and design: Again central to one of the Design Principles, the Word Banking review and revision process works to provide a more seamless transition between inclass and online collaboration. In this way, it takes on both synchronous and asynchronous supporting roles.
	DP9 - Course embeds opportunities to explore and practice career-relevant skills for sonography
	and/or education majors: The best example of this, primarily for Sonography-bound students, is the heart rate activity where they begin to graph waveforms (foreshadowing "M-Mode" in ultrasound physics).
	DP10 - Applications beyond the unifying theme enrich the learning experience: Both of the guided- inquiry activities make extensions beyond the Human Body Connections theme. Additionally, the "O FFT!" poem breaks from this theme to consider applications of the Fast Fourier Transform.
valuation Phase	
1. How do	I know if my course has been successful?
	How well did students perform on the summative assessments? This has yet to be determined. Student
	performance is not a part of this study.
	What trends were noticed in student feedback at the end of the unit (or course)? This has yet to be determined. Student performance is not a part of this study.
2. Which e	experts should review the materials before implementation?
	Physics and other Science Education experts (PhDs/EdDs), especially those with curriculum development experience
2 Which	banges should be made to improve the source after it is presented?

- 3. Which changes should be made to improve the course after it is presented? This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.
- 4. Do the results justify the time and effort spent developing the course? This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.

It is so crucial to again teach the ideal-world physics in light of what

the real-world experiences teach students. The power of this approach is that students are already disbelieving of ideal environments because life teaches them otherwise. By acknowledge the real-

world, you can reframe what students experience and help them to recompartmentalize these alongside of ideal-world (i.e., "exambased") physics concepts.

These are to be completed in post-implemenation as part of deliberate reflective practice.

ADDIE COMPONEN	т	NOTES, ANECDOTES, and HELPFUL HINTS:
Analysis Phase		
1. Is train	ning really necessary?	
	What are the performance goals of this lesson? (with syllabus and other objective references) Include	
	a general introduction to the lesson. This lesson adds to the experiences and concepts from the previous lesson and provides further physical and social activities to engage students and provide them with practice opportunities. The strength of this lesson is its diversity of applications and opportunities for students to consider concepts from multiple perspectives. The following Measurable Performance Objectives are addressed: 2.2 - List and identify units of measure for distance, time, speed, velocity, and acceleration. 2.3 - Calculate speed and acceleration from their definitions. 3.3 - Describe the microscopic character of liquids, solids, and gases. 4.1 - Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave, sonic boom, standing wave, node and antinode. 4.2 - Explain how frequency, period, wavelength, and wavespeed are interrelated. 4.3 - List and identify units of measure for frequency, period, wavelength, and wavespeed. 4.5 - Define infrasonic, ultrasonic, compression, rarefaction, natural frequency, forced vibration, and resonance. 4.6 - Explain how the above terms relate to sound waves and their production. 6.1 - Investigate and explain the properties of periodic motion in the laboratory. 6.5 - Investigate and explain the properties of heat in the laboratory.	
	What knowledge, skills, and attitudes are required? For this lesson, a typical human experience (e.g., cold vs. hot, sunlight, awareness of one's own heartbeat) will serve them well. They will need to be able to switch smoothly between whole-group physical activities, whole-group discussions, and individual checks for understanding.	
2. Who a	re the students?	
	What knowledge, skills, and attitudes are already in place? What misconceptions may be present? Again, basic self-awareness is important. For the typical student, these activities and discussions will relate directly to their own lives (in fact unavoidably in most cases). The major problem in terms of misconceptions is that the real world is not as simple as ideal world physics. E.g., the "Chattering Teeth" activity will in most cases not yield a uniform frequency or amplitude over time. A common misconception among students is that wave speed depends on frequency (Kennedy & de Bruyn, 2011, p. 1159, Pejuan et al, 2012, p. 673. Stepans, 1996, p. 174). Students also may believe that the speed of sound is greater in the direction in which the source is moving (Pejuan et al, 2012, p. 683), which has direct implications for the Doppler activity. In terms of units, students tend to confuse frequency with time due to their close relationship (Stepans, 1996, p. 174).	This lack of uniformity is actually very instructive, especially for ultrasound-bound students (e.g., in "Coded Excitation" applications)
	What special needs or constraints exist for these students? A few of the activities (e.g., E-M spectrum, Standing Wave Pattern) require some decent physical coordination. Another constraint which is salient through all of the lessons is whether students will be willing to engage in conversation that reveals their current level of concept comprehension.	The latter is of course an ongoing concern for all classroom environ- ments. The former, however, may act as a good opportunity for team levity. Be sure to take advantage of these opportunities and explain
3. What e	equipment, resources, and facilities are available?	(potentially through simulations or graphics) how ideal-world cases
	Is the lab space adequate for this lesson? The lab space is adequate, but the hallway space is better suited for some of the whole-group activities.	are "meant" to play out. In fact, it might prove useful to record students (or have a designate
	Is additional support needed for course delivery? It might be useful to pull in someone who uses ultrasound technology to demonstrate the carotic artery scan. I have such a person and facility within a 30-second walk, but this is not an option for most instructors. Online examples may be used in place of this to make the connection between the simulated scan and the actual process (Sonosite.com and it's YouTube channel are excellent resources).	"video recorder") to review in class in slow-motion what is occuring. This is also a good way to involve students who cannot otherwise partake in the more physical aspects.
	How can job conditions be mirrored in this lesson (e.g., problem- or situation-based)? Future teachers should be picking up on the heavily kinesthetic teaching methods and classroom engagement techniques, while future sonographers get exposed directly to a simulated (and potentially "live") ultrasound scan to connect pulse to what they feel and see at their carotic artery.	This is also a direct application of doppler technology for blood cell motion (i.e., blood flow dynamics).

Design	Phase
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1. What competencies and objectives must the student master? (pull learning objectives from Syllabus)

2.2 - List and identify units of measure for distance, time, speed, velocity, and acceleration. 2.3 - Calculate speed and acceleration from their definitions. 3.3 - Describe the microscopic character of liquids, solids, and gases. 4.1 -Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave, sonic boom, standing wave, node and antinode. 4.2 - Explain how frequency, period, wavelength, and wavespeed are interrelated. 4.3 - List and identify units of measure for frequency, period, wavelength, and wavespeed. 4.5 - Define infrasonic, ultrasonic, compression, rarefaction, natural frequency, forced vibration, and resonance. 4.6 - Explain how the above terms relate to sound waves and their production. 6.1 - Investigate and explain linear motion in the laboratory. 6.3 - Investigate and explain the properties of periodic motion in the laboratory. 6.5 - Investigate and explain the properties of heat in the laboratory.

2. What assessment, test items, and checklists can I use to determine whether students are competent? (must match the learning objectives)

There are two "Check for Understanding" formative assessment opportunities in this lesson. There is also an Exit Ticket aimed at providing timely and anonymously-solicited feedback. Additionally, WebAssign and Exam questions have been selected for summative assessments. (See the WebAssign and Exam questions documents which are matched to the Measurable Performance Objectives).

3. What is the overall lesson outline and concept progression for this lesson? See the lesson outline at the top of this lesson plan.

4. How does this lesson relate to the previous and/or upcoming material?

This content is a direct progression from the previous lesson. Looking ahead, these skills students have built (e.g., wave speed calculations, ray diagramming) are crucial to completing the activities in the upcoming lesson (e.g., human eye creation).

Development Phase

1. How should I create the lesson and organize content; what media will be used?

What is my overall delivery strategy (e.g., media, laboratory) This is a face-to-face lesson dependent heavily on classroom discussion where students add to a shared understanding (based again on shared experiences); strong use of datalogging + probe technology in conjunction with lower-tech students-as-apparatus techniques.

Do I have examples of correct performance for this lesson's learning objectives? As with the previous lesson, online simulations (e.g., Interactive Physics or PhET Simulations) can act as very good examples of "ideal wave phenomena." This could be especially important for the "messier" activities where students are really challenged to produce waveforms.

How will student performance be assessed for the learning objectives in this lesson? Formatively, there are two "Check for Understanding" activities aimed at key ideas (and typically confusing ones). These concepts also have summative representation in both Exam questions and WebAssign questions.

2. What instructor and student activities should be included?

What forms of additional support are available (e.g., educational technology, current events) Access to actual ultrasound technologists could prove very useful, but the online resources (e.g., SonoSite eLearning videos) can also help fill that role. All students should be given access to datalogging equipment -- this is truly a skill all students should practice, especially future teachers who have responsibilities in the classroom (just search the Next Generation Science Standards for examples of this!)

3. How do I provide practice and feedback for students?

What opportunities will there be for students to check their understanding and practice skills or tasks? Two literal "checks for understanding" are provided in this lesson. Students engage in activities that challenge their newly built understandings from the prior lessons (in other words, they are practicing and testing at the same time).

At what points and will confirming and corrective feedback be provided? As with the prior lesson, several formative and summative assessment points are built into this lesson. These are all aimed at providing very timely and corrective feedback. Discussions resulting from students' own experiences (i.e., from the activities) will also act to tie-in concepts and scaffold new ideas (i.e., students' questions "demand" new concept introduction to move further and see a larger picture).

These are 21st century relevant skills that all students should be engaged with, but so urgently for future educators. Sonography students who are asked to constantly engage with hands-on technology will also gain much from interacting with these tools.

mp	lementation	Phase
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1. How c	l ot	motivate	stuc	lents?
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How will lintroduce the lesson? I hook students by challenging the misconception that blankets or coats are naturally "warm" objects.

How do I facilitate confidence and ensure satisfaction? Just as I stated for the previous lesson, not only am I acknowledging the "whole student" by engaging them cognitively, socially, and physically, but the diversity of practice applications (devoid for the moment of grades) should help students feel more comfortable with their ideas.

2. What opportunities will there be for higher order thinking?

By starting the lesson off with a challenge of a common misconception, I hope to set the stage for higher order thinking and reasoning. Also, by making students responsible for acting out wave phenomena, they must go through the thought process to create this action. This approaches higher order thinking.

3. What logistical considerations are there in my use of presentation and activity media?

There will be a mix of data-logging hardware + software along with lower-technology activities. The flow between these must be as smooth as possible.

4. What summarization strategy will be employed at the end of this lesson?

The standing wave pattern will incorporate much of what students were required to learn, while an Exit Ticket helps to ensure that I catch remaining "big questions" from students.

5. What are the time considerations anticipated for each component of this lesson?

With strong discussion points involved, there is great opportunity to let the talks run away beyond useful, generative feedback. A strategy is to use the Word Bank during these activities (again, as a "living, always-accessible document") to give students a sense of when and whether their discussions have really added to the ongoing course dialogue.

6. How are each of the guiding principles for content design and delivery from the "Human Body Connections" Theoretical Framework represented used to support instruction and lesson development?

DP1 - Content is directly related to students' real life experience: "Warm" blankets, chattering teeth, pulses - all typically unavoidable experiences!

DP2 - Students co-construct meaning through the development of a shared language and peer

engagement: Paired here with shared experiences (e.g., warmed skin) and whole-group creation of complex wave phenomena, students will modify their understandings together.

DP3 - Terminology is foundationally introduced with an Energy-first approach which is continued

throughout the course: Discussions of infrasound, ultrasound, the E-M spectrum, and what types of energies are present in specific circumstances (e.g., energy flow for an electric toothbrush) carry on the Energy-first theme.

DP4 - Students are actively engaged with the content cognitively, socially, and physically: Strong discussions thread their way as a theme throughout this lesson. Basic inquiry activities like "Discovering the Doppler Effect" guide students toward understandings of key phenomena/concepts. Again, this lesson has students being very active physically to engage the senses (e.g., hearing, inertial effects).

DP5 - Concepts are scaffolded by being introduced as class inquiry demands: The prior lesson foreshadowed and built up to many of these concepts. They are for the most part next-step explorations to answer questions that would typically come up from these prior activities.

DP6 - Concepts are introduced contextually using a unifying, relevant theme: Most of the activities in this lesson directly engage or relate back to the human body and human locomotion (i.e., engaging students through kinesthetic teaching activities).

DP7 - Biological applications are explored in conjunction with physics content: An emphasis is placed on surface and superficial structures (e.g., skin, the carotid artery).

Challenging misconceptions will not always be attractive to students. Be prepared to have students who hold onto their misconceptions for

much longer than others (or indefinitely). The hope is of course to

help students move beyond these, but they have spent far more time

with their misconceptions than with a physics concept. One goal of using Human Body Connections as a theme is to help students to use their own experiences as opportunities for reconceptualization.

By reframing experiences, you are not asking them to challenge large,

sweeping ideas. Instead you give them a chance to look at what

taught them the misconception in the first place and follow a more logically (self-led) path to real phenomena.

A way to ensure this smoother transition is to get the most out of a

single type of probe (e.g., microphone probe) instead of switching back and forth between very different probes.

This also can act as a gauge for the instructor as to when it is best to move on to the activities (which, again, are meant to elicit more feedback toward the shared understanding.

Recall that the Word Bank should be a freely accessible online document which can be modified even outside of this "schedule" of lessons.

Time must be taken to keep track of and address new questions

students come up with. It is possible to engage and explore these questions through additional online assignments, swapping of activities in upcoming lessons for comparable (content-matched) ones, or other methods. At times it may be as simple of finding an article which addresses a students' question, while at other times a

full experiment or demonstration is needed.

DP8 - Course adheres to high standards of content delivery and design: Beyond basic practices in formative assessment, the Exit Ticket as a way of checking where students are is aimed at reaching students who are not apt to field important questions.

DP9 - Course embeds opportunities to explore and practice career-relevant skills for sonography and/or education majors: A specific look at ultrasound is the heart of this DP, but understanding of simple

human body concepts (e.g., body heat) will support future Educators in their units.

DP10 - Applications beyond the unifying theme enrich the learning experience: The basics of ray diagramming in a less-common (and highly traditional) physics application helps broaden these applications. This is complimented by another traditional but (to students) novel and challenging application of standing wave patterns.

Evaluation Phase

1. How do I know if my course has been successful?

How well did students perform on the summative assessments? This has yet to be determined. Student performance is not a part of this study. What trends were noticed in student feedback at the end of the unit (or course)? This has yet to be determined. Student performance is not a part of this study.

2. Which experts should review the materials before implementation?

non experts should review the materials before implementatio

Physics and other Science Education experts (PhDs/EdDs), especially those with curriculum development experience.

Which changes should be made to improve the course after it is presented?
 This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.

4. Do the results justify the time and effort spent developing the course?

This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.

I started using these simple Exit Tickets only during the time of this study. It has helped significantly in that I receive immediate (and typically very honest) feedback from students. I then have time to prepare a response and extra help between then and the next faceto-face session. If you use this as a mid-lesson check, that is also valuable. E.g., having students complete an Exit Ticket prior to a tenminute break may allow adequate time to address questions and provide students with very timely feedback.

These are to be completed in post-implemenation as part of deliberate reflective practice.

	Lesson 4 of 7: Conceptual Physics	. Waves and Periodicity	v Unit: "Social Co	onstruction of Sound	Concepts
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	Т	NOTES, ANECDOTES, and HELPFUL HINTS:
sis Phase		
1. Is train	ing really necessary?	
	What are the performance goals of this lesson? (with syllabus and other objective references) Include	
	a general introduction to the lesson. An online lesson, this provides students with opportunities to explore simulations and develop their own physical (JELL-O, potentially) model of the human eye. Supplemented by video clips (e.g., vLog notes) and shored up by Word Banking, this online lesson is more about practice and summarization than expansion of applications. The following Measurable Performance Objectives are addressed: 4.1 - Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave, sonic boom, standing wave, node and antinode. 4.4 - Explain the difference between longitudinal and transverse waves. 4.6 - Explain how the above terms relate to sound waves and their production. 6.1 - Investigate and explain linear motion in the laboratory.	
	What knowledge, skills, and attitudes are required? This online lesson requires students to apply the same inquiry-tolerance which they have practiced in face-to-face settings. There is also a challenging, somewhat open-ended homework assignment which requires a significant amount of self-reliance and direction.	
2. Who ai	re the students?	
	What knowledge, skills, and attitudes are already in place? What misconceptions may be present? Ideally, students by this time are more comfortable with the mix of individual responsibility and group interplay. Some misconceptions for this lesson might be that thunder produces lightning (or that the waves involved travel at the same speeds), that air and water (both fluids) will act identically (not just similarly) when placed under compression, and either an oversimplification or overcomplication of the human eye. Students tend to have a very diverse view of what sound actually is, especially in terms of moving particles (Pejuan et al, 2012, p. 680). Some	Ray diagramming will be a developing-skill for students at this t Since they will only be exposed to very fundamental examples of diagramming, it is important to avoid distracting them from the n
	other common misconceptions regarding sound are that sound only travels through air, it can travel through space, it "can be produced without using any materials," or that the harder an object is hit is related to sound pitch (Stepans, 1996, p. 184).	points in conceptuar physics for this topic. Hamery, that right for
	What special needs or constraints exist for these students? For the homework assignment, students may not	a specific path and that this path can be altered using mechanic
	all have access to the same resources. However, this may lead to inventiveness/ingenuity in their approach to the assignment. It may also just as easily lead to frustration and lack of completion. The homework assignment is crafted with that latter thought in mind as it makes room for a "give it your best shot" mentality.	means. It is less important to note how different wavelength lig from the same source will follow slightly deviated paths, althou
3. What e	equipment, resources, and facilities are available?	how this difference affects other phenomena (like Rayleigh scat
	Is the lab space adequate for this lesson? This is unimportant for the online environment, given sufficient student access to online and computer resources.	tering, for instance).
	Is additional support needed for course delivery? The webquest leans on the continued availability of online resources.	One of the worst troubles with relying on online resources (espe ly simulations) is that the material might either a) be taken dow
	How can job conditions be mirrored in this lesson (e.g., problem- or situation-based)? Education students are given the opportunity to take both supporting and leadership roles in an online discussion environment. Sonography-bound students get the chance to construct their own physical models of the human eye (also highly suitable (and potentially memorable) for Education and other majors) which will be tested using basic LASERs in the upcoming class. This mimicks indirectly the sound-based scans ultrasound technologists perform on	b) lose its support within browsers. This has most recently man ed itself on common online physics simulation websites. For the reason, it is very important to check all links across common browsers prior to making assignments available.

1. What competencies and objectives must the student master? (pull learning objectives from Syllabus)

4.1 - Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave, sonic boom, standing wave, node and antinode. 4.4 - Explain the difference between longitudinal and transverse waves. 4.6 - Explain how the above terms relate to sound waves and their production. 6.1 - Investigate and explain linear motion in the laboratory.

2. What assessment, test items, and checklists can I use to determine whether students are competent? (must match the learning objectives)

The Discussion Board assignment will require students to engage in a "thinking group activity" that mirrors the inclass inquiry activities in which they have already engaged. The homework assignment primarily looks at ray diagramming and requires students to consider how the characteristics of media affect wave path. Additionally, WebAssign and Exam questions have been selected for summative assessments. (See the WebAssign and Exam questions documents which are matched to the Measurable Performance Objectives).

3. What is the overall lesson outline and concept progression for this lesson?

See the lesson outline at the top of this lesson plan.

4. How does this lesson relate to the previous and/or upcoming material?

What students discovered concerning the Doppler Effect they now revisit in an online format. Taking motion in nonvacuum environments, they look at sonic booms and other "high-speed interaction" phenomena. Other skills such as ray diagramming are also now applied in a more open-ended format.

Development Phase

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1. How should I create the lesson and organize content; what media will be used?

What is my overall delivery strategy (e.g., media, laboratory) Online, both whole-class asynchronous and individual activities.

Do I have examples of correct performance for this lesson's learning objectives? Practice problems with solutions are provided to help students along with the basic mathematics underlying these concepts. There do exist other online resources to help them with their homework assignment, but these are left to the student to uncover.

How will student performance be assessed for the learning objectives in this lesson? Formatively, there is an asynchronous opportunity for students to collaboratively build a better understanding of sound. The homework assignment is also formative in spirit. These concepts also have summative representation in both Exam questions and WebAssign questions.

2. What instructor and student activities should be included?

What forms of additional support are available (e.g., educational technology, current events) The webquest takes advantage of the diverse wealth of online resources available.

3. How do I provide practice and feedback for students?

What opportunities will there be for students to check their understanding and practice skills or tasks? The homework assignment affirmation of "correctness" (perhaps more accurately defined as "directionality") is delayed by a lesson. However, students are given multiple formal practice problems to cover their mathematics responsibilities for the content.

At what points and will confirming and corrective feedback be provided? Teacher involvement on the discussion board is assumed, although to what extent is up to the individual instructor.

Interestingly, there are actually ties between sonic boom physics and ultrasound applications. These are more explicitly revealed in the online webquest activity.

Again, as these may vary from semester-to-semester, it is important to check their broswer compatability and general accessibility prior to releasing the assignment. If you find that a component needs to be replaced, there is little need for teacher creativity...in my experience, physics simulations are often found duplicated on different platforms many times over.

I do not recommend a completely hands-off approach. At the very least, I encourage "cheer-leading" frequently to maintain your

Implementation Phase

1. How do I motivate students?

How will I introduce the lesson? The lesson is introduced through the use of a vLog "summary" of content and activities to-date. This is to help provide grounding and a sense of direction for the unit. With so many activities, it might also serve to help students see that each component is truly part of a whole (although it is my underlying suposition that the overarching theme of Human Body Connections makes this somewhat more explicit).

How do I facilitate confidence and ensure satisfaction? Giving importance to each student voice and idea is crucial, here. Word Banking is still a main component as students build their shared understanding of the physics concepts.

2. What opportunities will there be for higher order thinking?

The online discussion is meant to act as a forum for this. It is also hoped that the homework assignment will push students individually towards higher order thinking in order to produce a somewhat realistic model of the human eyeball.

3. What logistical considerations are there in my use of presentation and activity media?

It will be crucial to ensure that all online resources are still active and accessible to all students.

4. What summarization strategy will be employed at the end of this lesson?

Student-based summarization for this lesson is primarily tied-up in Word Banking, although the asynchronous nature of the discussion board makes room for this there as well.

5. What are the time considerations anticipated for each component of this lesson?

It is difficult to gauge time for the discussion board activity, but it is important that students understand the expectation that they contribute early on in the assignment period to allow time for frequent returns/additions and continued conversations.

6. How are each of the guiding principles for content design and delivery from the "Human Body Connections" Theoretical Framework represented used to support instruction and lesson development?

DP1 - Content is directly related to students' real life experience: Everyday sound production and the "natural technology" of the human eye.

DP2 - Students co-construct meaning through the development of a shared language and peer engagement: Discussion board used as medium for online inquiry activity; continual development of Word Banking.

DP3 - Terminology is foundationally introduced with an Energy-first approach which is continued throughout the course: This is salient, of course, but makes is most strongly reinforced in the Word Banking activity.

DP4 - Students are actively engaged with the content cognitively, socially, and physically: Group discussions online replace face-to-face contacts, students are faced "with their own humanity" as they determine the basic state and nature of their own eyes.

DP5 - Concepts are scaffolded by being introduced as class inquiry demands: Students generate new ideas in the online discussion board.

DP6 - Concepts are introduced contextually using a unifying, relevant theme: Human Body Connections are very explicitly a part of the application-aspects of this online lesson.

DP7 - Biological applications are explored in conjunction with physics content: Biological sound-sources, visual accuity, and the function and structure of the human eye.

presence online. In my experience, discussion boards left to themselves yield only compliance-posts with very little genuine activity. If you find you have a group of students who are producing high levels of excellent interaction on their own, you might alter your approach accordingly.

Feel free to farm Word Bank additions/modifications based on the discussion board conversations. Just be sure to let students know plainly that you have made updates to the Word Bank based on what they have contributed to the conversation.

If a student requires a text-to-voice reader (e.g., if they are unable to

read text without the use of assistive technology), it may be import-

ant to replace or supplement particular online materials. The downside to many of these is that they are so heavily dependent on

graphics and lack the option of support for students with severe visual impairments.

	DP8 - Course adheres to high standards of content delivery and design: vLogging with closed captioning is employed to keep students "looking back" and "looking forward," students are engaged in online activities together (asynchronously), among other supportive components.	
	DP10 - Applications beyond the unifying theme enrich the learning experience: Thought-lab applications go beyond Human Body Connections, the webquest is based around transportation which is less obviously connected to the human experience, and the practice problems are made more generic to help students in transfer of skills and knowledge to other themes outside of the unifying theme.	
Evaluation Phase		
1. How do	I know if my course has been successful?	
	How well did students perform on the summative assessments? This has yet to be determined. Student performance is not a part of this study.	
	What trends were noticed in student feedback at the end of the unit (or course)? This has yet to be determined. Student performance is not a part of this study.	
2. Which e	experts should review the materials before implementation?	
	Physics and other Science Education experts (PhDs/EdDs), especially those with curriculum development experience.	These are to be completed in post-implemenation as part of
3. Which c	changes should be made to improve the course after it is presented?	deliberate reflective practice.
	This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.	
4. Do the r	results justify the time and effort spent developing the course?	
	This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.	

COMPONENT	NOTES, ANECDOTES, and HELPFUL HINTS:
lysis Phase	
1. Is training really necessary?	
What are the performance goals of this lesson? (with syllabus and other objective references) Include	
a general introduction to the lesson. Here students return to the face-to-face laboratory environment and mix cognitive inquiry activities with physical applications. It is in this lesson that light and sound as common wave scenarios are emphasized. It is also here that ultrasound physics is first very strongly visited. The following Measurable Performance Objectives are addressed: 4.1 - Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave, sonic boom, standing wave, node and antinode. 4.4 - Explain the difference between longitudinal and transverse waves. 4.5 - Define infrasonic, ultrasonic, compression, rarefaction, natural frequency, forced vibration, and resonance. 4.6 - Explain how the above terms relate to sound waves and their production. 4.7 - Identify the typical frequency range of human hearing. 6.3 - Investigate and explain the properties of periodic motion in the laboratory.	
What knowledge, skills, and attitudes are required? Much of this lesson is built around activities meant to provide students with opportunities to revise and add to their understanding of sound behavior. However, the early emphasis on light is designed similarly to the online thought experiments which drove the sound inquiry activity in the previous lesson. It therefore requires the same basic knowledge, skills, and attitudes.	
2. Who are the students?	
What knowledge, skills, and attitudes are already in place? What misconceptions may be present? This lesson again mixes whole-group generative activities with small-group explorations. Some major misconceptions (even by this point) may be that sound and light waves propogate through media identically, that sound produced from speakers does not interfere with other sound sources and reflections, and also (specifically pulled out to challenge misconceptions) that ultrasound scans are actual light-based images. There are many potential misconceptions on light, some of those most closely related to these activities being: "white light is colorless and pure," "a color filter adds color to a white beam," only mirrors reflect while other objects only absorb, the human eye gathers light (as if it were active and not passive), light only illuminates objects and "[makes] them visible" (Stepans, 1996, p. 200).	Remember that the Word Bank does not need to be abandoned simply because it does not feature directly in the lesson sequen For the last misconception, I have heard the idea (even at the medical professional's level) that there is a "light inside there"
What special needs or constraints exist for these students? Some students have hearing impairments.	allowing the ultrasound technology to "see" what is happening
Others speak very softly. Since hearing and voice projection are important components of basic classroom presence, these students are at a fundamental disadvantage without assistive technology or compensation methods.	inside of a patient. Tackling this misconception is not only reve ing for all students, it also seeks to avoid a rather embarrassin
3. What equipment, resources, and facilities are available?	professional situation!
Is the lab space adequate for this lesson? Lab tables and seating patterns are sufficient for these activities, especially since the purpose of some of these activities is to simulate the classroom environment.	
Is additional support needed for course delivery? Beyond basic lab and classroom equipment (e.g., movable speakers), there is no need for additional support in this lesson.	
How can job conditions be mirrored in this lesson (e.g., problem- or situation-based)? Both Education majors and Sonography Pool students are now asked to relate the Physics content specifically to their future careers.	

1. What competencies and objectives must the student master? (pull learning objectives from Syllabus)

4.1 - Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave, sonic boom, standing wave, node and antinode. **4.4** - Explain the difference between longitudinal and transverse waves. **4.5** - Define infrasonic, ultrasonic, compression, rarefaction, natural frequency, forced vibration, and resonance. **4.6** - Explain how the above terms relate to sound waves and their production. **4.7** - Identify the typical frequency range of human hearing. **6.3** - Investigate and explain the properties of periodic motion in the laboratory.

2. What assessment, test items, and checklists can I use to determine whether students are competent? (must match the learning objectives)

There a generalized "Check for Understanding" formative assessment opportunity in this lesson which can be applied to both sound and light applications. There is also an Exit Ticket aimed at providing timely and anonymously-solicited feedback. Additionally, WebAssign and Exam questions have been selected for summative assessments. (See the WebAssign and Exam questions documents which are matched to the Measurable Performance Objectives).

3. What is the overall lesson outline and concept progression for this lesson?

See the lesson outline at the top of this lesson plan.

4. How does this lesson relate to the previous and/or upcoming material?

This lesson takes the online discussion process for sound and translates it for light in the face-to-face setting. Each activity is based on introducing new concepts or taking previously explored wave and periodicity phenomena to the next cognitive level. The subsequent lesson will require students to teach these concepts in small groups made up of Sonography and Education majors. By seeding this lesson with direct applications in both disciplines, it sets the stage for students from the opposite major to consider those topics in both lights prior to being asked to work directly with their other-major counterparts.

Development Phase

1. How should I create the lesson and organize content; what media will be used?

What is my overall delivery strategy (e.g., media, laboratory) The lesson is delivered as face-to-face wholegroup and small-group laboratory activities.

Do I have examples of correct performance for this lesson's learning objectives? Students' own

experiences with classrooms and voice projection provide an excellent example of how "correct performance" examples can come directly from the "human experience." When students know what they expect of others, it opens the door for them to project these expectations back on their own performance.

How will student performance be assessed for the learning objectives in this lesson? Formatively, there is an understanding checkpoint which can be applied to both the majority of these objectives. The Exit Ticket strategy also makes an appearance. These concepts also have summative representation in both Exam questions and WebAssign questions.

2. What instructor and student activities should be included?

What forms of additional support are available (e.g., educational technology, current events) Basic online simulations and other computer software is available to run real-time ray diagramming. Students can compare the way LASER paths within their constructed eye model versus these computer models.

3. How do I provide practice and feedback for students?

What opportunities will there be for students to check their understanding and practice skills or tasks? Beyond the formal "Check for Understanding," each actitivy and demonstration is meant specifically to provide students with opportunities to challenge and refine their thinking.

At what points and will confirming and corrective feedback be provided? Each activity is designed so that confirming and corrective feedback fundamental to the purpose of their inclusion and placement.

Where students are physically unable to meet the needs of a traditional classroom environment, suggestions for technological and other-strategy supports could be offered.

Some of the simulation technology is very sophisticated, and the

mathematics of a true eye is complex based on surface curvature and other variations within the media that make up the eye. It would be prudent to keep things as simple as possible while still acknowledging the complexity of the eye.

Having extra lab components (e.g., lenses, polarized and unpolarized sunglasses, &tc.) will help address students' "but what happens when I _____?" questions. This way, they can explore their prior experiences within the laboratory setting more immediately instead

Implementation Phase
1. How do I motivate students?
How will I introduce the lesson? The Exit Ticket questions left by students most recently will be used to introduce this lesson. Since these are generated by students, themselves, they typically have been very attentive and (by this time in the course) have learned to look forward to this feedback.
How do I facilitate confidence and ensure satisfaction? Here is where the Word Bank as a living document should again be used to indicate to students that they are "on the right track" or "right on the mark" with what they are discovering in the activitites and resulting discussions/classroom-conclusions.
2. What opportunities will there be for higher order thinking?
Students need to improve on or modify their "classroom voice," which should require them to critically assess factors contributing to sound volume. The logic steps involved in the "Do you really see during an ultrasound scan" is another example of how students will need to challenge or strengthen their current understandings.
3. What logistical considerations are there in my use of presentation and activity media?
Since the homework discussion (on the eye model creations) is based on LASER testing, safe LASER practices must be in place. Also, it is assumed that there will be some diversity in their designs, so on-the-fly compensation (and potential alternative testing methods) should be in place.
4. What summarization strategy will be employed at the end of this lesson?
The Exit Ticket is a student-based summarization strategy. The diversity of ideas represented in this lesson make it difficult for an instructor-focused summarization, which is why the Word Banking process once again is a valuable tool.
5. What are the time considerations anticipated for each component of this lesson?
The LASER testing should not be allowed to take up too much time (certainly no more than 15-20 minutes) since this will not leave sufficient time for the guided inquiry and other exploration and discussion activities.
6. How are each of the guiding principles for content design and delivery from the "Human Body Connections" Theoret
Framework represented used to support instruction and lesson development?
DP1 - Content is directly related to students' real life experience: Direct applications within the guided inquiry activity, hearing assessments, and voice projection.
DP2 - Students co-construct meaning through the development of a shared language and peer
engagement: Word Banking continues, small group inquiry activities, range-distributions of hearing thresholds for the whole class, individual mapping towards construction of a map of sound amplitudes in a "theatre" setting, whole-class discussion on ultrasound image creation.
DP3 - Terminology is foundationally introduced with an Energy-first approach which is continued
throughout the course: Sub-theme continued through the use of Word Banking, also applied in guided inquiry setting.
DP4 - Students are actively engaged with the content cognitively, socially, and physically: This principle is represented in the majority of this lesson's activities.

of wasting opportunities to challenge any partial or complete misconceptions.

	DP5 - Concepts are scaffolded by being introduced as class inquiry demands: Explicitly done in a formal	
	guided-inquiry activity; carried over while conducting a whole-class "hearing test."	
	DP6 - Concepts are introduced contextually using a unifying, relevant theme: The human eye, human	
	hearing thresholds, and the use of light and sound waves in common experiences.	
	DP7 - Biological applications are explored in conjunction with physics content: Eye model creation, hearing tests, voice projection (vocal flaps); human internal physiology (ultrasound tie-in).	
	DP8 - Course adheres to high standards of content delivery and design: Closure of past Exit Tickets and use of new Exit Tickets in addition to continued use of the shared Word Banking	It might be prudent to backup unit Word Banks on a separate d
	DP9 - Course embeds opportunities to explore and practice career-relevant skills for sonography	sabotage and accidental erasure.
	and/or education majors: The end-of-lesson activities are both designed specifically around career expectations and tasks within the Education and Sonography fields.	
	DP10 - Applications beyond the unifying theme enrich the learning experience: The guided-inquiry activity extends beyond the Human Body Connections theme, and the sound interference pattern lab makes technology connections which are less specifically aimed at the human body (although there do exist specific connections to the human experience, which can encourage more generative "what if" or "what happens when" discussion).	
Phase 1. How do	o I know if my course has been successful?	
	How well did students perform on the summative assessments? This has yet to be determined. Student performance is not a part of this study.	
	What trends were noticed in student feedback at the end of the unit (or course)? This has yet to be determined. Student performance is not a part of this study.	
2. Which	experts should review the materials before implementation?	
	Physics and other Science Education experts (PhDs/EdDs), especially those with curriculum development experience.	These are to be completed in post-implemenation as part of
		deliberate reflective practice
3. Which	changes should be made to improve the course after it is presented?	
3. Which	changes should be made to improve the course after it is presented? This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.	
3. Which 4. Do the	changes should be made to improve the course after it is presented? This has yet to be determined. Reflective practice will ensure that this question is considered appropriately. results justify the time and effort spent developing the course?	

Lesson 6 of 7: Conceptual Physics, Waves and Periodicity Unit: "Student Teaching Sessions"

ADDIE COMPONENT NOTES, ANECDOTES, and HELPFUL HINTS: **Analysis Phase** 1. Is training really necessary? What are the performance goals of this lesson? (with syllabus and other objective references) Include It is up to the instructor as to whether students will be given the a general introduction to the lesson. Deceptively short, the bulk of this lesson is devoted to having students lesson assignments at the start of this session or in an earlier collaborate in mixed Sonography- and Education-major groups to design and deliver mini-lessons on waves and session. I believe there is value in having students brainstorm and periodicity concepts (as assigned by the instructor). The following Measurable Performance Objectives are develop mini-teaching lessons over a short period time, if only for addressed: 4.1 - Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, the fact that quick lesson planning is a professional eventuality. bow wave, shock wave, sonic boom, standing wave, node and antinode. 4.2 - Explain how frequency, period, wavelength, and wavespeed are interrelated. 4.4 - Explain the difference between longitudinal and transverse waves. 4.5 - Define infrasonic, ultrasonic, compression, rarefaction, natural frequency, forced vibration, and resonance. 4.6 - Explain how the above terms relate to sound waves and their production. What knowledge, skills, and attitudes are required? Students primarily need to be prepared to access resources and build lesson plans + presentations while building off of each other's strengths. They will be asked to work collaboratively with other-major students. Use of the Kahoot! whole-group quizzing format. 2. Who are the students? What knowledge, skills, and attitudes are already in place? What misconceptions may be present? The lessons so far have provided all students with opportunities to reflect on scenarios outside of their major. It is If any students are unfamiliar with Kahoot!, it takes only a short time assumed that students by this point in the course will have used Kahoot! in whole-class "competitions" previously. to provide an "orientation" to the system. This educational technol-Potential misconceptions will match prior misconceptions (although hopefully at this point addressed) since the topics used for the mini-teaching sessions are from all the prior lessons' content. ogy is cell-phone based, so strategic pairing or an alternative con-What special needs or constraints exist for these students? Up to this point, students may have grouped nection method should be employed as needed. themselves by major. Asking them to specifically use each other within a small group setting as human resources will of course necessitate a mixing of the majors! 3. What equipment, resources, and facilities are available? Is the lab space adequate for this lesson? For the Kahoot! quiz, the lab setup is functional enough. It may be desirable to change locations for the mini-teaching sessions, although this is not necessary. Students have seen the content teaching modeled in the lab room up until this point, in any case. Is additional support needed for course delivery? There is no additional support needed for these activities, although bringing in additional physics or sonography professionals for Q&A and/or rubric scoring is a possibility. How can job conditions be mirrored in this lesson (e.g., problem- or situation-based)? Nowhere are Education job conditions mirrored more perfectly than in the mini-teaching session. Ultrasound technologists often are called on to train new technologists (i.e., for "clinicals" during pre-service technologists' education), so this experience in mini-teaching may be one of the few opportunities they have in their education to practice teaching.

very end of class.

1 What co	omnetencies and objectives must the student master? (null learning objectives from Syllabus)
	4.1 - Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave sonic boom standing wave node and antipode 4.2 - Evolain how frequency, period wavelength and
	waves need are interrelated 44 - Evolain the difference between longitudinal and transverse waves 45 - Define
	infrasonic, ultrasonic, compression, rarefaction, natural frequency, forced vibration, and resonance. 4.6 - Explain
	how the above terms relate to sound waves and their production.
2. What a	ssessment, test items, and checklists can I use to determine whether students are competent? (must
match the	learning objectives)
	The Kahootl quiz is a formative assessment tool that engages the whole class. A separate rubric has been
	developed for the mini-teaching activity.
3. What is	the overall lesson outline and concept progression for this lesson?
	See the lesson outline at the top of this lesson plan.
4. How do	es this lesson relate to the previous and/or upcoming material?
	Each topic used to seed the mini-teaching assignments is based in the content from the previous lessons. The bulk
	of the subsequent (and final) lesson is further assessment.
Development Phase	
1. How sh	ould I create the lesson and organize content; what media will be used?
	What is my overall delivery strategy (e.g., media, laboratory) Whole-group formative assessment using
	digital quizzing technology; small-group mini-teaching experiences.
	Do I have examples of correct performance for this lesson's learning objectives? The Kahoot! quiz
	provides immediate corrective feedback, and the rubric will be provided to students to guide them toward correct
	performance.
	How will student performance be assessed for the learning objectives in this lesson? Kahoot! keeps track
	of student performance, although this will not be used summatively. The mini-teaching rubric will contain learning
	objective components based on the topics assigned.
2. What ir	structor and student activities should be included?
	What forms of additional support are available (e.g., educational technology, current events) The
	Kahoot! online quizzing system will be employed.
3. How do	I provide practice and feedback for students?
	What opportunities will there be for students to check their understanding and practice skills or tasks?
	Beyond the formative assessment, student "teachers" will be expected to field and respond to questions based on
	their knowledge of the physics content.
	At what points and will confirming and corrective feedback be provided? This is done immediately for the
	online quizzing program, and rubric feedback will be distributed to and discussed with students at the end of the

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Implementation Ph	lase		
1. How d	o I motivate students?		
	How will I introduce the lesson? Online quizzing tool in a "competition" format.		
	How do I facilitate confidence and ensure satisfaction? By requiring students to put together a product like this, they are being asked to stretch their understandings of the content into the realm of synthesis. "Ensuring" satisfaction is based on how well prepared students are at this point to teach the topics, but this is certainly a potential confidence-building activity. Strong feedback and sufficient time to review and discuss this feedback should help contribute to student satisfaction.		
2. What o	opportunities will there be for higher order thinking?		
	Again, students are being asked to put together a true "product" to be done well, it will require significant higher order thinking.		
3. What l	ogistical considerations are there in my use of presentation and activity media?		
	Student lessons must keep within the scope of their assigned topic. Otherwise, "above and beyond" student groups run the risk of covering another group's topic simply because it is closely related.		
4. What s	summarization strategy will be employed at the end of this lesson?		
	The entire class is basically a student-centered summarization.		
5. What a	are the time considerations anticipated for each component of this lesson?		
	Adequate time must be given for each mini-teaching team while still leaving time for adequate and timely feedback.		If you find you have no time left at the end of the presentations to distribute and discuss your feedback (or if you did not have sufficient
6. How a	re each of the guiding principles for content design and delivery from the "Human Body Connections" Theor	retical	time to leave adequate feedbak), then this may be done either at the
Framewo	ork represented used to support instruction and lesson development?		next face-to-face opportunity or via online means (either synchron-
	DP2 - Students co-construct meaning through the development of a shared language and peer		ously or asynchronously).
	engagement: Student teaching assignments.		
	DP4 - Students are actively engaged with the content cognitively, socially, and physically: Whole-class "competitive" quizzing, mini-lesson design and delivery.		
	DP9 - Course embeds opportunities to explore and practice career-relevant skills for sonography		
	and/or education majors: Integrated sonography + education roles in the mini-teaching experience.		
Evaluation Phase 1. How d	o I know if my course has been successful?		
	How well did students perform on the summative assessments? This has yet to be determined. Student performance is not a part of this study.		
	What trends were noticed in student feedback at the end of the unit (or course)? This has yet to be determined. Student performance is not a part of this study.		
2. Which	experts should review the materials before implementation?		
	Physics and other Science Education experts (PhDs/EdDs), especially those with curriculum development experience.		These are to be completed in post-implemenation as part of
3. Which	changes should be made to improve the course after it is presented?		deliberate reflective practice.
	This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.		
4. Do the	results justify the time and effort spent developing the course?		
	This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.		

MPONENT	NOTES, ANECDOTES, and HELPFUL HINTS:
Phase	
1. Is training really necessary?	
What are the performance goals of this lesson? (with syllabus and other objective references) Include	The journal reflection is crucial to understanding where students are
a general introduction to the lesson. This final lesson, fully online, is primarily based around practice and	individually and should be used in conjunction with other forms of
assessment. It makes some final connections to a common favorite of some students (i.e., music applications) and culminates in exam preparation, summative assessment via WebAssign, additional practice and shared language construction, and a journal reflection by the students for the unit. The following Measurable Performance Objectives are addressed: 4.1 - Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave, sonic boom, standing wave, node and antinode. 4.2 - Explain how frequency, period, wavelength, and wavespeed are interrelated. 4.3 - List and identify units of measure for frequency, period, wavelength, and wavespeed. 4.4 - Explain the difference between longitudinal and transverse waves. 4.5 - Define infrasonic, ultrasonic, compression, rarefaction, natural frequency, forced vibration, and resonance. 4.6 - Explain how the above terms relate to sound waves and their production. 4.7 - Identify the typical frequency range of human hearing. What knowledge, skills, and attitudes are required? Journaling is a skill on its own. Tolerance for and discipline in the proper use of exam preparation resources. The ability to apply physics concepts in mathematical	assessment. It is important to immediately use it to identify mis- understandings and provide timely feedback. Instead of providing students with an "ideal journal" that could cause them to constrain their flow of ideas, I suggest retroactive
and logical reasoning.	building of this journaling skill through detailed feedback on initial
2. Who are the students?	journal entries from prior units.
What knowledge, skills, and attitudes are already in place? What misconceptions may be present? As foreshadowed, by this point in the course journaling should be a deliberately honed skill. It also is not the first time students are asked to complete WebAssign-ments.	
What special needs or constraints exist for these students? The exam preparation resources can be time- consuming to use correctly.	Students should be forewarned to anticipate this, and they should be told how crucial and helpful exam preparation will prove.
3. What equipment, resources, and facilities are available?	
Is the lab space adequate for this lesson? Lab space is not a consideration in this online environment.	
Is additional support needed for course delivery? The music applications are somewhat supplemented by authentic scenarios (e.g., actual examples of music in action). The WebAssign activity includes built-in resources and an "ask your teacher"-type communication module.	
How can job conditions be mirrored in this lesson (e.g. problem, or situation-based)? Elementary	

1. What competencies and objectives must the student master? (pull learning objectives from Syllabus)

4.1 - Define amplitude, frequency, period, wavelength, wavespeed, interference pattern, Doppler effect, bow wave, shock wave, sonic boom, standing wave, node and antinode. **4.2** - Explain how frequency, period, wavelength, and wavespeed are interrelated. **4.3** - List and identify units of measure for frequency, period, wavelength, and wavespeed. **4.4** - Explain the difference between longitudinal and transverse waves. **4.5** - Define infrasonic, ultrasonic, compression, rarefaction, natural frequency, forced vibration, and resonance. **4.6** - Explain how the above terms relate to sound waves and their production. **4.7** - Identify the typical frequency range of human hearing.

2. What assessment, test items, and checklists can I use to determine whether students are competent? (must

match the learning objectives)

The Journal Entry is used to assess students' conceptualization of the physics content and activities from the unit. Additionally, WebAssign and Exam questions have been selected for summative assessments. (See the WebAssign and Exam questions documents which are matched to the Measurable Performance Objectives).

3. What is the overall lesson outline and concept progression for this lesson? See the lesson outline at the top of this lesson plan.

4. How does this lesson relate to the previous and/or upcoming material?

The connections to the previous lessons are primarily based on the fact that this lesson is heavily assessmentfocused. The unit that follows this final Waves & Periodicity lesson is based around Earth & Space Science. There are significant opportunities to discuss periodicity (e.g., Kepler's Laws of Planetary Motion; seismic waves) and revisit concepts from this unit (e.g., background radiation; the Greenhouse Effect).

Development Phase

1. How should I create the lesson and organize content; what media will be used?

What is my overall delivery strategy (e.g., media, laboratory) Online expansion of applications, exam preparation via written questions and corresponding video clips, online summative assessment.

Do I have examples of correct performance for this lesson's learning objectives? The exam preparation resources show fully worked-out and explained examples of correct performance; the WebAssign questions come packaged with integrated example questions.

How will student performance be assessed for the learning objectives in this lesson? WebAssign and Exam questions have been selected for summative assessments. *(See the WebAssign and Exam questions documents which are matched to the Measurable Performance Objectives).* Additionally, the unit's Journal Reflection activity is key for gaining a view of students' perspectives, conceptions, and relative importance or persistence of course content.

2. What instructor and student activities should be included?

What forms of additional support are available (e.g., educational technology, current events) YouTube is used as a platform for the Exam review explanations. There is the potential for current events in physics journals as they relate to musical applications (e.g., nanoscale development of musical instruments).

3. How do I provide practice and feedback for students?

What opportunities will there be for students to check their understanding and practice skills or tasks? The WebAssign-ment allows for multiple submissions, and the exam preparation questions are there for students to practice their concept application skills.

At what points and will confirming and corrective feedback be provided? Immediate feedback is provided for WebAssign activities. Exam questions will be seen on the final exam for the course, and so feedback is minimal in this area. This serves to further emphasize the importance of the formative and lower-stakes summative assessment activities/assignments used throughout the unit.

Implementation Pha	se		
1. How do	I motivate students?		
	How will I introduce the lesson? Musical applications are used with the hope that this will strike a chord with		
	students beyond simply "adding more physics content" didacticly.		
	How do I facilitate confidence and ensure satisfaction? Consistent and timely feedback on all activities		
	should support these components of the learning experience.		
2. What or	oportunities will there be for higher order thinking?		
	For the most part, this lesson is based more on knowledge application and practice than on higher order thinking opportunities.		
3. What lo	gistical considerations are there in my use of presentation and activity media?		
	Exam review materials need to be focused on the learning objectives (for accurate assessment) and should be easily accessible by all students across multiple platforms/browsers. For this reason, the YouTube video host was chosen to support the review video clips.		
4. What su	immarization strategy will be employed at the end of this lesson?		
	Journaling is the primary summarization strategy for students. Instructor-based summarization is wrapped up in the exam preparation materials.		
5. What ar	e the time considerations anticipated for each component of this lesson?		
	Students all progress at different paces through review materials, even when the video clip lengths are kept		
	manageable. Additionally, time should be given for help and feedback during the WebAssign period.		
6. How are	e each of the guiding principles for content design and delivery from the "Human Body Connections" The	oretical	
Framewor	k represented used to support instruction and lesson development?		
	DP1 - Content is directly related to students' real life experience: Musical applications (i.e.,		
	hobbies/interests).		
	DP2 - Students co-construct meaning through the development of a shared language and peer		
	engagement: Continued use of the Word Banking strategy.		
	DP3 - Terminology is foundationally introduced with an Energy-first approach which is continued		
	throughout the course: This is carried through with the online Word Banking document.		At times the Energy connections may not feature as obviously with
	DP4 - Students are actively engaged with the content cognitively, socially, and physically: Word Banking,		student feedback. This can be encouraged based on instructor
	online exploration, and individual journal entry.		guidance early on in the process, however.
	DP8 - Course adheres to high standards of content delivery and design: Online document sharing/collaboration, reflection, exam preparation strategies; immediate and corrective feedback through use of the WebAssign system.		
	DP9 - Course embeds opportunities to explore and practice career-relevant skills for sonography		
	and/or education majors: Journal-keeping and reflection will prove applicable in these career fields.		
	DP10 - Applications beyond the unifying theme enrich the learning experience: The exam preparation		
	and WebAssign questions are generally outside of the theme of Human Body Connections. The musical		
	applications activity is also purposefully not directly aimed at this theme.		
Evaluation Phase 1. How do	I know if my course has been successful?		
	How well did students perform on the summative assessments? This has yet to be determined. Student performance is not a part of this study.		
	What trends were noticed in student feedback at the end of the unit (or course)? This has yet to be		
	determined. Student performance is not a part of this study.		
2. Which e	experts should review the materials before implementation?		
	Physics and other Science Education experts (PhDs/EdDs), especially those with curriculum development experience.		These are to be completed in post-implemenation as part of
3. Which c	hanges should be made to improve the course after it is presented?		deliberate reflective practice.
5	This has yet to be determined. Reflective practice will ensure that this question is considered appropriately.		
4 Do than	esults justify the time and effort spent developing the course?		
4. DO the f	This has yet to be determined. Reflective practice will ensure that this question is considered appropriately		
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Appendix J

UNIT TEMPLATE

Analysis Phase

1. Is training really necessary?

What are the performance goals of this lesson? (with syllabus and other objective references) Include a general introduction to the unit.

What knowledge, skills, and attitudes are required?

2. Who are the students?

What knowledge, skills, and attitudes are already in place? What misconceptions may be present?

What special needs or constraints exist for these students?

3. What equipment, resources, and facilities are available?

Is the lab space adequate for this unit?

Is additional support needed for course delivery?

How can job conditions be mirrored in this unit (e.g., problem- or situation-based)?

1. Is there a task analysis to guide the design process, or must it be created?

2. What competencies and objectives must the student master? (audience, behavior/action, conditions, and degree/standard components must be represented)

3. What assessment, test items, and checklists can I use to determine whether students are competent? (must match the learning objectives)

Development Phase [Greater detail for this phase is provided in the Lesson Template]

1. How should I create the lesson plans and organize content; what media will be used?

What is my overall delivery strategy (e.g., media, laboratory)

Do I have examples of correct performance?

How will student performance be assessed for the learning objectives in this unit?

2. What instructor and student activities should be included?

What forms of additional support are available (e.g., educational technology, current events)

3. How do I provide practice and feedback for students?

What general strategies will be used to provide opportunities for students to practice the skills and concepts?

At what points and will confirming and corrective feedback be provided?

Implementation Phase	Greater detail	for this phase	is provided in th	e Lesson Template
	Levenue. actain			

1.11000 00	What about this unit may be the most interacting and attention grabbing for students (i.e. lasses
	what about this unit may be the most interesting and attention-grabbing for students (i.e., lesson
	introduction and sustaining motivation)?
	How are the learning objectives relevant to students' goals?
	How do I facilitate confidence and ensure satisfaction?
2 M/h = + =	
2. What o	pportunities will there be for higher order thinking?
3. What lo	gistical considerations are there in my use of presentation and activity media?
4. What g	eneral summarization strategies will be employed at the end of lessons?
5 W/bata	re the time considerations anticipated for this unit?
J. What a	
aluation Phase	-
1. How do	I know if my course has been successful?
	How well did students perform on the summative assessments?
	what trends were noticed in student recuback at the end of the unit (or course)?
2. Which e	experts should review the materials before implementation?
3. Which o	changes should be made to improve the course after it is presented?
	manulas institutes the stime and offerst energy devices the second of
4. Do the	results justify the time and effort spent developing the course?
Appendix K

LESSON TEMPLATE

esson Template (adapted from IREC's Solar Energy Education & Training Best Practices: Developing a Quality Course, 2012)
DDIE COMPONENT
nalysis Phase
1. Is training really necessary?
What are the performance goals of this lesson? (with syllabus and other objective references) Include a general introduction to the lesson.
What knowledge, skills, and attitudes are required?
2. Who are the students?
What knowledge, skills, and attitudes are already in place? What misconceptions may be present?
What special needs or constraints exist for these students?
3. What equipment, resources, and facilities are available?
Is the lab space adequate for this lesson?
Is additional support needed for course delivery?

How can job conditions be mirrored in this lesson (e.g., problem- or situation-based)?

Design Phase

1. What co	ompetencies and objectives must the student master? (pull learning objectives from unit plan)
2 What a	Less ment test items and checklists can Luce to determine whether students are competent? (must
2. What a	best in the second s
match the	
3. What is	the overall lesson outline and concept progression for this lesson?
4 How do	this losson values to the provinus and/or uncoming material?
4. HUW UU	
Development Phase	
1. How sh	ould I create the lesson plans and organize content; what media will be used?
	What is my overall delivery strategy (e.g., media, Jaboratory)
	Do I have examples of correct performance for this lesson's learning objectives?
	How will student performance be assessed for the learning objectives in this lesson?
2 What in	structor and student activities should be included?
2. Wildt II	
	What forms of additional support are available (e.g., educational technology, current events)
3. How do	I provide practice and feedback for students?
	What opportunities will there be for students to check their understanding and practice skills or tasks?
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	A such a such a such a still a sufficient a such a successful of a 10 - 11 - 12 - 12
	At what points and will confirming and corrective feedback be provided?

Implementation Phase

ntation Phase				
1. How do I motivate students?				
	How will I introduce the lesson?			
	How are the learning objectives relevant to students' goals?			
	How do I facilitate confidence and ensure catisfaction?			
	How do Fracintate commence and ensure satisfaction?			
2. What or	oportunities will there be for higher order thinking?			
3. What logistical considerations are there in my use of presentation and activity media?				
4. What su	immarization strategy will be employed at the end of this lesson?			
5. What ar	e the time considerations anticipated for each component of this lesson?			

6. How are each of the guiding principles for content design and delivery from the "Human Body Connections" Theoretical Framework represented used to support instruction and lesson development?

Content is directly related to students' real life experience: Students co-construct meaning through the development of a shared language and peer engagement: Terminology is foundationally introduced with an Energy-first approach which is continued throughout the course: Students are actively engaged with the content cognitively, socially, and physically: Concepts are scaffolded by being introduced as class inquiry demands: Concepts are introduced contextually using a unifying, relevant theme: Biological applications are explored in conjunction with physics content: Course adheres to high standards of content delivery and design: Course embeds opportunities to explore and practice career-relevant skills for sonography and/or education majors: Applications beyond the unifying theme enrich the learning experience:

Evaluation Phase

	How well did students perform on the summative assessments, when appropriate?
	What trends were noticed in student feedback and interactions during and after the lesson (e.g.,
	discussion board engagement, student questioning)?
Which e	xperts should review the materials before implementation?
Which c	hanges should be made to improve this lesson the next time around?
Do tho r	acults justify the time and effort ment developing this lesson?
Dottiel	
Do the r	esults justify the contact-hour time spent with these activities?
	· · · ·

Appendix L

INSTRUCTIONS FOR ACCESSING AND NAVIGATING THE UNIT

The online version of the unit materials is a reflection of what students would experience in the learning management system. As such, it is designed to be navigated similarly: with layers of folders. Since the web-based version is not an exact replica of the learning management system, I have added hypertext links above and below the content on each page to assist in both navigation between content pages and also to provide quick access to the corresponding *ADDIE* unit and lesson plans. Provided also are the templates for future use and adoption by other instructors.

<u>To access the main page</u>: Using an internet browser, navigate to <u>http://mrlafazia.com/PHY111</u> (this lands you on the "Learning Materials" page that offers a brief introduction to the unit).

From there, clicking on the unit folder will bring you to the seven-lesson outline page. Selection of any of these lesson folders (or clicking anywhere on the lesson outlines) will bring you to the corresponding lesson content.

In each <u>lesson folder</u>, full descriptions of activities are provided. Some have embedded links to online material while others are themselves links to activity documents or websites. Again, the hyperlinks above and below the content areas provide increased navigability.

Appendix M

MEMORANDUM TO PHYSICS DEPARTMENT LEADERS

TO: Physics Department Leaders 2016

DATE: May 12th,

FROM: David G. LaFazia

SUBJECT: Recommendations for Conceptual Physics based on Ed.D. Research Study

I recently completed my doctoral studies at the University of Delaware where I focused on the Conceptual Physics course and improving its relevance to the Elementary Education and Diagnostic Medical Sonography majors. As one product of the study, I developed a full unit (on Waves and Periodicity) the content of which focuses on the integration of human biology content with physics concepts, the application of kinesthetic teaching strategies, and the use of an energy-centric view of physics along with several other support strategies. Over the course of this study, I conducted surveys and interviews with a number of the physics instructors within your departments.

First, I thank you for allowing them the time to participate in my study, and also to those of you who were involved in the study directly. Second, I am providing below a bulleted list of several recommendations which came from this study that I felt might be of particular use to you and/or your instructors.

- <u>Course Syllabus Suggestion</u>: Review of the Measurable Performance Objectives to ensure that they are in line with the *Next Generation Science Standards*' primary practices of science
- <u>Teaching Strategy</u>: Form connections between human biology (everyday and common physical experiences) and physics concepts
- <u>Teaching Strategy</u>: Inclusion of kinesthetic teaching practices while making accommodations for diverse learners

- <u>Teaching Strategy</u>: Use of whole-class construction of understandings and concepts as they develop (organized online: e.g., through Padlet or GoogleDrive) to promote argumentation and development of a shared language of physics in the classroom
- <u>Advisement Resource</u>: Distribution of the *Connections to the NGSS and JRC-DMS Standards* chart (attached) to Elementary Education and Diagnostic Medical Sonography program advisors as an example to help students see some of the immediate relevance of Conceptual Physics to their chosen career paths

Other insights and support strategies were gained from my study. If you would like to discuss these recommendations with me further, or if you would like to view the full study or resulting unit materials, please feel free to contact me. My contact information is available through the Employee Directory.

Electronically Signed,

David G. LaFazia

David G. LaFazia Physics Adjunct Instructor Energy Technologies Department Chair

ATTACHMENTS: Connections to the NGSS and JRC-DMS Standards

Appendix N

INSTRUCTOR'S ORIGINAL COURSE CONCEPTUALIZATION



Appendix O

INSTRUCTOR'S REVISED COURSE CONCEPTUALIZATION



Appendix P

ADDITIONAL RESOURCES AND READINGS

These references act as acknowledgment of readings that were influential in the shaping of my understanding for this study while not directly appearing in the actual executive position paper content. They may serve also as starting points for future adaptations of the design principles.

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Appendix Q

INSTITUTIONAL REVIEW BOARD (IRB) EXEMPTION LETTER



RESEARCH OFFICE

210 Hullihen Hall University of Delaware Newark, Delaware 19716-1551 Ph: 302/831-2136 Fax: 302/831-2828

DATE:

November 23, 2015

TO: FROM:	David LaFazia, BA, MS University of Delaware IRB
STUDY TITLE:	[836330-1] Reframing Conceptual Physics: Emphasizing Connections to the Human Body
SUBMISSION TYPE:	New Project
ACTION: DECISION DATE:	DETERMINATION OF EXEMPT STATUS November 23, 2015
REVIEW CATEGORY:	Exemption category # (2)

Thank you for your submission of New Project materials for this research study. The University of Delaware IRB has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations.

We will put a copy of this correspondence on file in our office. Please remember to notify us if you make any substantial changes to the project.

If you have any questions, please contact Nicole Farnese-McFarlane at (302) 831-1119 or nicolefm@udel.edu. Please include your study title and reference number in all correspondence with this office.

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