# THE RELEVANCE OF PHYSICS: A CRITICAL LOOK AT THE WAYS IN WHICH STUDENTS FIND MEANING IN INTRODUCTORY PHYSICS

By

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**ABSTRACT**

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The relevance of physics is an active line of inquiry within the physics education research (PER) community. Many studies have shown that physics instruction typically negatively impacts students' sense of the relevance of physics to their lives. Irrespective of students' beliefs, physics is communicated as being relevant through policy recommendations and program requirements. Until now, most efforts in PER to measure or interpret students' beliefs around relevance have been limited to attitudinal and epistemological surveys that provide an incomplete picture and tends to promote deficit interpretations of students' abilities. We first challenge notions of the "real world" and "everyday life" that are ubiquitous in current efforts to understand relevance. These phrases lack meaning and we use case studies of students to argue for an expanded holistic view of relevance. We then introduce a framework that accomplishes viewing relevance in an expanded fashion by adapting ecological systems theory. We trace students' experiences to argue that this framework provides a richer picture of what it means for physics to be relevant to a student. Finally, we present a longitudinal case study of a student who experiences a remarkable transformation in his view of physics. Through the lens of relevance, we articulate the connections he makes during his journey through introductory physics. These connections end up being critical for a lasting impact that empowers him to promote the relevance of physics to others. We argue in this dissertation that using this framework of relevance, physics educators can start to design classrooms that facilitate more positive affective and attitudinal experiences for students. Through relevance, physics classrooms can become inclusive and engaging environments for students to forge lasting connections to a discipline.

I dedicate this to the memory of my cat Cola who passed last year.
She was my best friend and roommate for over a decade. Cola accompanied me through every major struggle and accomplishment and I'm sorry she wasn't able to see me get this final degree.
She would have been unimpressed.

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I want to thank my students, you were the highlight of my dissertation process. The experiences you shared and the stories you told are the core of my dissertation. I will always be reflecting back on your successes and accomplishments with a smile, I am proud of every single one of you. Never let physics or any other discipline intimidate you, just remember that you belong and keep persisting.

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Anyone who has gone through the physics PhD program since 2015 knows how important Kim Crosslan has been to their success and yet I'm finding that I cannot express fully how much Kim means to me. Kim has repeatedly and consistently shown me patience, love, and compassion. She has looked after me as if I were her own family, and for that I will be forever grateful. I went to Kim whenever I needed help; she was truly a life-line and a confidant. Kim always made time for me whether I needed to vent or cry. She is much more than a staff-member of the physics department —to me, she is family. Doing work that made her proud was one of my most cherished achievements here at MSU.

I want to thank my best friend, partner in crime, and wife Rachel. You are the reason I ever applied to MSU. You have given me unwavering support to pursue my passions and you inspire me every day. You are beautiful inside and out, and I am lucky to have gotten to know you during that blizzard in Chicago. You are my everything.

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# CHAPTER 1

# INTRODUCTION

I trace the origins of the questions tackled in this dissertation to a memory of my time student teaching a high school honors physics course. The class was working on a vector addition exercise presented with the context of giving directions to travel between two locations on a map. A student was refusing to do the in-class activity. When I approached her, she stated that there wasn't a point in doing this activity and asked me when she'd ever need this information. We both laughed. She was a very capable student unwilling to spend time doing an activity she believed to have little return on her investment of time and effort. She was also a high school student interested in pushing the boundaries of my temporary authority in her classroom. I was a nervous student teacher with extensive experience on what it meant to do physics and felt confident in my ability to convince her of the relevance of physics. I proceeded to offer up a litany of reasons why this physics activity may be relevant to her life or her future career and each reason was met with convincing counter-arguments from this young student. After failing to convince her, I had exhausted my own willpower and, unbeknownst to her, I was starting to agree with her. Resigned, I asked, "Well, can you work on it anyway, as a favor to me?" "Okay" she said simply with a smile and got started.

I do not include this story as a representation of good teaching practice or classroom management. Instead, I use this story to highlight several insights that will be revisited throughout this dissertation. First, there is far from universal agreement about the notion that physics is relevant to one's life. Second, students have legitimate reasons for their having certain beliefs about physics. Students' beliefs are never a deficit that needs to be fixed but rather can be reflective of their experiences so far. Third, designing toward building relationships in the classroom can be a powerful mediator for engagement. In this specific case, the rapport I had built with this student was important to her finally starting work.

Shortly after my student teaching semester was over, I started my work to explore the relevance of physics at the introductory level. Physics is represented as relevant to undergraduate students in several ways: program requirements for many STEM degrees, through inclusion in the MCAT, and through national policy recommendations for the integration of knowledge and practices across the disciplines [1–3].

Physics education has placed significant emphasis on reforming instruction for improved student understanding and for improved student attitudes and beliefs [4–10]. Success in these two areas of focus are strikingly different. PER's body of literature reflects a largely universal acceptance that research-backed instructional strategies can and do improve student understanding. In contrast, there is no such universal acceptance of ways to promote student attitudes and beliefs toward physics. In fact, it is the status-quo of PER that students will leave the physics classroom believing that physics is less connected to their lives than when they entered [8].

The overwhelming majority of those that enroll in introductory physics courses are not physics majors. Students majoring in the life sciences comprise one of the largest portions of the enrollment in introductory physics at most large institutions [11]. It is important for the sustainability of these physics departments that many degree programs continue to include physics as a requisite course and deem physics knowledge to be relevant to their students. This puts the importance of focusing on the relevance of physics into perspective. It is not simply an abstract intellectual pursuit but rather critical to the livelihood of physics programs that rely on a large non-major student enrollment.

## 1.1 Structure of the dissertation

This dissertation is centered around four qualitative research studies that explore the relevance of physics in a stepped manner.

We start in Chapter 4 with the ways in which relevance is measured in PER through commonly used pre-to-post attitudinal and belief surveys. We critique and expand on the areas of students' lives these surveys intend to measure, focusing on two areas regularly reported as showing a deterioration in students' beliefs after instruction. We then operationalize a more expansive framework for relevance in Chapter 5. Finally, we apply this framework to characterize a dramatic transformation in a student's view of physics in Chapter 6.

Chapter 4 consists of two published papers examining issues with how relevance is measured and interpreted in commonly used surveys in PER. The first is a published study we conducted to critique the narrow conception of the "Real World" as used by these surveys [12]. We suggest that this phrase has little concrete universal meaning amongst students, and that it mostly refers to an abstracted sense of the "natural world." Students' real worlds during their time in introductory physics can include disciplinary experiences that push on this definition. The second half of the chapter is a paper currently in-press of case study of a student, Sam, reporting the relevance of physics through everyday experiences [13]. This is an under-reported form of relevance in the PER literature. It in fact is common to find examples of students laughing at the implication that physics may be relevant to their everyday lives [12, 14]. We describe the settings, roles, and relationships that helped Sam forge these connections, suggesting that allowing students to bring those experiences into the classroom can be a way to foster these moments of relevance through everyday life.

While Chapter 4 outlines limitations and challenges to PER's current view of relevance, we operationalize a more expansive framework of relevance in Chapter 5. This chapter consists of a paper outlining a framework for operationalizing relevance [15]. We adapt ecological systems theory and the organizational structures of attitudes and beliefs to propose a new framework of relevance which captures a more complete and richer representation of relevance.

Chapter 6 consists of a longitudinal case study of a student who initially enters the physics classroom with fear and anxiety. We use our framework of relevance to explore his transformation from fearing physics to promoting the relevance of physics to others over the course of three semesters.

In Chapter 7 we describe the conclusions from the three previous chapters as step-wise explorations of the relevance of physics. We outlined the need for a new approach to relevance in PER (Chapter 4), operationalized a new framework of relevance (Chapter 5), and applied that framework to point to mechanisms of a transformation in a student (Chapter 6).

## 1.2 Evolution of ideas through the dissertation

The studies that form Chapters 4, 5, and 6 were written across a nearly three-year span. The ideas presented understandably evolve with time, this section is aimed at helping the reader understand how ideas have changed.

Chapter 4.1 marks my first published exploration of relevance in physics education. During that time, the model of relevance was built upon what had previously been studied in PER using attitudinal and epistemological surveys. A consequence of this is that relevance is confined into different categories which represent different manifestations of relevance in students' lives.

Chapter 4.2 continues to describe relevance confined to specific areas such as Everyday Life. It pushes on the common narrative that students in physics will rarely report thinking of or doing physics in their everyday lives. By using a case study, we describe the significant supports required in a student's life to argue for an expansion of the goals of an introductory classroom to include the inclusion and validation of outside experiences. Previous work on introductory physics connecting to everyday experiences limited the attention to the domain of the physics classroom and focused on how instruction can be reformed to affect students' views. I expand my view of relevance through everyday experiences to include areas of students' lives outside of the classroom such as peer and social groups.

Chapter 5 marks a dramatic expansion in the model of relevance used. I shift away from pre-determined bins of areas of students' lives that we have seen described in PER surveys. I, instead, moved towards mapping areas of students' lives where physics may be relevant. I adapt representations from ecological systems theory to describe relevance as manifested by connections across different settings in students' lives.

Chapter 6 continues with the same framework as the previous chapter and applies it to explain how a significant transformation may have occurred. I use relevance as a lens for understanding how a student can shift their views of physics from once fearing it to ultimately embracing it. This chapter marks the departure from using concentric circles to represent the nested systems to a more detailed map of the settings in a student's life and the connections between them.

# CHAPTER 2

# BACKGROUND

This chapter provides a summary of the background context to the studies presented in this dissertation. While these areas will be described in more detail in the relevant chapters, it is instructive to have an overview of the context within which this work exists.

## 2.1 Notion of relevance

One of the challenges of studying a construct such as relevance is that there is not a clear uniform definition. Scholars of relevance have noted that although the specific definition of relevance may shift to fit the needs of specific applications, the main quality of relevance is that it represents a relationship between a participant and the subject in question [16, 17]. In our case, relevance exists between a student and physics.

While the specific definition of relevance may differ across contexts, we see much more uniform agreement in how relevance has been communicated in science education. Relevance has been used to shape policy recommendations in this country for decades around preparing students for careers, helping students understand science and use it in their lives, and to promote students becoming scientifically literate and productive citizens in society [18].

Throughout this work our notion of relevance will be focused on the relationship between the student and physics. We will argue that you can observe or measure this sense of relevance through connections across the settings that students experience directly. These settings can include different classrooms, family or peer groups, or any other environment in which they report reaching for ideas or practices from physics.

## 2.2 Attitudinal & belief surveys in PER

Physics has looked at several different areas of relevance through attitudinal and belief survey measures that are given to students pre-and-post instruction. Shifts in student responses are then reported as positive if responses become more expert-like after instruction and negative if they become less expert-like. We focus our attention on the Colorado Learning Attitudes about Science Survey (CLASS), Maryland Physics Expectations Survey (MPEX), Epistemological Beliefs Assessment for Physical Science (EBAPS), and Views About Science Survey (VASS) [4, 5, 19, 20].

These four survey measures make up the primary ways PER has evaluated the effectiveness of specific curricula and pedagogy to promote a positive (expert-like) shift in students' responses. Within these measures of attitudes, the focus of research on relevance has primarily focused on: physics being of use in students' future careers, physics being connected to the world in which students live, students reporting physics entering their everyday lives, and students reporting a personal interest in learning or doing physics. Chapter 4 critically examines how PER has traditionally explored relevance through these focus areas.

The surveys are typically structured as individual Likert-style statements that students endorse with their level of agreement. These individual questions are then grouped using clustering techniques to arrive at clusters of topics the survey is intended to probe. Some of these clusters do not relate to relevance but each survey has at least one cluster of questions dedicated to probing the relevance of physics. As we will discuss in more depth in Chapter 5, there are issues with the interpretation of the results from these clusters that suggest that PER's current measure of relevance is not complete and often relies on deficit-framing.

## 2.3 The theoretical organization of relevance

The design of PER surveys belies an organizational structure to its measurement. Individual questions ask students to endorse belief statements, these are then organized to form a higher order grouping (attitudes). Thus, each cluster can be thought of as measuring an attitude. This agrees with an organizational structure for beliefs and attitudes that Rokeach originally proposed in 1968 [21]. We organize relevance as a higher order structure on top of attitudes, such that the relevance of physics is composed of one or more attitudes toward physics. Each attitude composed of one or more beliefs about physics. Details of this organization will be discussed in Chapter 5.

## 2.4 Adapting ecological systems theory

Ecological systems theory was introduced by Urie Bronfenbrenner in 1979 to describe human development as a concentric organization of systems [22]. A student's life can be represented in this framework as an ecology of systems, the systems on the periphery being more distant in interaction while the inner systems are directly experienced by the student. We use ecological systems theory to help map connections between the various settings in a student's life.

The meaning of "settings" is intentionally broad. Settings can include a variety of environments depending on the scale of the research question. If one were interested in dynamics between home life and academic life, you can imagine that one can represent the whole of academic life as one setting. If instead, you are interested in exploring connections between coursework, each course can represent a setting. The grain-size of inquiry can be represented in the description of the settings.

Connections between physics and other aspects of a student's life will be places where a sense of relevance can be promoted or hindered depending on the nature of the connection. To do this work, we focus our attention primarily on the two innermost systems: the microsystem and the mesosystem. The microsystem encircles the individual and represents the settings, roles, and relationships a person directly experiences. The mesosystem represented connections across settings within the microsystem. In Chapter 5 we show that the relevance of physics to a student's life is directly attributable and characterized by the connections present in the mesosystem.

We are adapting the systems view representation from a theoretical view on human development that is nearly 40 years old as of this writing. Since Urie Bronfenbrenner presented this work in 1979, much work has been done to push our understanding of human development and we do not bring in the whole of Bronfenbrenner's theory into our work. Nevertheless, ecological systems are the most direct representation of our ideas as we worked to understand our students. In their interviews, our students were describing the many roles and contexts they work in courses, extra-curricular clubs and organizations, research, and service. Ecological systems theory is useful to visualize the many settings students exist within outside of the physics classroom and gives us the language to describe connections between these settings.

# CHAPTER 3

# METHODOLOGY

## 3.1 Course context: BLiSS Physics

This work is situated in a two-semester sequence of introductory physics course for the life-sciences that is taught in a studio-format. The course is named Briggs Life Science Studio (BLiSS) Physics. It has been reformed to leverage connections to biology and chemistry in the learning of physics. Studio physics is a phrase coined in 1993 at Rensselaer Polytechnic Institute to refer to a reformed classroom design [23]. Since then studio physics has been adopted at numerous institutions, each with a slightly different implementation. Some examples include: Modeling Instruction at Florida International University [24]; Studio Physics at Colorado School of Mines [25]; SCALE-UP at North Carolina State University [26]; and TEAL at Massachusetts Institute of Technology [27]. Broadly there are some features that are common to most implementations: (1) lecture and laboratory activities are combined into one class period with less time devoted to pure-lecture format instruction, (2) students work in small groups with a high level of faculty-student interaction, and (3) the classroom utilizes technology to facilitate group work and to provide students hands-on activities.

My research project starts in the very first iteration of this reformed course design, and the findings from my work heavily influenced future iterations and redesign efforts. BLiSS Physics is taught in Lyman Briggs College (LBC), which is one of multiple residential colleges on campus that focus on a specific discipline. LBC focuses on science with a heavy emphasis on cross-disciplinary knowledge integration. There are no additional requirements to be accepted to LBC beyond MSU's overall admission criteria; students can elect to choose to be placed within LBC for a residential college experience as they pursue a science degree. Students are required to take biology, chemistry, and physics courses. Additionally, students are required to take History, Philosophy, and Sociology of Science (HPS) courses, which ask students to integrate their knowledge of science within a larger context. In the BLiSS classroom, most students are majoring in the life sciences with a large proportion intending to pursue health professions. At MSU, LBC is typically considered amongst students to be a more rigorous degree path and is often analogized to being like an honors college. Students are generally very motivated to achieve high grades and often arrive with Advanced Placement (AP) or International Baccalaureate (IB) credit. We can expect students entering the first semester of physics to have completed one or more semesters of biology and chemistry, in addition to any research experience students have.

## 3.2 Study design considerations

The work in this dissertation is gathered in the context of a larger design-based research project that spanned two years of BLiSS Physics. Across the two years the primary data stream was in the form of semi-structured interviews with students longitudinally-spaced along their experiences in the classroom. Additionally, focal groups that included interviewed case students were video recorded while they worked through activities in class.

### 3.2.1 Case studies

This study utilizes a qualitative case study methodology because it is especially equipped to explore students' evolving conceptions of the relevance of physics. Every case study presented in this dissertation consists of multiple data streams including multiple interviews spaced across students' experiences. Within each case study we probe the evolving attitudes and beliefs students have around the relevance of physics.

Case studies are especially suited for our exploration of relevance because they allow for an in-depth understanding of students' experiences [28]. Case studies allow us to situate students' experiences within the context of the physics classroom. An individual case allows us to see the impacts of the classroom experiences in evolving a student's sense of relevance. Multiple cases within the same course context allows us to broaden our claims and remark on the design and implementation of activities to promote relevance.

In this dissertation I will focus on select cases from a larger collection of data. The reader may infer that my intention is to present a representative sample of a larger data-set —this is not true. Case studies were chosen as the structure of my work on relevance because they are especially well-suited to developing a theory and illuminating how relevance is perceived and experienced by these case students. Our goal in the end is not to argue that the experiences presented in this work are representative of the entire population of our data-set. Instead, we look to intentionally select and sample case students to expound on the variety and diversity of ways students experience the relevance of physics [29].

Physics education research is lacking a thorough understanding of the relevance of physics and its implications for designing reformed classroom environments. Case studies help develop an expansive and thorough understanding of relevance so that in the future we can attempt to undertake the task of arguing for generalizability.

### 3.2.2 Embedding within a larger design-based research effort

The work presented in this dissertation does not stand alone; it exists within a larger design-based research project that aims to understand student experiences through the reformed BLiSS Physics classroom through a variety of lenses including self-efficacy, mindset, and relevance [30].

Design-based research (DBR) is a research methodology that advocates for the removal of the barrier that typically separate classroom design from research that is conducted within the classroom. We are interested in studying student experiences within the context of the course and DBR provides a framework in which we can study student experiences in concert with design efforts. The research and design branches of our project inform and learn from each other.

One of the implications of the nature of design-based research is that the research and the curriculum design directly and reciprocally impact each other in real-time. They live and breathe together and cannot be considered independent of one another. In the pursuit of providing students with the best possible experience, changes to instruction are directly shaped by the emergent research findings. One product of this interaction between research and curriculum in BLiSS is a new lab activity exploring the second semester topic of equipotential lines [31]. The features of this lab became a significant touchstone for students and helped shape our ideas of accessibility and familiarity being important in conveying that physics can be explored outside of a specialized lab setting.

### 3.2.3 Researcher roles

My roles in the BLiSS classroom reflected the holistic treatment of a classroom design and the research involved. I was embedded in the course as a researcher, curriculum developer, and instructor. We ensured that I did not research students with whom I played an instructor role. I was deeply embedded in the classroom and observed nearly every class period over the two years of this project. My role when not an instructor was typically as a passive observer and, at times, participant observer.

Students generally regarded me as a fixture in the classroom who can help them if no other instructional team member was available. I intentionally minimized my availability as an extra helper in the classroom to focus on observing rather than interacting. One of the consistent themes in my role in the classroom is that instead of presenting myself as an alternative knowledge source, I focused on being a curious observer. I celebrated with students during moments of triumph and commiserated with them during moments of frustration. This became an invaluable factor in my success fostering trusting relationships with students in interviews and e-mail correspondences. Students saw me as someone who was cheering them on and genuinely interested in their success. Students would remark in interviews or reach out after their time as a student in BLiSS with moments they wanted to share with me of encountering physics outside of the classroom.

## 3.3 Participant recruitment & selection

Case student selection was informed by a questionnaire given to students early in the course that asked them to describe their previous experiences in science courses as well as their beliefs about learning physics. Independent of the questionnaire, students were asked to volunteer to

| Pseudonym | Major | Previous Physics Experience |
|---|---|---|
| Alisa | Neuroscience | IB Physics |
| Anne | Microbiology | None |
| Aurora | Physiology | HS Physics |
| Benjamin | Zoology, Marine Biology concentration | HS Physics |
| Beverly | Human Biology | HS Physics |
| Cody | Human Biology | HS Physics |
| Deanna | Chemistry | HS Physics |
| Forest | Plant Biology & Biochemistry | HS Honors Physical Science |
| Hana | Human Biology | HS Physics |
| Isabella | Biochemistry & Molecular Biology | HS Honors Physics |
| Kathryn | Biochemistry | HS Physics (1 semester) |
| Kelly | Biomedical Lab Sciences & Human Biology | HS Physics |
| Kirk | Astrophysics | AP Physics |
| Leslie | Zoology | 8th Grade Trebuchet |
| Lian | Human Biology & Biochemistry | HS Physics |
| Maria | Microbiology | HS Physics (2 Trimesters) |
| Melanie | Neuroscience | IB Physics |
| Miles | Biochemistry | None |
| Nicole | Genetics | None |
| Priya | Genomics & Molecular Genetics | AP Physics |
| Radhika | Physiology | HS Physics |
| Randy | Physiology | HS Physics |
| Sam | Nutritional Science & Kinesiology | AP Physics |
| Sidney | Fisheries & Wildlife | HS Physics |
| Wade | Microbiology | HS Honors Physics |

Table 3.1: Pseudonyms, majors, and previous physics experiences for selected case students.

participate in the study. Potential case students were identified by cross-matching volunteers for the study with their responses to the questionnaire. We selected students who expressed a strong disciplinary identity, stated high levels of anxiety toward physics, or students who were optimistic that physics could be relevant to them. Emails were sent to potential case students and participation was incentivized with a $10 Amazon gift card for every interview a student participated in.

In this dissertation, each study employed purposeful selection of participants to help develop a framework for understanding the relevance of physics [29]. Cases were not selected to form a representative sample of the students in the course. Apart from practical limitations of scheduling conflicts and student response rate, the main motivation behind participant selection was to seek out diversity in experiences to help create an expansive framework for the relevance of physics. Table 3.1 describes an overview of some of the case student pseudonyms, disciplinary majors, and previous experiences with physics. In Figure 3.1 we show a selection of graphs created with the MAXQDA MAXMaps [32] feature which show the different codes used for participant selection and the accompanying questionnaire responses.

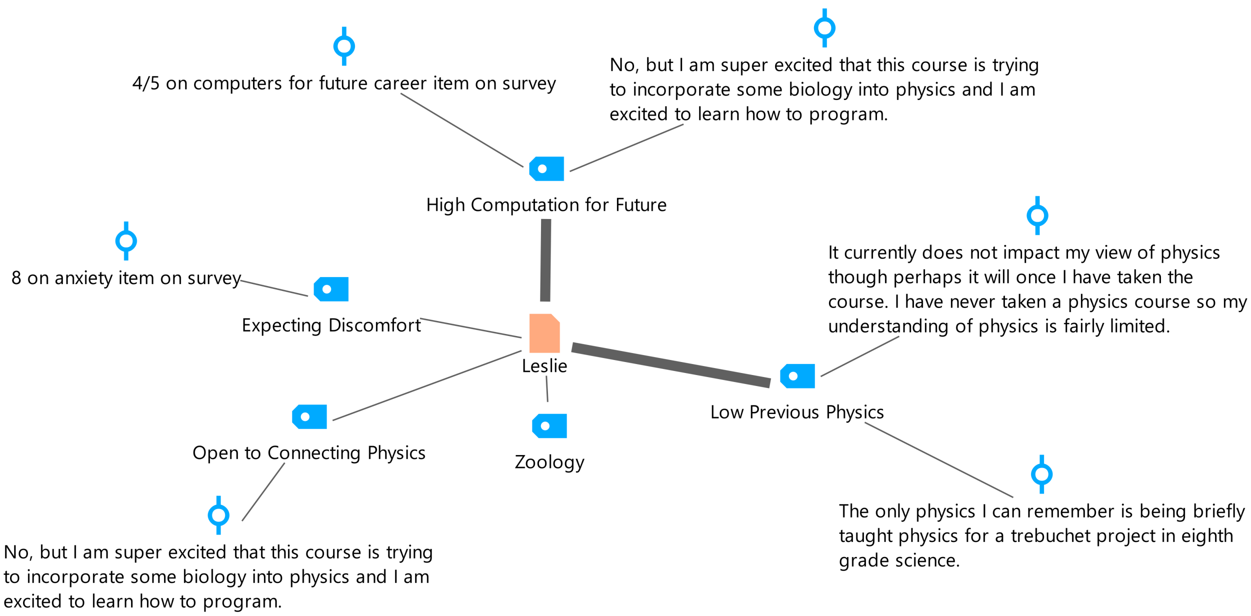
## 3.4 Data collection & analysis methods

Data for this project was collected across multiple streams including questionnaires, semi-structured interviews, in-class video recording, field notes, brief faculty reflection interviews, and e-mail correspondences with case students. Figure 3.2 outlines the data collection time-line for the 2 years of data collected.

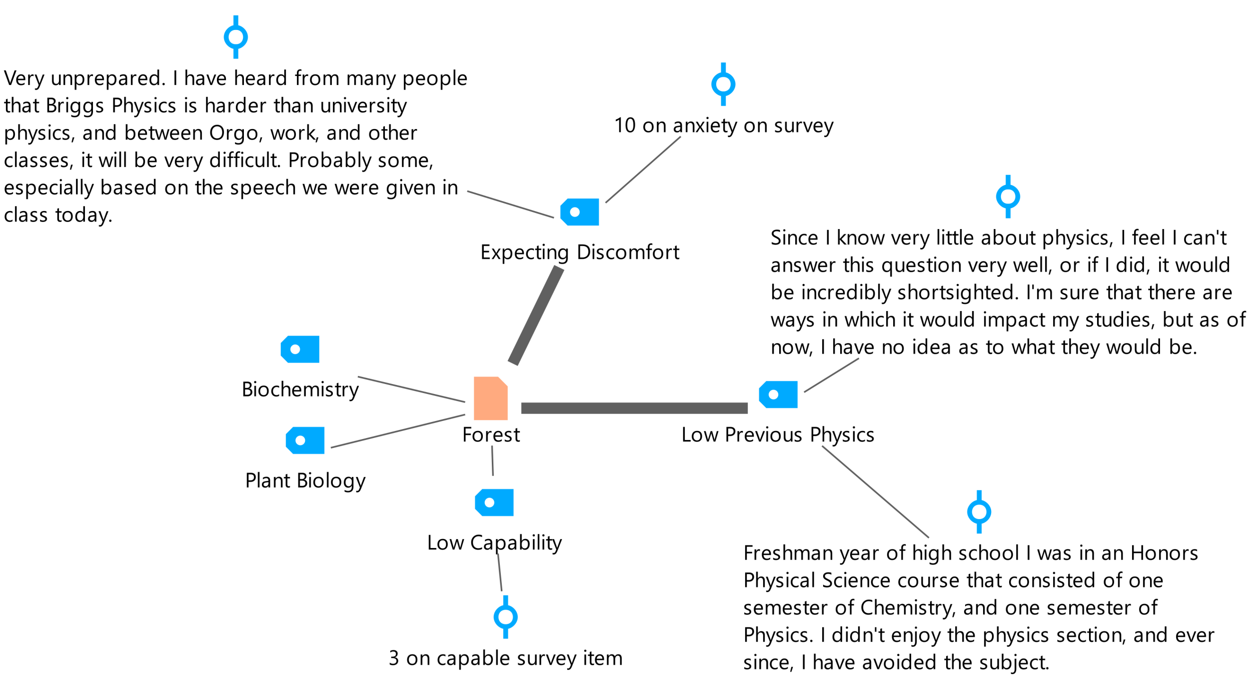
During the initial phase of this project task analysis was completed on the commonly used attitudinal and belief surveys. Codes were created to signify the different areas of students' lives these surveys probed. These categories became the initial codes we used in analyzing student interviews.

The video-recorded data (in-class video and interviews) were transcribed by me using InqScribe or a 3rd party transcription service. In addition to coding for the categories found in the PER surveys, I utilized open-coding to identify themes that emerge across case students as well as for a specific case student as they progress through the semester [33].

As the project evolved our conception of relevance broadened, as discussed in Chapters 4 and 5. Interviews were coded for the settings involved in students' lives with explicit focus on connections between physics and other settings in a student's life. Moments described in interviews were corroborated with in-class footage whenever possible.




(a) Leslie is open to making connections to physics, reports 4/5 on the needing computation for her future career, reports 8/10 on anxiety, and has little previous physics experience.




(b) Forest states he is very unprepared, reports 10/10 on anxiety, reports 3/10 on capability, and has little previous physics experience.

Figure 3.1: Two selected examples of MAXQDA MAXMaps showing how the course questionnaire was coded to support participant selection. Codes are connected to the corresponding open-response from the questionnaire. All ratings are self-reported using either a 5 or 10-point scale.

| | BLiSS Physics (1st Semester) | | | | | Other Physics (2nd Semester) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year 1: 2016-2017 | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May |
| **Course Questionnaire** | ✓ | | | | | | | | | |
| **In-Class Video Recording**<br>Computational Sequence on Diffusion<br>3 class sections, 3 focal groups each | | | ✓ | | | | | | | |
| **Interviews (37)**<br>Sep: 18 interviews with initial cases<br>Nov: 10 interviews with continuing cases<br>Mar: 9 interviews with continuing cases | | ✓ | | ✓ | | | | ✓ | | |

| | BLiSS Physics (1st Semester) | | | | | BLiSS Physics (2nd Semester) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year 2: 2017-2018 | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May |
| **Course Questionnaire** | ✓ | | | | | ✓ | | | | |
| **In-Class Video Recording**<br>2 sections, class view + 3 focal groups each | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Interviews (46)**<br>Sep: 17 interviews with initial cases<br>Nov: 10 interviews with continuing cases<br>Jan: 3 interviews with new cases<br>Feb: 9 interviews with continuing cases<br>*6 of 9 interviewed while in other physics course<br>Mar: 7 interviews with continuing cases<br>*3 of 7 interviewed while in other physics course | | ✓ | | ✓ | | ✓ | ✓ | ✓ | | |

Figure 3.2: The data collection time-line for the project. During Year 2, some case students that completed the Fall semester of BLiSS Physics were enrolled in a different physics course in the Spring semester. 20 interviews in Year 1 were conducted by other members of the research team and I completed the rest of the data collection. This allowed me to have a unique and deep understanding of the course context and its students.

## 3.5 Validity

### 3.5.1 Researcher identity

It is important to reflect on researcher identity when doing deep qualitative research as it can help readers assess the interactions and relationships between the researcher, the students, and the course environment. I immigrated to the suburbs of Chicago, Illinois from the southern Indian state of Kerala in 1992. The specificity of the region of India may seem to the reader to be overly specific but it is important to me that I am seen as a South Indian. In America, there is often a monolithic notion of Indian identity in media and cuisine that neglects to acknowledge the variety and diversity in a country as populous as India. I gained my United States citizenship several years later. I identify as coming from Indian descent and being an American citizen, though my life experiences have shown me that my citizenship is qualified by my skin color.

In high school, physics was my favorite class and I completed honors physics as well as AP Physics C (AP course names have since been renamed). After high school, I went into a combined BA/MD medical program that I did not enjoy. I would return to physics and complete my Bachelor's and Master's degrees in Chicago. During that time, I conducted research in high energy nuclear physics. I then completed a Master's in Education in Secondary Science specializing in teaching physics and received my teaching license in Illinois. My time student teaching in the Englewood neighborhood of Chicago helped me understand that institutional structures will inherently promote racism and misogyny if there isn't a relentless effort to stem the tide.

I still had the desire to produce research and joined the Physics PhD program at Michigan State University. During my time in Michigan, it was made clear to me that my appearance as a brown man made me stand out. This was surprising since I blended in as one of the many shades in a crowd in Chicago. I came with a mission to question the presumed truth that physics is relevant. Throughout my work you will find ideas inspired by the works of scholars in the fields of race, equity, or gender studies but I must be clear that I am not a scholar of race, equity, or gender. I am a physicist by trade, and I am here to question the notions that keep a high-quality education in physics out of the grasps of all but a select few.

### 3.5.2 Issues of power & influence

While I held many roles in the classroom, I only conducted research with students in the sections where I was not assigned with an instructional role. The students within the sections where I had an instructor role were interviewed by others on the research team.

There is clearly an opportunity for a power differential between me and the students in this study. To mitigate this concern, I have explicitly reminded the case students that I have no influence over their grades and that the data will not be accessible to the instructors until after the students are no longer in their classroom and when the instructors no longer have influence over their grades.

### 3.5.3 Validity of claims from case studies

When readers are presented with a paper that is a case study of one or two students, a common concern is the validity of claims made from one student's experiences. Out of the 40 total students that were interviewed as case students for this project, 28 were interviewed by me and many were interviewed multiple times. I argue that I have extensive knowledge of students' experiences in this course through my experiences of numerous interviews, observation and field notes, in-class video recording of nearly every class period, and co-development of activities in this course. While at times my unit of analysis is one student's experiences explored over time, care is taken to situate any claims within the context of this larger project. There are times when the experiences of one student exist in stark contrast to the rest of the research sample population. For these situations we take care to explicitly describe claims in comparison to the class as a whole. For example, in Chapter 4 we see the experiences of case student Sam noting that her views of physics being relevant in her everyday experiences stands in contrast to the views of others [13].

Throughout this study, analytic memos were created to articulate low-level claims and tie these claims directly to data. Higher inference level claims made from the data were discussed in a research team of physics education researchers that includes graduate students, undergraduate researchers, post-doctoral researchers, and faculty.

## 3.6 Limitations

BLiSS Physics is situated in Lyman Briggs College (LBC) at Michigan State University. LBC is one of multiple residential colleges at MSU that specialize in a specific discipline, in this case science. LBC emphasizes and promotes the importance of cross-disciplinary connections in students' science preparation. We must be aware that the claims of relevance in this work are limited by the diversity in student experiences represented in the BLiSS classroom. Some of the common characteristics of our student population in BLiSS physics include a high level of science preparation, high levels of involvement in undergraduate research or extra-curricular groups, and a relatively high proportion of students intending to pursue medical careers.

As I have been the principal data collector and interviewer within this project, it is quite possible that this study is limited by any biases present in my decision-making process. Decisions on who to observe in-class as well as decisions around the follow-up questions during interviews can impact and limit what data is present for analysis.

MSU is a predominantly White institution with White students constituting approximately 76% of undergraduate enrollment as of Fall 2017 [34]. Within our BLiSS Physics classroom, during 2016-2018 White students were approximately 80% of the student enrollment. Any claims made in this dissertation must be interpreted with the understanding that they are made from a fairly racially homogeneous population.

# CHAPTER 4

# RELEVANCE IN THE REAL WORLD & EVERYDAY LIFE

## 4.1 Using disciplinary perspectives to refine conceptions of the "real world"

### 4.1.1 Introduction

It has been stated, in PER, that students often demonstrate an unfavorable shift in attitudinal measures in general and that students leave the physics classroom stating that physics is less connected to the world than when they started the course [4, 19]. Items that assess the connection of physics to students' lives appear across several attitudinal and epistemological measures such as the Views About Science Survey (VASS), Epistemological Beliefs Assessment for Physical Sciences (EBAPS), Colorado Learning Attitudes about Science Survey (CLASS), and the Maryland Physics Expectations Survey (MPEX) [4, 5, 19, 20]. Students' unfavorable responses to items on these measures are often interpreted as students not perceiving the relevance of physics to the real-world, to everyday life, personal interests, or future careers [4, 19, 20]. This paper aims to complicate this oft-stated finding by exploring the types of connections students make between physics and their lives outside the physics classroom.

### 4.1.2 Theoretical Framework

We posit that the clusters and items in the VASS, EBAPS, CLASS, and MPEX that assess how connected physics is to students' lives are part of a broader question of "how relevant is physics?" Relevance as a construct has been difficult to define [16, 17]. One of the challenges with defining relevance is the variety of colloquial meanings - such as significance, importance, applicability, and more [17]. Newton explores relevance in the context of teaching science to primary and secondary students, specifically the challenges teachers face when responding to calls for more relevant science teaching [17]. Bookstein approaches relevance in the context of information sciences and attempts to operationalize relevance for the purposes of information retrieval [16]. Building on their work, this paper operationalizes relevance in physics education to have the following characteristics:

1: It is a relation between the student and physics

2: It addresses some need, aspiration, or expectation

To evaluate the relevance of physics we can look to see how physics is situated in the larger context of students' lives. With an operational definition of relevance to work with, we turn to PER measures to explore which areas of students' lives are being probed for connections to physics. We identify the following clusters as pertaining to relevance:

CLASS: : Personal Interest & Real-World Connection

MPEX: : Reality Link

EBAPS: : Real-life Applicability

VASS: : Personal Relevance [1]

In these clusters we see 2 broad types of items, those that probe (1) the connection between physics to life outside the physics classroom and (2) students' affect, motivation, and interest in physics. In this paper, we narrow our focus to connections between physics and life outside the physics classroom. Adams et al. have reported the distinction between "whether students think that physics describes the real world and whether they care or think about the physics they experience in everyday life [19]." We argue that for our life-science students with rich disciplinary experiences, this distinction into two categories may be insufficient to capture the diverse ways in which students connect physics to their lives. We will explore how our life-science students articulate physics connections to their world and show the complicating nuances in how these connections manifest in students' lives.

[1]Present in version P204 but removed in P05.07, we include it because it adds valuable insight into how questions around relevance are being asked in PER

### 4.1.3 Methods

This work is situated in the first semester of an introductory physics for the life-sciences course that is taught in the studio format. We solicited volunteers for interviews and cross-matched using a survey to identify students who were feeling fearful, had a strong disciplinary identity, were feeling skeptical of the course being meaningful to them, or were optimistic the course could be relevant. This paper represents work from a case study of 3 students, together they demonstrate a variety of ways in which students may connect physics to their lives. We draw from two semi-structured interviews with each of these students. The interviews included items intended to probe the relevance of physics to students' lives. The first interview took place in the early weeks of the course, and the second interview took place near the midpoint of the semester.

### 4.1.4 "Beverly"

Beverly is a human biology major on a pre-medical track who also has volunteered her time at a clinic and the Red Cross club on campus. At the time of the study, Beverly has had physics in high school, which was a negative experience for her.

BEVERLY: I took it [physics] senior year of high school and I hated it. My teacher was awful...I didn't really learn anything from him [Int 1]

In the early weeks of the course, Beverly doesn't believe physics is going to be relevant to her intended future as a physician.

BEVERLY: I don't need physics. It's not really a key aspect in my future or I don't believe it will be...I view it as more of a requirement, I just have to go through it...I talked to like various physicians I've shadowed...they're like 'I don't really use that much physics' [Int 1]

Despite her belief that physics will not play a role in her intended future, the design of the course was such that there were multiple places in her life where physics could have been meaningful;

the course explicitly leverages students' expertise of biology and chemistry as they learn physics [35]. For example, Beverly had volunteered in a wound clinic; in class, students study the motion of bacteria and neutrophils in the context of wound healing. The students were asked to use video tracking software to measure the speeds of E. coli, neutrophils, and tissue healing to determine if antibiotics needed to be prescribed. Beverly didn't find this activity to be an authentic application of how physicians would make decisions around prescribing antibiotics.

BEVERLY: Not too much. . . I actually shadowed an infectious disease doctor a couple times, and by the time his patients got to him they needed the antibiotics, it wasn't just a matter of if they would need them. . . [Int 1]

Beverly also recalls conversations with her family around the dangers of her driving a small car and the implications of a collision; in class, students modeled a collision between a car and an SUV. Beverly states that it's clear which car does better and doesn't find the unpacking of physics laws to be relevant to her future.

BEVERLY: Most of us could figure out if it's an SUV vs. a small car in a collision, most of us could pretty much guess which vehicle would do worse in that situation...the bigger object tends to fair a little better [Int 1]

In the second interview Beverly revisits the car crash, and states that she can better explain what happens in collisions but doesn't label it as thinking of physics concepts. This is consistent with Beverly's previous statements that she finds physics reasoning in car collisions to be intuitive.

INTERVIEWER: Do you think activities like this one [investigating collisions lab] have equipped you to answer questions outside of class?

BEVERLY: . . . it was actually weird my cousin was just in a car crash a week ago. . . I could like pair that with this knowledge and be like OK so nothing too awful could have happened, she had airbags which we've looked into a little bit [in class]. Like I felt like a little more secure in that knowledge

INTERVIEWER: You found yourself thinking of physics concepts when that happened or?

BEVERLY: Slightly. . . I guess I've always thought about them, I just didn't define them or label them as physics. [Int 2]

Beverly recognizes that physics can be applied to real world situations but states that she won't need the detailed physics content knowledge. Beverly's unfavorable responses connecting physics to the real world could be interpreted as Beverly believing that "ideas learned in physics have little relation to experiences outside the classroom" [4]. We contend that Beverly's responses are more nuanced than this interpretation allows. One issue is the difference between Beverly recognizing that physics can be used in the real world and her believing that she doesn't need to bring in physics in those experiences. Beverly's statements are about the practical necessity of using physics in these real-world scenarios, and not a reflection of how much she values thinking about physics. These statements reflect a sophistication that's grounded in her medical experience as well as her sense for when physics is *needed*. Although Beverly connects physics to real world events, she insists that this is something she has always done and doesn't label it as physics. This is consistent with earlier statements that she doesn't think of physics in everyday life.

INTERVIEWER: Do you think of physics outside the classroom?

BEVERLY: . . . I don't really do. If I throw something, I don't really think about it [Int 1]

The notion that Beverly doesn't typically think of physics outside the physics classroom is not surprising considering her previous experiences and her statements that she doesn't *need* physics.

#### 4.1.5 "Maria"

Maria is a microbiology major with a minor in epidemiology who identifies strongly as a microbiologist. She has leadership positions in multiple biology related organizations and works in a microbiology research lab. Maria recalls her high school physics experience as being disconnected from her interests.

MARIA: The last time I've had physics was sophomore year of high school...I just don't think they did a very good job of connecting it back to everyone's interests...it was just theoretical pure physics. so, not my thing. . . [Int 1]

Maria is optimistic that this course may be more relevant.

MARIA: I think in this course it may be a little more [relevant], 'cause of the [biology] connections, otherwise I would probably say no [*laughs*] [Int 1]

For Maria, the wound healing activity was meaningful and the type of connection she was hopeful for.

MARIA: I kind of knew like. . . it was hopefully going to be like this. . . I'm a microbiology major, I know physics is important for what I want to do but like physics like I was taught in high school. . . it's too conceptual, too theoretical but this [wound healing activity] was you know like here's where you would apply it, like what concepts to use specifically in microbiology. [Int 1]

When asked if she is finding physics in any of her other courses, Maria readily sees areas in her courses where physics may play a role.

MARIA: My past epi [epidemiology] course was really focused on like. . . osteoarthritis. . . I can definitely see how you would be like focused on like the physics of it all, like what causes the fractures, what can we do to prevent them and things like that. Not so far in like prokaryotic physio but I'm feeling once we get to flagella and pillae and things that are moving, maybe a little more. [Int 1]

This connection to her prokaryotic physiology course ends up foreshadowing a strong, meaningful connection to physics for Maria midway through the semester.

INTERVIEWER: So in microbio, if you have flagella like that, would physics help you answer that?

MARIA: Oh for sure. [*laughs*]. . . you have the chemistry interactions that get you the movement, they happen inside the cell, and then the physics can explain those chemistry interactions [Int 2]

When asked how she realized physics can explain why, Maria explains that it didn't happen until she had the tools to make the connection between microbiology and physics.

MARIA: . . . sure you can see something and be like 'physics probably explains that' but I don't know physics, so why would I think about it that way if I don't have that tool?. . . taking this course, the microbio course alongside physics where things like work and torque and force are coming up in a field that I know about, it helps you see. [Int 2]

This moment is so powerful for Maria that she suggests these types of investigations is the physics she would imagine herself doing.

MARIA: The physics I'd be interested in doing is something like this [paramecium activity]. . . it's too late in my career, my parents would kill me if I switched my major. . . I'm interested in how it [physics] relates to the macroscopic biological world. I know other people do other things but this is where the physics I like. [Int 2]

Maria's real-world connections are shaped by her disciplinary identity as a microbiologist. When physics can connect to the world she identifies with, we see Maria articulate connections linking physics content knowledge with biology. When asked if she thinks of physics outside of the classroom, Maria responds

MARIA: . . . not so much [Int 1]

Similarly, Maria states she doesn't talk about physics with friends or family.

INTERVIEWER: Do you talk to your family or friends about physics?

MARIA: No [shakes head] other than my friends that are in the class I don't know who. [Int 1]

Maria's connections to physics are different in nature to Beverly's. Beverly's connections involve her projecting forward to her intended future career as a physician and the practices of a physician, informed by observing and talking with physicians. Maria, on the other hand, makes connections across the disciplines, informed by her strong identification as a microbiologist. Overall, we see the intersection of physics and biology aligning with Maria's interests.

### 4.1.6 "Miles"

Miles is a first-generation college student majoring in biochemistry with a minor in bioethics who has never taken a physics course. He enjoys biology and conducts research in a biochemistry lab. Miles is fearful of physics and recalls horror stories.

MILES: I'm most nervous about physics to be completely honest, I've never taken physics before, never. . . you hear horror stories about physics [Int 1]

From his experience as a tutor for the biology and chemistry portions of the MCAT, he has seen negative experiences others have had with physics

MILES: That was kind of like the first time I saw physics like right up close. . . tutors were pulling their hair out, these kids just looked terrible after the physics parts. . . [Int 1]

This was Miles's first time learning physics and he was not certain how physics fit into the larger world but he repeatedly states that *"it has to be physics"* underlying many of the phenomena of the world. Miles uses the context of water molecules moving away from each other to explain how he sees biology, chemistry, and physics as being related

MILES: There's obviously driving forces behind it like I said I never really took physics so I didn't know. . . it has to be physics, it has to be. I think physics is a driving force behind everything, it has to be. [Int 1]

When asked if he sees physics concepts in other courses, Miles points to topics in his chemistry course.

MILES: Yeah I've seen glimpses, and I just, it has to be physics, like it has to be physics. In my mind it has to be physics but I just don't know like how exactly yet. [Int 1]

Miles looks to make connections between physics and his other coursework. When asked if he still has open questions about diffusion, he is interested in knowing why diffusion occurs.

MILES: I mean I guess like why it [diffusion] happens. I mean I know why, I can say because of entropy because you discretely, it's favorable to increase disorder. But I guess I don't know why exactly that's a thing, and I feel like that's why physics comes into play because that's the driving force behind all this movement, I think? [Int 1]

Early in the course, Miles was uncertain where physics fit into the larger picture but was certain physics had a role to play. After the unit of diffusion, in Interview 2, he is finding physics as connecting to biological processes.

INTERVIEWER: Do you think the idea of diffusion connects to biological molecules?

MILES: Oh yeah, for sure yeah yeah. . . I think that's relevant in any type of like physiology or biochemistry. . . things float around in solution for a reason, things are kept at different concentrations for a reason. . . [Int 2]

Miles's connections to the real world are more general than Maria's specific disciplinary connections to biology and different from Beverly's connections to car crashes and medical care. He believes that physics is important and expresses a sense that physics is the discipline underlying most phenomena. Similar to what we see with Beverly and Maria, Miles does not think of physics outside the classroom and does not talk with friends or family about physics. This is not surprising as this is his first physics course; he is still forming his conception of what physics *is*.

INTERVIEWER: Do you think of physics outside of the classroom?

MILES: No, literally never. . .

INTERVIEWER: Do you [talk to] family or friends about physics?

MILES: Not once.

INTERVIEWER: Or even about the concepts you learned in class recently?

MILES: No, [*laughs*] no. [Int 1]

#### 4.1.7 Discussion and Conclusion

In this paper we explored how PER surveys have aligned with an operationalized construct of relevance in physics education, especially in the ways they probe the relation between physics and students' lives. Beverly, Maria, and Miles do not commonly think of physics outside the classroom or talk about physics in their everyday life. Our larger data set suggests that thinking of or talking about physics in everyday life is rare for life-science students. We don't find this result surprising, the expectation that non-physics major students should perceive connections to physics in their everyday life is optimistic. However, our students have a rich set of disciplinary experiences. The separation of their connections to the real world into only two categories [19] is insufficient to capture the diverse ways students connect physics to their world.

Beverly, Maria, and Miles connect to the real world but in different, nuanced ways. Beverly understands the role physics *can* play but generally finds bringing in of physics to be (1) inauthentic based on her medical experience and (2) unnecessary to understand events like car collisions or throwing of a ball. Maria makes specific cross-disciplinary connections between physics and biology. She finds these connections engaging and discovers a new interest she was not aware of. Miles attributes the underlying mechanism for most things to physics. As he experiences more physics, he believes he will be able to more strongly articulate why physics is relevant to his disciplinary interests in biology and chemistry.

In this paper, our goal is to complicate the interpretation of unfavorable shifts in attitudinal and epistemological measures. We argue that students do see the relevance of physics in their lives but make sophisticated judgments on the role that physics plays. Our cases provide evidence that thinking of physics in everyday life manifests differently in student experiences and that students often make these connections without valuing them, which adds a complexity to interpreting results from these measures.

The relevance of physics to a student's life can take on many forms, and the collection of PER measures probes some of those ways. The cluster names are often descriptive labels put on a set of items that have been found to align together by validating the survey. Suggesting that a set of students respond unfavorably in connecting physics to the real world is a significant and meaningful statement. Our case studies demonstrate that the space around students' connections to the real world is complex and that measures of these connections should be nuanced or expanded if they are to reflect students' rich disciplinary experiences. This becomes especially important when teaching a physics for the life-sciences course in which we actively work to make physics relevant to life outside the physics classroom.

## 4.2 An uncommon case of relevance through everyday experiences

### 4.2.1 Introduction

Physics education research (PER) has probed for the relevance of physics in students' everyday lives. Attitudinal and epistemological surveys have asked students if they think of or use physics in their daily lives. We have previously documented how it is uncommon that our life science students describe using or even seeing physics in their daily life [12]. This result was unsurprising and aligns with previous scholarship of students majoring in disciplines outside of physics; we have previously argued that it is optimistic for scholars to expect students with disciplinary homes outside of physics to see their experiences through a lens of physics. The PER community commonly uses attitudinal and epistemological surveys [4, 5, 19, 20] for a variety of reasons including the evaluation of courses as well as the measurement of students' beliefs around the relevance of physics. For example, the Colorado Learning Attitudes about Science Survey (CLASS) contains two clusters of items that probe relevance: *Real-World Connection* and *Personal Interest* [19]. The majority of the items in these two clusters focus on how students think of or use ideas in physics outside of the physics classroom with many asking about students' everyday lives.

In our introductory physics for life sciences (IPLS) course we have found that students rarely report bringing physics ideas into their everyday experiences. Our case students have commonly laughed when we ask if they think of, use, or talk about physics in their daily life. This result is not surprising when placed in the context of previous scholarship on students' beliefs around physics.

Elliott [14] reports similar stories of students laughing at the thought of bringing physics ideas outside of the classroom. Many physics education research studies on survey measures report a deterioration in students' beliefs around physics as a result of instruction [4, 19]. Nair, Irving, and Sawtelle [12] have previously argued that it may be optimistic for physics instructors to expect or hope for life science students to see their everyday experiences through the lens of physics.

The data presented here is part of a larger design-based research effort to operationalize the construct of relevance for study in PER [12] as well as to articulate design conjectures of a classroom that attends to students' identity, affect, and beliefs [36]. In this paper we challenge our own previous claim that it may be optimistic for instructors to expect life science students to report the relevance of physics to their everyday lives [12] and present a contrasting case of a life science student (Sam, a pseudonym) who reports physics impacting her everyday experiences. The goals of this paper are to (1) articulate the important aspects of Sam connecting physics to her everyday life and (2) discuss the implications of Sam's story in designing more relevant physics classroom experiences for life science students.

### 4.2.2 Theoretical Framework

Relevance is a term that is commonly used in calls for reforming physics instruction [2, 18, 37] and in reports on the impact of instruction on student beliefs about physics [7, 9, 38]. We operationalize relevance as a construct based on how surveys in PER have described and measured areas of relevance [4, 5, 19, 20] and theoretical descriptions of relevance as a relation between the student and physics [16, 17]. We define relevance as *the opening of a conduit between two settings or experiences, through which meaningful knowledge or skills can be exchanged.*

In a classroom, relevance can be observed in moments where students bring in experiences from outside the classroom in meaningful ways. Reciprocally, it can also be seen as students bringing classroom experiences out of the classroom into the real world, future careers, or everyday life. Beliefs of relevance can be elicited through surveys or interviews and constitute only part of the complete picture. Another important part of relevance is situated in and facilitated by the interactions between students and their environments. For the purposes of this paper, we limit our attention to the ways in which students see the relevance of physics through everyday experiences.

### 4.2.3 Methods

This study is situated in the first semester of an IPLS course that is taught in the studio format. The course adapts available IPLS curricula and designs new materials with the aim of making physics relevant to life science students. This course also adapts discursive structures and participation frameworks from Modeling Instruction for introductory university physics [39, 40]. The classroom structures, norms, and participatory roles were designed to position students as experts, leveraging their extensive disciplinary experiences in biology and chemistry as they learn physics [36]. The course's design encourages students to engage in the practice of physics through argumentation and white-board meetings [40] in order to arrive at a classroom consensus.

Author Nair was embedded in the classroom nearly every day of instruction to manage data collection and capture field notes. He also supported the design and implementation of the course materials both as a researcher and previous instructor in the course. This paper focuses on analysis of the experiences of one student but is informed by the 22 other case students interviewed throughout this project, with some students being interviewed multiple times throughout their time in the classroom. To identify students for this larger data set, we solicited volunteers for interviews and in-class video observation. Volunteers were cross-matched with results from a course survey to identify volunteers who had a strong disciplinary identity, were fearful or anxious of physics, were skeptical of the value of the course, or were optimistic that the course could be relevant. Including participants that reported a strong disciplinary identity outside of physics was important in exploring how physics may be relevant to students who will never become physicists.

We present data from three interviews with one student, Sam. Each interview was video-recorded and followed a semi-structured protocol that included items to probe the relevance of physics to students' lives. The first interview took place in the first month of Fall semester. The second interview was conducted a month before the end of the Fall semester, and the third interview took place in the middle of the Spring semester, after Sam had moved onto a second semester physics course with different design goals.

### 4.2.4 Sam

Sam is a student dual majoring in nutritional sciences and kinesiology. Her mother is a physician and her father is a physical therapist. At the time of this study Sam is considering a range of career paths including neurology, orthopedic medicine, and psychiatry. Sam is interested in fitness and is an avid weightlifter working towards her personal training certification. In her initial course survey Sam reports that her personal training lessons are about "how the body functions as a series of machines, so physics is part of the human body and not just simple machines." She has previously taken AP Physics and in the first interview describes herself as consistently receiving "straight A's" in high school. In college she is finding the classes more difficult and her grades have dropped. In the initial survey Sam reports —on a scale of 1-to-10— maximum anxiety (10/10) about the physics course, low level of preparation (3/10), and low sense of capability (4/10). We note this here to point out that Sam is not intrinsically interested in physics from the start but in the following sections, we will describe moments in which Sam describes physics being relevant to her everyday experiences. Consistent with our definition of relevance, we frame these examples as intersections of physics and the different settings, roles, and relationships in Sam's life.

### 4.2.5 Classroom activities intersecting with Sam's lived experiences

Early in the Fall semester, students work through an activity on wound healing in which they are tasked with analyzing the motion of different cells moving in videos captured from a microscope. Students are asked to compare the speeds of the bacteria, neutrophils, and tissue healing to conclude whether antibiotics would be required [41]. Sam found this activity interesting and related it to her own experience with a wound.

SAM: The wound healing, that was very interesting. It was actually really cool to see the video of the wound closing. I had this severe cut on my arm, so I got to watch over time how the wound healed and how it's still healing right now. . . so watching that on video was really cool to me. To see how the body can reform itself and produce scar tissue when it's been completely sliced. [Int 1]

Sam connects the wound healing activity to her own experiences with a cut and watching it heal over time. Near the end of the first interview the first author asks Sam "Have you had any moments that you're proud of in class?"

SAM: Yeah. The wound healing. I keep going back to that. Being able to track that certain point; I found very satisfying. I was very proud of myself to be able to find the rate at which that wound healed. And if I could do that on a real person that would be really cool. Tell this person, oh you need antibiotics because this wound is not healing fast enough because this travels faster. [Int 1]

This activity becomes a central experience for Sam that she recounts in every interview, even well after finishing the Fall semester. In the second interview, Sam states that this activity was her favorite and that it was "*super eye-opening in how many different ways you can test whether or not a patient needs something*. [Int 2]" In the third interview, Sam describes "*it was just really cool to see what actually happened in my arm*." [Int 2] Sam also reports that she talked to people all the time about the wound healing activity telling them "*it's just like what happens in everyday wounds*! [Int 3]" She then jokingly tells us that people tell her she's crazy for talking about the activity.

In this section, we have seen the wound healing activity impact Sam's sense of the relevance of physics; the activity aligned with her interests, gave her a new perspective on her own experience with wounds, and led to conversations about physics in her daily life. In addition to this classroom activity, Sam reports seeing connections to physics in her everyday experiences in the gym and discussions with her friends. In the next section, we will describe Sam making relevant connections with support from her peer network.

### 4.2.6 Social activities & peers support Sam to see the world through the lens of physics

Our first sign that Sam's peers had an impact on her making connections to physics in her daily life is in Interview 1. Sam states "I like how. . . this class relates everything to what this world is." We then ask her to say more words around this.

SAM: You can apply physics to pretty much everything.

INTERVIEWER: When did you start thinking that physics can be applied to everything?

SAM: I have some friends who are engineers and they're pretty much into physics I guess. When I hear them talk about, how this works in this way, that makes me think. I have a friend who's an engineer right now or who's schooling in engineering right now. He just got into weightlifting, I'm helping him out. He's like 'I find it really interesting how the body is a bunch of levers and pulleys.' I've never thought of it that way, and in my course for personal training, there's a whole chapter about how the body is a bunch of machines. [Int 1]

Sam's engineering friend has an impact on how Sam thinks about the relevance of physics to the mechanics of the human body. Later in the interview, we ask, "Do you ever find yourself sitting and thinking about it like outside of the classroom setting?"

SAM: Uh-huh (in agreement). I go to the gym with my engineering friend a lot and doing a set either of us watching each other or just watching myself, I see how that works. You could also use physics to determine how to work a muscle better. Because if you were to —for a biceps curl for instance— if you were to go all the way down you would get most of the muscle and bring it all the way up. Whereas going down to 90 degrees is not going to work the entire muscle. . .

INTERVIEWER: I see. Is your friend also into thinking about the levers and stuff? Or is it something that you bring in?

SAM: Yeah he is. Yeah he is the one who brought the idea into my head. He's really into physics. He loves physics and so he'll find any way to relate back. [Int 1]

This engineering friend plays an important role in promoting conversations around physics in social settings. We interviewed Sam again near the end of the Fall semester and asked, "When you're out in the real world, do you ever find yourself thinking about the physics you learned in physics class?"

SAM: Yes, actually today, I was thinking; I was on my way biking to my 8 am class. . . I was on my highest gear, and I was like, what's the force I'm exerting on this peddle? . . . because it's not the force on the peddle, it's like the force in my muscles. And how do my muscles get energy to produce that amount of force? Well, when it's in the food that I eat, and then where does that energy come from? It's just cycles. So sometimes it pops into my head, yeah.

INTERVIEWER: Awesome. Were there any other examples that come to mind?

SAM: With my engineer friend, he brings it up a lot. . . . we were talking about how the wheels-to-wheels law, where you're supposed to be biking with the traffic. . . . we had this debate, and he's like, "Well, you're more safe if both momentums are going the same direction, as opposed to a head-on collision." And then I brought up the point where you have time to react when you're going the opposite way, whereas, if they just come up and clip, you don't have time to react because you don't even see them. So he brought up a bunch of physics. . . we just had the large debate and brought physics into it. [Int 2]

This debate over the correct rationale for the direction of bicycles on the road is memorable for Sam as she brings it back up in the third interview. She reiterates both her and her friend's arguments and mentions that they may still jokingly bring up this debate. We then ask, "do you have other moments where you are kind of in the world, observing things and physics comes to mind?"

SAM: Yeah! If you see an icicle fall, depending on how high it is, it could totally kill someone. [*laughs*] I was like talking about that with a friend like 2 days ago.

INTERVIEWER: Really? Take me into that conversation.

SAM: We were walking, because I live in an apartment now, and we were walking by the complexes. There are these giant icicles hanging from the gutters and she was like "Wow! Those could kill you." I was like well I guess it depends on how far they fall because if they're right above you then there's not much gravity to carry it down. And she's like well I guess so but the height they are they probably could kill you because they're huge! And that just brings in the mass and acceleration because you have the acceleration due to gravity and you have the mass of the icicle. Yeah, so that's where that conversation went.

INTERVIEWER: Why do you think you're noticing these things? What would you credit that to?

SAM: Um. . . I actually would credit it to my friend, he's an engineer. . . because he sees physics in everyday life more than I do. And so when he'll bring it up, it'll make the wheels in my head turn. And now that I understand these concepts given my professors, I can apply that to different things that I see. So I guess I credit it to everybody. Now that I have the knowledge and someone is helping me apply it to make my mind start going off somewhere else where it normally wouldn't. [Int 3]

Sam credits her seeing physics in her daily life to both the knowledge she's gained from learning physics and her engineering friend in helping her apply those concepts to the world. She then makes connections to physics unprompted to reason through what variables are important in considering the lethality of falling icicles.

### 4.2.7 Discussion & Conclusion

Connecting physics to everyday life is a major component of attitudinal and epistemological measures in PER that serve to evaluate course designs and their impacts on student beliefs around physics. Previous studies in PER and our own findings have reported that it is likely students will leave a physics course believing physics and the real world are more disconnected than when they entered the course. This commonly found result has been reported as a negative shift or deterioration of students' beliefs around physics.

We presented a contrasting case of Sam, a student who reports thinking about physics in her daily life and seeing relevant physics as she experiences the world around her. We describe how her views were supported and facilitated by conversations with an engineering major and her hobby of weightlifting. We also described how her course activities prompted her to reflect on her own everyday experiences. In curricular reforms to make physics relevant to the life sciences, there have been efforts to make physics activities relevant to student interests by framing them in contexts that students may find interesting [9, 35] or related to their future careers [38]. Sam's experiences show us that this is only part of the solution. Sam was certainly interested in the wound healing activity but an important part to her finding that activity relevant was her own lived experiences of watching her own wound heal and her desire to understand how it worked.

Sam's experiences suggest that future reforms in making physics instruction more relevant should focus on designing activities and spaces to allow for students to bring their rich lived experiences into the classroom. Relevance for Sam is largely developed outside of the classroom, and classroom reform efforts setting out to affect relevance will be strengthened if they can incorporate students' outside of the class experiences. Her stories also imply that students are capable of making connections to physics if there is sufficient support and intersection between their interests, coursework, and support systems. It is the interaction of Sam's classroom activities, her interests, and her social support systems that facilitate the co-construction of the notion that physics is relevant to Sam's everyday life.

#### 4.2.8 Implications for Future Work

We have previously argued that the use of the phrase "real world" is abstract and excludes many of the disciplinary experiences life science students may have. We described how these disciplinary experiences were important in making relevant real world connections to physics [12]. Students' beliefs around the role of physics in the "real world" and their everyday life have constituted the bulk of the commonly used items designed to probe students' perceptions of the relevance of physics [4, 5, 19, 20]. Research into both areas of relevance through narratives of student experiences have highlighted the importance of classroom structures, norms, and culture in helping facilitate and amplify students' sense of relevance. In future work, we set out to articulate design principles that will guide the creation of more relevant physics classrooms and push for holistic classroom reform efforts beyond applying a veneer of relevance in problem statements.

**CHAPTER 5**

**OPERATIONALIZING RELEVANCE IN PHYSICS EDUCATION: USING A SYSTEMS VIEW TO EXPAND OUR CONCEPTION OF MAKING PHYSICS RELEVANT**

## 5.1 Introduction

National policy recommendations for the integration of knowledge across the disciplines continue to position physics concepts and reasoning skills as being important and useful to degrees in STEM or careers in the health sciences [1, 3]. Many undergraduate students pursuing a degree in STEM will be required to complete an introductory physics course [42] but research in Physics Education Research (PER) suggests that students do not share the belief that physics is relevant to them [4, 6, 19, 20, 43–48].

In a typical large physics department, non-physics majors constitute one of the largest proportion of students in an introductory physics classroom (algebra-based and calculus-based combined) [11]. It is important to the success of these students, who do not plan on pursuing physics as a career, that they build connections from physics to their lives [4, 49].

Our purpose in this paper is two-fold — first to review the ways in which scholars in PER have attempted to probe students' sense of relevance and show how the picture of relevance generated by such measurements is incomplete. Our second goal is to operationalize a construct of relevance that explores the systems that comprise students' lives and use it to analyze student experiences in an introductory physics for the life sciences course. We present the experiences from two case studies that highlight the affordances of this approach in capturing a richer, more expansive picture of students' sense of the relevance of physics. During this work, we critically examine the implications of having an incomplete picture of students' abilities to connect physics to their lives in perpetuating deficit-interpretations of the abilities of life science majors.

### 5.1.1 What we know about relevance

Even in the midst of calls for instructors to make their curricula more relevant to students, there is much disagreement across the disciplines on the definition of relevance [16, 17, 50]. Newton (1988) noted that "the notion of relevance in science education seems fraught with inconsistency, obscurity, and ambiguity." Bookstein described this issue very concisely —"relevance is one of the most central concepts of information retrieval; however, attempts to provide it with a definition have been frustrating and confusing" [16]. Scholars of relevance agree that the sense of relevance we are exploring is a relationship between the participant and the subject in question [16, 17]. In order to study this sense of relevance in our physics classroom, we focus on students' experiences that contribute to development of meaningful relationships between classroom elements and their lives.

Relevance is a challenging construct to explore due to the differing meanings in the literature. Relevance has been used as a synonym for student interest, perceived meaningfulness, perceived utility, relating to real-life, or a combination of all the above. Stuckey et al. (2013) trace the differing notions of relevance in science education throughout history and find that there is an evolving focus of policy recommendations on how science *should* impact areas of students' lives. The authors identify three possible purposes for making science education relevant [18]: (1) preparing students for potential careers in science and engineering; (2) helping learners understand scientific phenomena and coping with challenges in life; and (3) supporting students becoming effective future citizens in society.

Although the specific meaning of relevance may be difficult to pinpoint in the literature, we have decades of policy and curriculum recommendations from science educators outlining how relevant instruction should or could impact students' lives. Our goal here is to shed light on how student experiences can inform the ways in which a physics classroom can be relevant. In order to operationalize relevance as a construct, we draw upon the work already done in the PER community around probing and describing relevance. We start by focusing on areas of students' lives that surveys in PER have probed, highlight its limitations, and articulate a more expansive view of relevance that will then serve as a research lens we can apply to students' experiences.

### 5.1.2 How physics education research has probed relevance

Students' beliefs around the relevance of physics has been a focus of many attitudinal and epistemological surveys used in physics education research [4, 5, 19, 20]. In this section, we focus on the Colorado Learning Attitudes about Science Survey (CLASS), the Maryland Physics Expectations Survey (MPEX), the Views About Science Survey (VASS), and the Epistemological Beliefs Assessment for Physics Science (EBAPS) to show how they have probed relevance. We argue that the image of relevance generated from the items on these surveys is incomplete.

Starting with these survey measures and expanding to include scholarship around relevant physics instruction, we arrive at areas of students' lives being explored and the desirable outcomes after instruction:

- Future Career: Students reporting that the physics they have learned will be of use in their planned future career [4, 38, 51]
- Real World[1]: Students reporting that physics is connected to the world in which they live. [4, 5, 19, 20]
- Everyday Life: Students reporting thinking of, talking about, or using physics in their daily life [4, 5, 19, 20]
- Personal Interest: Students' reporting that they enjoy doing physics or that it provides a sense of satisfaction [4, 5, 19, 20]

Beyond these survey measures, there have been recent efforts to expand what areas of students' lives contribute to their connection with physics, specifically looking at disciplinary interests. Crouch, Geller, and colleagues have investigated student attitudes, interests, and performance in

[1]We have argued that this category can be problematic in interpreting students' negative responses [12]

physics activities framed expansively with biological contexts [9, 10]. In the next sections we explore each of these surveys in more detail.

#### 5.1.2.1 MPEX - Reality Link

The Reality Link cluster of the MPEX is described as probing whether students believe that ideas learned in physics are relevant and useful in a wide variety of real contexts, rather than having little or no relation to outside experiences [4]. The authors of the MPEX directly state that interpretations of this cluster are about the relevance and utility of physics.

In Redish and colleagues' large study using the MPEX, spanning six institutions (N=1,528 students), they report that students entered with strong favorable responses in the Reality Link cluster. By the end, however, "every group showed a deterioration on this measure as a result of instruction, and some of the shifts were substantial [4]." This is not uncommon, a decline in favorable responses or an increase in unfavorable responses on the Reality Link cluster has been reported by studies across a variety of curricula, pedagogies, and student compositions [43, 52–56]. The Reality Link cluster was intended to probe whether students believe that ideas in physics are relevant and useful to a wide variety of real contexts rather than having little or no relation to outside experiences. The implication being that students with a negative shift in this cluster do not believe ideas learned in their physics course are relevant to real contexts or their experiences.

#### 5.1.2.2 CLASS - Personal Interest & Real World Connection

The CLASS has two clusters that appear to probe the relevance of physics, Real World Connection and Personal Interest. These clusters are described as probing whether students find the physics ideas they learn to be interesting or connected to the real world. [19]

The authors of the CLASS have reported that the typical result for both the Personal Interest and Real World Connection clusters is a negative shift in favorable responses [19]. Negative results on these two clusters were reproduced in several other studies as well [44–47].

There have been some positive results reported on this cluster; Zhang and colleagues conducted a study of 441 students and compared CLASS results across traditional lecture methods and Peer Instruction. They report traditional methods resulting in negative shifts in both clusters and Peer Instruction sections producing generally positive in both clusters [57]. Brewe and colleagues initially reported positive shifts in both clusters in a small study of two semesters (N=22 and N=23) of physics taught using Modeling Instruction and reproduced positive shifts with a larger sample of 221 students [6, 7]. Another study of 44 students utilizing Modeling Instruction by de la Garza and colleagues reported a null shift in the Personal Interest cluster but a positive one in the Real World Connection cluster [58]. From these studies we see that the typical result for the CLASS across many classroom contexts is negative, with some examples of positive results.

#### 5.1.2.3 VASS - Personal Relevance

The VASS has had a personal relevance cluster[2] consisting of five items that were intended to probe if physics was relevant to everyone's life rather than the exclusive concern of scientists and if studying physics was an enjoyable experience [20].

The designers of the VASS state that "traditional physics instruction has no significant effect on student views about science" and that "on most VASS items, students tend to shift a little more toward folk [considered opposite of expert] views than expert views, after instruction." Unfortunately we could not find studies that reported shifts from pre- to post-instruction within the Personal Relevance cluster.

#### 5.1.2.4 EBAPS - Real-life Applicability

The EBAPS contains a cluster called Real-life Applicability, which probes whether students believe that the ways of thinking in a physics class is restricted to the classroom or if it is applicable in real life. In other words, do students find the ways of thinking in a physics class to be ***relevant*** outside the classroom?

[2]Personal Relevance appears in VASS version P204 and is absent in P05.07

In studies of high school physics students in California (N=27) and Virginia (N=55) Elby (2001) reports a null shift in this cluster in the California study, and a positive shift in the Virginia study [49]. He reflects that the "failure in California caused me to use more real-life examples and to make other modifications when I taught in Virginia." In a larger study (N=255) Marx and colleagues created a modified cluster of items from both the EBAPS and the MPEX probing the relationship between classroom science and the real world. In both the traditional course as well as the "learning-centered" course using research-backed practices, they find a negative shift in this cluster. The authors reflect on this finding, "our Learning-centered course implicitly addresses issues related to several of the clusters by. . . having students experience simple, explainable, real-world phenomena in the classroom (Reality). Nevertheless, it fails to improve students' attitudes [48]."

Clusters in these four surveys in physics education claim to probe student beliefs of the relevance of physics. It is the results from these surveys along with other scholarship around how students interpret the role of physics, that have formed physics education's understanding of the question: Do students believe physics is relevant to them? When exploring the results to this question, we find that negative shifts in beliefs around the relevance of physics are typical but that positive shifts are possible. It remains unclear how to use these results to inform changes to physics courses to directly impact students' beliefs around the relevance of physics. In the next section, we will reflect on some of the interpretations scholars have made about students' unfavorable beliefs around the relevance of physics.

### 5.1.3 Deficit-based interpretations of student beliefs around relevance

One of the challenges of probing student beliefs around relevance is that the endorsements of belief statements are often placed on a spectrum between novice-like and expert-like. Unsurprisingly, experts in physics believe that physics ***is*** relevant. The gap between students' novice-like beliefs and experts' beliefs can sometimes to lead to the problematic interpretation that students with unfavorable responses have not committed themselves to making connections or have failed to see the relevance of physics. For example, Kortemeyer reported in his study of pre-medical students that "the results of the MPEX indicate that over the course of the semester, the perceived relevance of physics decreases. [43, page 3]" Reflecting on this finding, he notes "contrary to the student responses in the MPEX Reality Link Cluster, physics simply is relevant for a physician. [43, page 3]"

The notion that students are somehow lacking the ability or unwilling to see the relevance of physics is reflected in scholarship that suggest instructors should persuade, demand, or force students to make connections. "In order to realize instructionally significant gains in epistemology, it seems we must carefully craft materials demanding students to overtly and critically evaluate how they learn science and the nature of science itself. [48, page 4]" Bennett, Roberts, and Creagh (2016) reported the success in establishing relevance in a foundational physics course through a 2-hour workshop focused on self-reflection and group work designed to position students' learning in relation to their future lives and careers. They recommend instructors "ensure that students perceive the material they are asked to learn as authentic and of relevance to their future lives and careers. [38]"

We argue that these recommendations should be modified to move the focus away from fixing the student and toward designing classrooms to invite and support students in bringing-in their experiences, thereby incorporating the students into what it means to learn physics. Our view is in line with and supported by a study by Gray and colleagues (2008) that found that students reporting novice-like beliefs on the CLASS are "quite aware of what physicists believe about physics and learning physics; they just do not believe that these ideas are valid, relevant, or useful for themselves. [59]" They recommend that instructors should concentrate on strategies "that go well beyond telling students about how experts view physics and focus on making adoption of expertlike views truly useful and relevant for students. [59]"

Life science students taking a physics course may only be required to take one or two semesters of physics depending on their major. If physics education continues to position student beliefs on a spectrum of expert-like and novice-like, or on a degree of "sophistication", we risk underestimating the relevant connections life science majors make. Adams and colleagues have found that "students' incoming [CLASS Personal Interest cluster] scores increase with level of physics course. Thus, students who make larger commitments to studying physics tend to be those who identify physics as being more relevant to their own lives [19]" We hope to complicate this picture by providing examples of life science majors without a "larger commitment" to studying physics beyond the introductory sequence who articulate relevant connections to physics.

We argue that insisting that physics, as it is taught, ***is*** relevant is bound to create tension with students due to mixed messaging they may receive on the relevance of physics. Beverly (pseudonym), who is majoring in human biology with the intention of attending medical school, states that physicians she has shadowed have told her they do not find physics relevant to what they do.

> BEVERLY: I talked to like various physicians I've shadowed and asked them like what do you actually use. . . they're like. . . "I don't really use that much physics"
>
> —[*Int* 1]

Beverly's belief that physics is a course she just has to get through seems in agreement with the beliefs of medical students, graduates, and physicians who state that physics was irrelevant to their success [60–62]. There have also been studies reporting that physics has no strong correlation with success in medicine [63, 64]. We will show how, instead of challenging students' beliefs about the relevance of physics to their future careers, we can start to incorporate their rich disciplinary experiences to make physics more relevant.

Failure in a student's ability to see physics connecting to one's world or life appears to be damning indictment of the abilities of students to engage in thoughtful reflection about their coursework. We don't believe the authors of every article reporting negative results on clusters from these surveys mean to suggest this. We believe the issue lies in the limited picture of relevance and what it means to *measure* a student's sense of relevance. We suggest that perhaps the measure of relevance provided by such attitudinal and belief surveys is incomplete, especially with regard to how disciplinary experiences outside of physics impact that sense of relevance. We present analysis in this paper that pushes against deficit interpretations and instead argues that if students' ideas are brought into the classroom, students can and do make relevant connections.

### 5.1.4 An incomplete picture of relevance

We argue that results from clusters probing relevance are not sufficient to form a complete answer to the question: Do students believe physics is relevant to them? The majority of the work on relevance in PER [4, 5, 19, 20, 38] has been centered on the local context of the physics classroom, how physics may impact students' future careers, or how students relate physics to their world (the generalized "real world" or their everyday lives). These areas of intersection between the physics classroom and a student's life fail to capture some critical ways in which students inform their attitudes toward physics. Students often arrive at the introductory physics classroom with attitudes and beliefs informed by experiences outside of the physics classroom, conversations with friends and family, and the disciplinary perspectives they may hold. We argue for expanding our notion of what contributes to a student's perception of the relevance of physics to include these additional experiences. The students in this article are all life science majors; they have a rich set of disciplinary experiences outside of physics that may inform and impact their relationship with physics [36]. Through their experiences, we will show that expanding our probes to include disciplinary experiences outside of physics captures a richer image of how physics can be relevant.

To support this expansion of what contributes to relevance, we adapt ecological systems theory [22] to represent students as existing in overlapping systems that all contribute to their perception of the relevance of physics. This approach enables us to build a construct of relevance that goes beyond treating a student's sense of relevance as contained ***within*** the student, it allows us to ask questions about the intersection of the many experiences in a student's life that have contributed to their view of the relevance of physics.

## 5.2 Theoretical Framework

In this section, we revisit the messiness of relevance as a construct and attempt to give it more structure and definition. In constructing a theory of relevance for physics education research, we remind ourselves of the purpose of this entire enterprise. We are interested in finding out if we, as instructors and researchers, can impact students' beliefs around physics. With this in mind, we set out to answer the following questions. For what purposes will students retrieve the information they have learned in physics outside of the classroom or vice versa? Will students find meaning or value in physics beyond its purpose in the classroom? Do students construct productive connections between physics and other scientific disciplines?

### 5.2.1 Positioning relevance as a theoretical construct amongst attitudes & beliefs

"Do you ***believe*** physics is relevant to you?" How we colloquially probe relevance in conversations invokes belief systems, as does the language used in survey measures in PER [4, 5, 19, 20]. Beliefs, then, serve as a starting theoretical foundation for us to build upon in operationalizing relevance. Pajares provides a thorough view of beliefs, tracing its development as a unit of analysis and the challenges in arriving at a consensus for the meaning of a belief. He articulates a set of findings, inferences, and generalizations researchers have confidently reported about beliefs. Drawing from Pajares's 16 fundamental assumptions about beliefs —each supported with a body of literature— and from the decades of focus on improving physics instruction we can move forward reasonably confident that (1) Students' beliefs about physics exist and may impact many aspects of students' lives and (2) students' beliefs about physics are the focus of many efforts to improve physics instruction.

In order to start building a structure to organize relevance, we adapt Rokeach's organization of beliefs and attitudes [21]. Rokeach describes an attitude as a set of beliefs focused on or aligned towards an object or situation [21]. We argue that a student's sense of the relevance of physics is not informed by a single belief but that a student uses many beliefs, formed and shaped by many

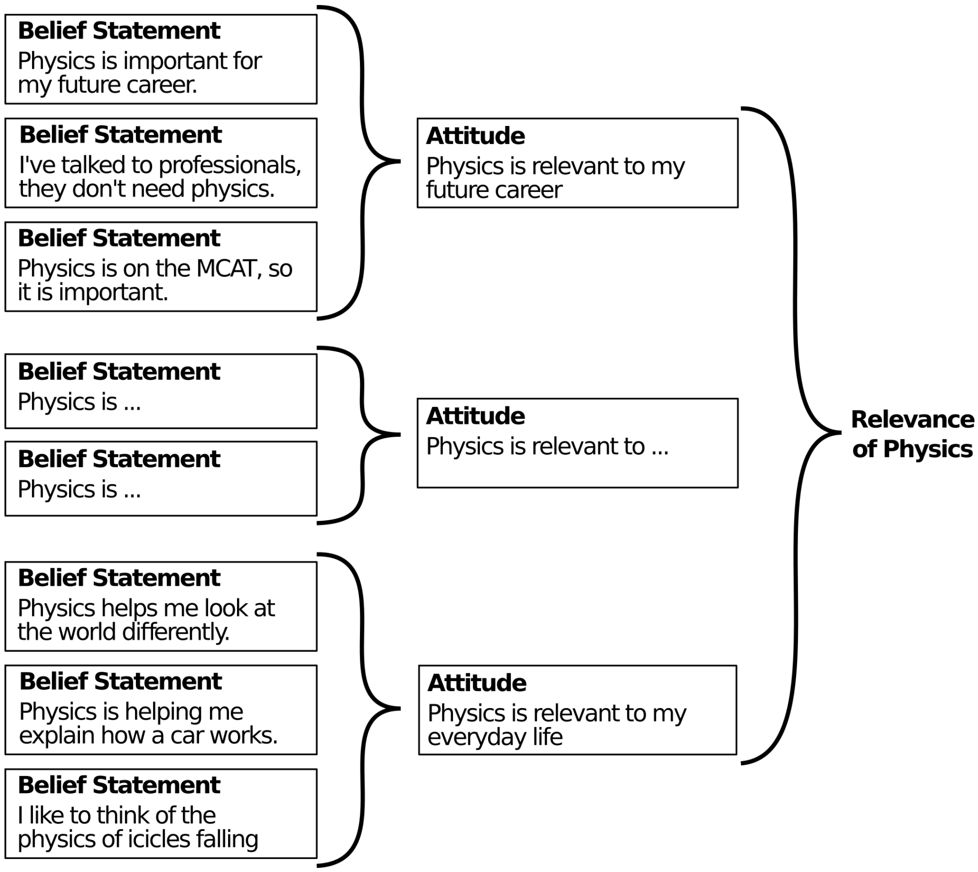



Figure 5.1: A representation of relevance consisting of multiple attitudes and beliefs. This is not intended to be an exhaustive list of all beliefs and attitudes that help form a sense of relevance but serves to give an example of such an organization. Multiple beliefs (inferred by belief statements) are organized into attitudes. Multiple attitudes constitute a sense of relevance. Belief statements are used to infer beliefs in this structure as they are the most readily accessible to researchers measuring students' beliefs. This organization of relevance aligns with (1) the structure of previous survey measures of relevance in PER and (2) Rokeach's theoretical organization of beliefs.

experiences, to evaluate how relevant physics is to them. Similarly, we contend that a student can have multiple attitudes that form a sense of relevance. A student may have an attitude around "physics being relevant to their future career" as well as an attitude focused on "physics being irrelevant to their everyday life" and these in concert, along with numerous other attitudes, can influence a student's sense of the relevance of physics.

This organizational structure (Fig 5.1) —relevance consisting of one or more attitudes, which themselves consist of one or more beliefs —aligns well with commonly used survey measures in PER [4, 5, 19, 20]. In these surveys, students are asked to endorse individual belief statements by choosing levels of agreement on a five-point Likert scale or to situate their viewpoint between two opposing belief statements on a five-point scale. These individual items representing belief statements are then grouped using quantitative methods to arrive at sets of items or clusters that probe similar ideas. This approach to the design of the surveys aligns with Rokeach's organizational structure: individual question items ask students to endorse belief statements, and a set of these belief statements are grouped together to characterize a broader attitude toward physics.

### 5.2.2 Adapting ecological systems theory

A student's life has many layers, they participate in a multitude of settings and we expect their sense of the relevance of physics will be impacted by these numerous contexts and interactions. Ecological systems theory (1) preserves the richness and complexity of students' lives, (2) serves as a map for scholars studying relevance to locate relevant intersections of contexts, and (3) provide utility to physics instructors as they attempt to make instruction more relevant to their students. Ecological systems theory was originally developed to characterize different layers of systems that affect human development. Bronfenbrenner (1979) describes the ecology of human development as the study of how a person and the dynamic settings they experience mutually accommodate and adapt to each other under the influence of relations between settings and larger contexts the settings are embedded within [22].

There are three underlying features of this framework that will be important in our construct of relevance: (1) The person is considered a dynamic entity with agency to impact their environment; (2) The interaction between a person and their settings is reciprocal by nature, each having the ability to impact the other; (3) The environment that is influencing the person is not limited to a single setting but expanded to include connections between settings and external influences. We adapt the first two features to mean that a physics classroom does not simply impart knowledge on its students but is shaped by the students and the experiences they bring in. We adapt the third feature to state that a student's sense of relevance of physics is not solely influenced by their physics classroom.

In adapting these features of ecological systems theory, we bring along a situative view of the classroom[65–67]. Specifically, we will consider how the structures and cultural values of a physics classroom can inform relevance through interactions with other settings in a student's life. This situative perspective on what contributes to a student's sense of relevance will have implications for our view of the ability of commonly used attitudinal and belief surveys to probe the whole of relevance. Particularly, items probing students' beliefs around connections between different disciplinary courses are missing. We will show how these connections can be an important contribution to a student's sense of the relevance of physics.

An additional affordance of this situative perspective on relevance is that it gives us the power to describe the enactment of physics classroom with more richness. This view positions the classroom as an actor on the stage rather than a passive environment the student experiences. The situative perspective necessitates that we acknowledge that the design and implementation of a classroom is imbued with cultural values through its structures and not simply a collection of curricula and pedagogy. The classroom's tools and materials, discursive practices, participatory structures, and task structures [68] all convey cultural values. We believe that viewing the classroom as one actor among many in a students' ecosystem can help in articulating the structures within the classroom and relationships across classrooms that promote relevance.

#### 5.2.2.1 Structure & Organization of Ecological Systems

Bronfenbrenner [22] organized ecological systems theory as a set of concentric systems encompassing an individual as shown in Fig 5.2. Each system represents layers of contexts and interactions which may inform the development of the individual. In the descriptions that follow, we will adapt ecological systems theory from its original purpose, which was to explore human development, to describe students in a physics classroom.

The characteristics and identities of the individual including but not limited to age, sex, race, or health are positioned in the center. The first layer encompassing the individual is the microsystem, which is defined as "a pattern of activities, roles, and interpersonal relations experienced by the

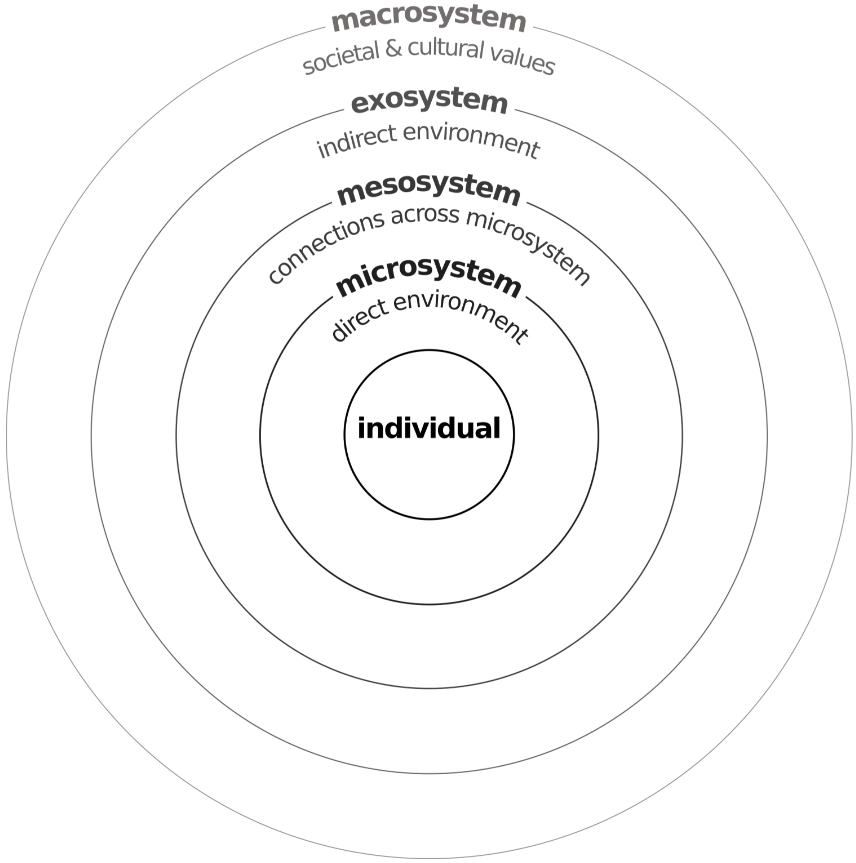



Figure 5.2: A visual representation of Bronfenbrenner's [22] organization of ecological systems theory as a set of concentric systems encompassing an individual —moving outward from the center are the —micro-, meso-, exo-, and macrosystems.

developing person in a given setting. . . [22]" We can imagine this system being occupied with settings a student actively participates in including their coursework, research groups, jobs, social settings with peers and family, and more. In addition to the settings, the microsystem also includes the roles the students play in these settings and the interpersonal relations within these settings.

The mesosystem "comprises the interrelations among two or more settings in which the developing person actively participates. . . [22]" The mesosytem can help us describe the interrelations between settings in the microsystem. For example, a physics course and a biology course may interact with each other through the culture enacted in each course which can incorporate the pedagogy, curricula, or participation structures. A common interaction we encounter in the mesosystem is that our students enter our course having heard horror stories of physics experiences from their peers, family, or from the broader messaging that physics is difficult and not directly applicable to the future careers of life science students. In this paper we will focus on elements of students' mesosystems and show how they can be powerful mediators of a student's sense of relevance.

The exosystem includes the settings that the student does not actively participate in but nonetheless impact or are impacted by the settings in which the student actively participates. Examples of elements in the exosystem include the physics experiences of family or friends, the employment of a student's primary caregiver, or the policies that impact a student's education. This level of the student's ecosystem can also hold future career qualifications, medical school admissions criteria, and even mass media. All of these interactions inform not only a student's participation in the physics classroom but also influence the design and implementation of the classroom itself.

The macrosystem contains cultural and societal norms that exist consistently within any set of lower-order systems —micro-, meso-, or exo- —and can include belief systems and ideologies that govern the lower-order systems. We can imagine the contributions of the culture and society to a student's perception of the relevance of physics. If we narrow our focus to the culture within specific scientific disciplines, there may emerge a set of norms, attitudes, ideologies, or expectations that govern participation in a variety of settings of a student's microsystem. The macrosystem has important implications for our study of relevance. All of the students described here have a disciplinary major outside of physics; the culture of a student's home discipline can inform their participation in and attitudes toward physics. [69, 70]

Bronfenbrenner would later add a layer beyond the macrosystem called the chronosystem which includes events and transitions in one's own life as well as the environment around them. In this study we exclude the chronosystem from consideration as we do not have sufficient longitudinal data from student's entire lives to comment on the significance of major life events and transitions beyond their time in our physics classroom.

Each of these systems will play a role in students' lives but for the purposes of this paper we will focus our attention on the microsystem and mesosystem. We believe these two layers represent rich spaces to explore the relevance of physics and are the most readily accessible in the design of this study.

### 5.2.3 Relevance through transformation of participation

A consequence of using a situative approach to relevance is that the settings and the structures that comprise them are embodied with values and they are intertwined with the co-construction of relevance with the student. Rogoff and colleagues (1995) described this in their work on defining development as a transformation of participation. "Individuals' efforts and sociocultural institutions and practices are constituted by and constitute each other and thus cannot be defined independently of each other or studied in isolation [66]." This directly informs how we interpret students' experiences presented in this paper. Our students' statements around finding physics to be relevant are often intertwined participatory acts that reciprocally impact and are impacted by the classroom structures. The classroom structures and the student, in concert, shift their participation from experiencing an activity in physics to transforming the activity with their contributions.

## 5.3 Methodology

### 5.3.1 Studio & IPLS classrooms are rich contexts to study relevance

The context for this work is an introductory physics for the life sciences classroom in a residential college within Michigan State University called Briggs Life Science Studio Physics (BLiSS Physics). This physics course has been recently reformed to leverage connections to biology in the learning of physics. As previously mentioned in the description of the mesosystem, one way we expect students to find relevance in physics is through cross-disciplinary connections. Classrooms that promote building of connections across disciplines are a rich context to explore a construct such as relevance. A student who is majoring in the life sciences may already have a strong sense of relevance of their own areas of study that may not extend into the physics classroom. A context that emphasizes connections between physics and the students' home disciplines provides the opportunity to observe students experiencing and reflecting on these connections. These moments are characterized by the nature of the classroom activity and a student's participation impacting one another.

BLiSS Physics adapts curriculum, discursive structures, and participation frameworks from Modeling Instruction for introductory university physics [39, 40]. In addition to breaking the traditional distinction of lecture and laboratory, our implementation of the studio format in this course emphasizes student-led investigations as an entry point into every unit. Student groups design and implement investigations to arrive at empirical rules supported by evidence that govern a phenomena. The entire classroom then utilizes white-board meetings and argumentation to arrive at a classroom consensus [40, 71]. Computational activities are used throughout the course to support students gaining competency in using vPython to model and visualize phenomena that cannot be done using traditional closed form analytic methods. In these activities, students are presented with minimally working code that runs without errors but is lacking the correct physics. Students then are asked to use their physics concepts to write or correct the few lines of code so that the physics used in the simulation is correct. Students are never asked to write python code from scratch, rather the focus is on students developing an understanding of foundational programming structures (constants, loops, conditional logic statements, etc.) and to gain competency in modifying existing code to suit their needs.

In introductory physics classrooms we often position students as being novice without consideration to the extensive rich disciplinary content knowledge they possess outside of the discipline of physics. To address this, BLiSS Physics intentionally positions students as being expert in their home disciplines and has space designed to allow students to **bring in** their expertise [36]. When students engage in bringing in disciplinary content knowledge or life experience into the physics classroom, it presents a significant opportunity to forge connections between students' lives and physics.

### 5.3.2 Data Collection

The data presented in this article are part of a larger design-based research [30] endeavor in (1) developing and iterating on an introductory physics for the life sciences course and (2) articulating

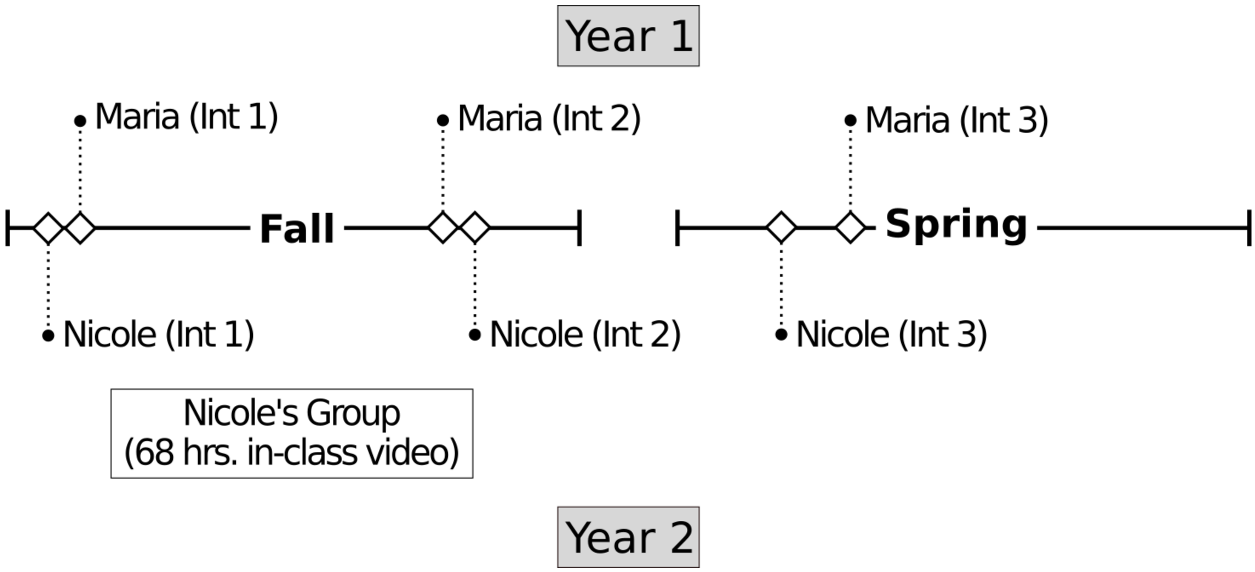



Figure 5.3: The time-line of data collection for the case studies presented in this paper, Nicole and Maria. Both students took the BLiSS Physics course in the Fall semester and a different second semester physics course in the Spring. In Year 1 of this study, in-class video was recorded of focal groups working through a unit on diffusion. In Year 2, focal groups were recorded throughout the entire semester. This figure represents a subset of a much larger research study that followed over 25 students across the 2 years.

design conjectures [68] in establishing a classroom environment that attends to student affect, positions students as disciplinary experts in the life sciences, and promotes the relevance of physics. design-based research is a situated approach to studying classrooms; the embedded nature of this methodology is reflected in the analysis which coordinates across multiple streams of data across two years of iteration in the course.

Potential case students were identified from a course survey given in the first week of class that asks students to reflect on their previous experiences with physics as well as their disciplinary interests. The survey included both open and closed responses and were reviewed for the presence of certain factors such as students expressing a strong disciplinary identity, high anxiety or fear leading into the first semester of physics, or students who were open to physics potentially playing a role in their future career.

Independent of the survey, students were asked to consent to in-class video recording as well as volunteer to participate in research interviews. Students whose survey responses were deemed interesting based on the factors described above were cross-matched with interview volunteers. A semi-structured interview protocol was developed to probe students' beliefs around the relevance of physics as well as their beliefs around the design of the course. The case students that were interviewed were recorded in class as they worked on activities in small groups. Based on the initial interview, in-class video, and availability students were interviewed multiple times.

Author Nair was embedded in the course both as a researcher and as a member of the instructional team (in sections he was not conducting interviews). Field notes and observations were used to capture significant moments in the classroom as well as the general effectiveness of classroom activities in achieving their learning outcomes. This deep involvement in the classroom environment helped form an understanding of the culture of the classroom as well as the discursive and participatory norms practiced throughout the course.

The first interview took place in the first few weeks of the Fall semester. The second interview took place approximately halfway through the semester after a unit on diffusion. The third interview was conducted midway through the Spring semester (Fig 5.3). One of the case students, Maria, became an undergraduate learning assistant in the course and was interviewed a fourth time midway through their first semester on the instructional team.

### 5.3.3 Analysis Methods

In this paper, we include data from two case studies. Maria (pseudonym) was a student in the first year of the course, and Nicole (pseudonym) was a student in the second year of the course. After articulating categories of relevance PER has previously explored (Section B of the Introduction), we conducted semi-structured interviews to probe each category and discover new categories. Each interview with these case students was video recorded and transcribed. We used MAXQDA [32] to code each interview's transcript for evidence of student's beliefs around the relevance of physics. We utilized an open coding scheme to expand and refine areas that contributed to the relevance of physics. Each case student's in-class video was analyzed to find and corroborate events described in interviews, the resulting moments were transcribed and analyzed. In the classroom, author Nair was present for the vast majority of class sessions and recorded field notes of interesting moments in which the case students' senses of relevance may have been impacted. Based on his observations in class author Nair conducted impromptu audio-recorded interviews with the instructor on multiple days to better understand instructional choices and to capture reflections of moments shortly after they occurred. MAXQDA was used to triangulate these different streams of data and to record analytic memos as the project progressed. This analysis was presented and discussed at multiple research meetings to check the validity of interpretations and claims.

In the next few sections, we outline case studies of Maria and Nicole: two students majoring in the life sciences who report relevant connections to physics. Their rich experiences go beyond what can be revealed by current survey measures and challenge the deficit interpretations of life science students' ability to see the relevance of physics. Informed by their experiences, we argue for an expanded view of relevance that includes the connections students make across course structures as well as relevance co-constructed in a classroom designed to support relevant connections. Maria's case highlights the importance of the mesosystem in fostering relevance through connections between courses. Maria's experiences have implications for how a physics course can be designed to foster relevance but in past scholarship these attempts involve layering-on activities of reflection and meta-cognitive development. Instead of looking for ways we can impose relevance on students, we trace the experiences of Nicole as an example of how course design and participatory structures can impact a student's sense of relevance and have lasting effects after the course.

## 5.4 "Maria"

Maria is a microbiology major with a minor in epidemiology who identifies strongly as a microbiologist. She has founded or held leadership positions in multiple biology and infectious disease related organizations. She works in a water microbiology research lab, tutors students, and conducts campus tours. At the time of the interview Maria was concurrently enrolled in the physics course and a prokaryotic physiology course. Maria had previously taken physics in high school and recalls that experience as being disconnected from her interests. During this study Maria was in her junior year of her undergraduate education and planned to pursue a graduate degree in public health after graduation. In our first interview, Maria reflects on her previous experience with physics.

MARIA: The last time I've had physics was sophomore year of high school. . . I just don't think they did a very good job of connecting it back to everyone's interests. . . it was just theoretical pure physics. So, not my thing. . .

—[*Int* 1]

Maria states that the type of physics course she experienced in high school was not effective in connecting to students' interests in general and has concluded that physics is "not her thing." When asked if she believes physics is relevant to her, she is optimistic about the BLiSS Physics course and suggests that connecting to biology may be a path towards relevance for her.

MARIA: I think in this course it may be a little more 'cause of the [biology] connections, otherwise I would probably say no [*laughs*]

—[*Int* 1]

In this section we explore the ways in which Maria is finding relevance in BLiSS Physics that go beyond what attitudinal and belief survey measures have the ability to capture. We adapt Bronfenbrenner's ecological systems theory to describe some of the contexts in Maria's life that have connected to her physics course and impacted her view of physics. Finally we argue that students like Maria, who are life science majors can and do find physics to be relevant. We shift away from deficit-framing to look for ways in which the design of the physics classroom and the ecology of her disciplinary experiences have supported amplification of her sense of relevance.

### 5.4.1 Describing Maria with ecological systems theory

If we were to imagine the ecosystem that Maria's life exists within, there may be a multitude of elements that are not visible to instructors or researchers. Even though we are unable to fully describe Maria as a person —we doubt any theoretical model can fully encapsulate a person's life

—there are many elements and relationships that we see playing an important role in her sense of relevance. We focus on those areas in what follows.

#### 5.4.1.1 Maria's microsystem

Starting with the most central system, Maria's microsystem includes her courses, her microbiology major program, her water microbiology research lab, her clubs and organizations, as well as her family and peers. Additionally, her microsystem includes the roles she takes on as well as the interpersonal experiences within these settings. These are the settings in which Maria actively participates and engages in activities and we expect them to contribute to her sense of relevance.

#### 5.4.1.2 Maria's mesosystem

Maria's mesosystem involves the relations between the settings in her microsystem. Maria was enrolled in a prokaryotic physiology course —concurrently with the first semester of physics —which impacted her sense of the relevance of physics in answering questions in microbiology. The research she conducts in water microbiology impacted how she perceives or participates in a physics activity exploring the resistive forces experienced by a water-dwelling paramecium.

#### 5.4.1.3 Maria's exosystem

Expanding further, the settings in Maria's exosystem include her microbiology major's undergraduate program committee, future graduate schools, and future career opportunities within microbiology. It also includes settings that her family, friends, and peers engage in. These are settings in which Maria doesn't actively participate in or impact but they have implications for the settings within her microsystem. For example, the requirements in a future graduate program or career can impact the courses that populate her microsystem. Maria's friends and family may have had experiences in classrooms or workplaces that can impact how she participates in her own coursework.

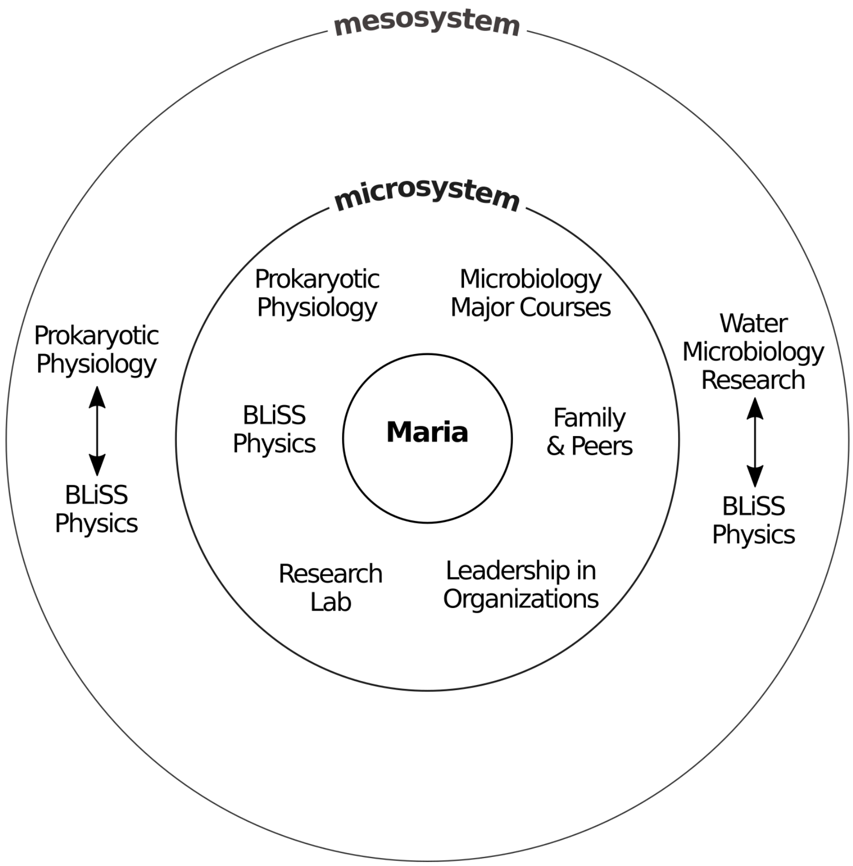



Figure 5.4: Maria's microsystem and mesosystem. While the whole of Maria's experiences can never be captured in any diagram, this figure represents areas of Maria's life that we consider important to exploring the relevance of physics to Maria.

#### 5.4.1.4 Maria's macrosystem

Lastly, Maria's macrosystem accounts for the culture, beliefs, or ideologies permeating through her more inner systems —micro-, meso-, and exosystems —that form a consistent thread throughout her experiences. Maria readily points out that she identifies as a *micro*biologist and not a *macro*biologist. Microbiology as a disciplinary area of study contains a set of norms and expectations on the appropriate scales of research questions as well as ways of communicating within their community. The physics classroom will attempt to set norms and expectations for what it means to do physics but these norms and expectations interact with and are woven into a larger network of culture, beliefs, or ideologies of what it means to **do** physics as opposed to biology.

Mapping Maria's experiences onto ecological systems theory helps us see the value of the mesosystem. There are a few items on commonly used PER surveys that probe the mesosystem to ask about potential connections between the physics classroom and the student's life outside of the classroom. We contend that moving away from an abstract sense of *life outside of the physics classroom* and moving toward identifying specific settings will help reveal useful connections instructors and researchers can leverage in building relevance with students. In the next section we dive deeper into Maria's mesosystem for specific settings, roles, and interpersonal relationships that have impacted Maria's sense of the relevance of physics (Fig 5.4).

### 5.4.2 Interactions between physics and microbiology in Maria's mesosystem

In the first interview with Maria, she was a few weeks into the first semester of physics and already identified potential connections between physics and her other courses. When asked if she saw biology, chemistry, and physics as being related she replied:

> MARIA: Why are things moving that way within the cell? Why can the cell do that? Well, it's physics. actually, we talked about lateral motility within the cytoplasmic membrane in um. . . in microbio, and I'm pretty sure my professor's words were something like 'the thermodynamics and the physics of the you know the cytoplasmic membrane are a glorious chapter in microbio!' [*laughs*] . . . anytime anything is moving, or even just you know the thermodynamic things, things you don't think about, it's physics.
>
> —[*Int* 1]

When asked if she sees connections between physics concepts she is currently learning and her other courses, she notes that the connections are mostly related to motion and that they are basic in nature.

> MARIA: These are a little more basic but I mean I know it's going to apply somewhere. You know you can find velocity of a bacteria like we did actually in our activity [motion tracking video of bacteria] and stuff like that, and you know how different things affect their velocity and stuff like that. But so far it's pretty basic. . .

—[*Int* 1]

There are two features of Maria's statements that reflect commonly espoused beliefs in our interviews. (1) Students attribute that many things in the world happen because of physics, or that physics underlies everything. This is in line with the disciplinary culture of physics in which it claims to be fundamental or foundational to other disciplines. [72] (2) The connections students are most readily able to make early in the course are around motion. Since motion constitutes the first few units of the course [40], it is understandable that students attribute motion of objects or creatures to physics. Maria's early connections do not reveal deeper connections occurring beyond observing that physics sometimes pops up in her other courses in the form of motion or a statement of reverence for the physics underlying more complex mechanisms.

#### 5.4.2.1 Maria's evolving sense of relevance

Midway through the first semester of physics we interviewed Maria again and ask if she thinks biology and chemistry play a role in her physics activities.

MARIA: Yeah, I laughed. Because so I'm in prokaryotic physiology. . . I'm a microbio major, the number of times physics comes up is a little. . . Yeah. Because we were talking about the movement of flagella. And how some parts are using the torque and what does the work, and different things like that. I'm like, this is physics. And then we were talking about the strength of the cell wall and the different components, and what's resisting and the inside forces, and what's really providing the protection in terms of physics. So we never go into details but the words are like, it's there. You know it's physics.

INTERVIEWER: And then you're seeing that connected here?

MARIA: Yeah, I think when we talked about the diffusion lab, that we had talked about that previously. In that class, the diffusion across the cell membrane, and you know, viewing it as smaller elastic collisions.

—[*Int* 2]

Maria is seeing physics come up in her prokaryotic physiology class enough to warrant her laughing about it being a common occurrence. In this exchange we see Maria identifying physics concepts that play a role in her prokaryotic physiology including topics of movement of flagella, forces inside the cell, as well as diffusion across a cell membrane. Later in the same interview, we ask Maria her thoughts on an activity calculating the resistive forces that a paramecium experiences in water [35]. This activity involved making assumptions about the density of the paramecium and Maria shares a story of her bringing in her microbiology expertise.

INTERVIEWER: How about the paramecium one?

MARIA: I like the paramecium one.

INTERVIEWER: You liked it.

MARIA: Because I'm a microbiologist. So I was like, this makes so much sense. Because I think actually she [the professor], when you had to take the density of it, I thought of it in a way like, she actually had me tell it to the class. Like she hadn't thought of it that way. But I know as a microbiologist, the paramecium is going to take in its surroundings, like osmosis. And a cell is 99% water as it is. So I knew I could take the paramecium's density approximately as water. Which is not how, she saw it as like oh, it's floating in the water, so the densities have to be relative. But I would never have thought of it that way.

—[*Int* 2]

Maria reflects on her identity as a microbiologist and the disciplinary expertise that she brings with her into the physics classroom. She offers up an alternative reasoning path that differs from the professor's explanation. In the course, positioning students as experts in biology is a significant design feature and it manifests here as the professor validating her idea and having her share it with the entire class. This participatory act of Maria bringing in and successfully incorporating her biology content knowledge into a physics activity is an observable display of relevance.

These interactions in Maria's mesosystem between her biology and physics courses prove to be a powerful influence that Maria articulates near the end of the second interview. Maria is asked to expand on why she believes physics has the power to explain why things happen.

> MARIA: I've always kind of thought of physics as more of a conceptual, being able to explain things. Because it takes it to such a simple and mathematical, you can model with it. But not really until taking this class and getting the tools. Sure, you can see something and be like oh, yeah, physics probably explains that. But I don't know physics, so why would I think about it that way. I don't have that tool. But I think taking this course, the microbiology course alongside physics, where things like work and torque and force are coming up, in a field that I know about. That helps you see. . . But, I think if I were to look at physics, I think I'm interested in how it relates to the macroscopic biological world. I know other people do other things but this [paramecium activity] is the physics I like.
>
> —[*Int* 2]

In the exchange above Maria states that it wasn't until she was taking the physics class alongside prokaryotic physiology course that she saw how the tools of physics connect with a discipline she has expertise in. Maria sees connections across the two courses, and states that the physics activity on paramecium represents the physics she would like to do. We believe this is a significant marker of relevance. Maria expresses interest in physics and she sees physics as a tool that can be used in microbiology.

When this physics course was designed, we did not imagine or plan for this synergistic relationship with prokaryotic physiology. It is not feasible for an instructor to predict that a student like Maria will enter their classroom and make significant connections to a specific disciplinary course. We do not credit the relevant connections Maria builds to the physics curricular materials or activities, we instead point to designed course structures that make space for students to bring themselves into the physics classroom. Maria brings into the physics classroom her disciplinary expertise and her identity as a microbiologist. The connections she makes are validated by the instructor and amplified by sharing them with her classmates. The physics course structures and environments are not changing Maria, she arrived in the physics course seeking to make connections and to incorporate knowledge across the disciplines. Early in the course, Maria states that she sees physics playing a role in a variety of biological contexts. Through interactions between her courses, we see an amplification of Maria's sense of relevance. We articulate structures of the classroom that have supported this amplification in the next section as we trace the experiences of Nicole whose sense of relevance is also amplified through interactions between courses.

## 5.5 "Nicole"

Nicole is a genetics major who is interested in a career in data science in health informatics. Nicole has substantial disciplinary experience in the life sciences. She holds three jobs as an undergraduate: a biology laboratory learning assistant, a part-time researcher in an entomology lab, and a researcher in a genetics lab studying the effects of gene mutations on protein function. She has never taken physics before and has heard from her friends that physics courses at the university were difficult and terrible. Nicole decided to take our BLiSS Physics course after a recommendation from a friend who previously worked as a learning assistant in the classroom. In addition to physics, Nicole is concurrently enrolled in biochemistry and a computational modeling course. We split our discussion of Nicole's experiences into two sections that focus on connections across settings in Nicole's mesosystem. The first section describes Nicole's views on the relevance of physics informed by connections between her coursework. We represent these forms of relevance in a way that aligns with previous cognitive perspectives used in physics education research —these views of relevance represent what the attitudinal and epistemological measures discussed earlier [4, 5, 19, 20] aim to probe. The second section also looks at connections present in Nicole's mesosystem but pushes beyond the cognitive perspective into a situative perspective where we consider classroom structures, norms, and values as powerful agents that help co-construct and amplify relevance with Nicole.

### 5.5.1 Nicole's perspective on the relevance of physics

In this section we present evidence from a series of interviews to describe Nicole's beliefs around the relevance of physics. We focus on the mesosystem level to describe her perspective of how physics, computational modeling, and biochemistry courses can be relevant to one another.

#### 5.5.1.1 Relevance between computational modeling & physics

Our first glimpse that Nicole is seeing connections between physics and her computational modeling class is in our first interview in the early weeks of the Fall semester.

INTERVIEWER: Have you encountered physics in any of your other courses?

NICOLE: . . . in my [computational modeling] class —actually yesterday— we had to come up with like, we ended up coming up with our own models for dropping a ball off of Beaumont Tower. And then a skydiver so. . . and then I have homework to do for that class this weekend about a bungee jumper. So yeah! I am seeing physics a lot right now, actually.

INTERVIEWER: So, what makes those examples physics to you?

NICOLE: For me, it's like whenever there's something involving motion, like I immediately think physics. . . So all those things that like with that [computational modeling] class, they're all involving some sort of motion, like actually they're all falling motions. But, that is physics, like first thing that comes to mind.

—[*Int* 1]

Later in the same interview we probe if Nicole believes physics will be *helpful* for completing her other courses or degree.

NICOLE: I've already seen it help me with like my [computational modeling] class just yesterday, actually. Like, it was nice because I went from coding in physics' lecture. And then I went to that, and we were doing like a similar type of thing. So that was kind of nice to like it's nice to have those connected. . .

INTERVIEWER: Wow. Can you tell me about some of these examples of —so like take me into the perspective of you— like when you walk into class, and after doing physics and now you're going to [the computational modeling course], when did you realize the basic connections?

NICOLE: Um, we were trying to like write some code, and I was like, "Well, hey? Like I did this in physics today – well, I'll be looking to see if there's any similarities, anything I could take from that." And there was actually like one little point that I realized like, "Oh, I need to put this in my loop. . . "

—[*Int* 1]

Nicole is seeing parallels between the types of activities and resources used for both her physics course and her computational modeling course. The similarities between the type of activities cued her to *bring in* elements from her completed physics solution into her computational modeling programming homework. [3] Near the middle of the semester we follow-up with Nicole in a second interview and we ask her to elaborate on connections between physics and her other courses and again she makes connections to her computational modeling course.

NICOLE: Yeah, so I think it is important for me to have like a class like physics be able to connect to other classes because like I sometimes wonder like, "Oh, when will I ever use physics?" But like this [Wound Healing Activity [35, 41]] kind of shows that, "Oh, it is relevant". Like it does mean something to like what I might be wanting to do in the future. And that's another thing that like with another class I'm taking, I'm taking like that computational modeling. And sometimes I can kind of see how like physics would fit into that where at least like those concepts you use in physics that kind of seem to be applicable in that class, too. And we've done a lot of stuff with like modeling like the spread of disease and stuff. So that's been really interesting to kind of see how like

[3]It should be noted again that these two courses were not designed intentionally to have this alignment and overlap; Nicole's experiences were the first indications that these two courses had the potential to be synergistic in promoting her sense of relevance.

even though it's not directly physics, it's like concepts that we've used in physics are also being used there.

INTERVIEWER: Gotcha. Do you have any specific examples of when you made those connections with the computational modeling class?

NICOLE: When we talked about in class yesterday, like the Lennard-Jones potential, like we ran a model like including like that specific equation.

INTERVIEWER: Really?

NICOLE: Yeah. So it was modeling like- it was a lot like the one we did in [physics] class where we were modeling like the collisions. It was similar to that. And then like he used the Lennard-Jones potential. . . I was sitting in physics yesterday, and I like turned to my (inaudible), like, "Oh, hey, like we modeled this. I like have this equation on my computer right now that we used". So I thought that was cool.

—[*Int* 2]

Nicole describes a moment where she is in her physics course and realizing that she has completed work from computational modeling that is relevant to the physics activity she's working on. This is analogous to the moment Nicole describes in the first interview, where she has a relevant programming activity from physics she can use to complete her computational modeling work. Physics and computational modeling are two settings that have a reciprocal connection that strengthens Nicole's belief that the concepts in physics are useful to computational modeling, and vice versa. Physics connecting to computational modeling has a deeper implication in that computational modeling is a critical skill for Nicole's planned future career in data science. In the above excerpt we see this connection between courses as entangled with Nicole's posited belief that physics may be relevant for what she wants to do in the future. In the next section, we continue to describe relevance within a cognitive perspective as we describe what can be considered an ideal manifestation relevance, connections across two disparate disciplines: Physics and Biochemistry.

#### 5.5.1.2 Mesosystem Interactions Between Physics & Biochemistry

One of the learning objectives for the first semester of BLiSS Physics is to cover phenomena students may have seen in their Biology and Chemistry courses and to unpack the physics interactions underlying them. We see Nicole state that she may not use physics practices directly in a another course but that physics explains why larger processes occur. We see Nicole apply this idea specifically to in-class activities in her Biochemistry course when we ask her to reflect on an activity exploring the force and energy required to unfold a protein using optical tweezers [35].

NICOLE: I thought this one was pretty interesting because I'm taking Biochem right now. So like we talk a lot about like protein unfolding and stuff and like the consequences it has. So like basically every lecture or so, she'll talk about like what happens with certain like mutations in genes and stuff. And a lot of it has to do with like messing with the protein structure. So I thought that was kind of interesting because it applied back to Biochem and kind of gave like an additional layer to what I had already learned in that class as to why stuff like that was happening. So that was interesting.

INTERVIEWER: So did knowing that like physics is involved in those processes help kind of. . .

NICOLE: It did actually kind of help like because like I understood the chemical background of it. But like seeing an actual like more of a physical reason for it rather than just, "Oh, like this amino acid is in the wrong place." Like it kind of like helped like connect; like bridge that gap between like, "Oh, this is in the wrong place. Because it's in the wrong place, this is happening"

—[*Int* 2]

Nicole states that physics provides a layer of understanding to the topics she covers in her Biochemistry class and finds these connections to help her bridge the gap between describing a process and understanding why it occurs. She revisits this idea later in the same interview when we ask her if she sees courses connecting to what she wants to do in the future.

NICOLE: Yeah, actually. All three of them [Biochemistry, Computational Modeling, & Physics], I could see being applicable to like what I want to do in the future. . . with Biochem, like I can kind of see how like I want to kind of go in like a genetics-based type of informatics thing and like work on like bridging that gap between like genetics and the clinicians and how to help them. So like Biochem has helped with that because it's like shown me like different types of mutations and diseases and stuff and like why they're caused. And then the physics kind of goes with that because like Biochem shows why it's caused, and physics shows why the Biochem kind of happens. So yeah, I do think everything is kind of connecting.

INTERVIEWER: When did you first start thinking that the physics explains why the Biochem is happening?

NICOLE: It was these types of activities. I think there was another like similar protein type of one. And it was like that was when I kind of realized like, "Oh, like a month ago, we did this in Biochem, and now we're doing it in physics." It like makes sense.

—[*Int* 2]

In the past two sections we have discussed examples of Nicole making connections across courses she is enrolled in simultaneously. We now turn our attention to an instance where Nicole continues making relevant connections after she has left the first semester of physics.

#### 5.5.1.3 Mesosystem Interactions Between Physics & Eukaryotic Cell Biology

In our third interview with Nicole, halfway through the Spring semester, we discuss Nicole seeing physics come up in another course.

INTERVIEWER: Are you seeing physics pop up in other places?

NICOLE: I'm not seeing like physics as in like oh, this is physics. But more like concepts like in the Eukaryotic Cell Bio class I'm taking. We talked, we spent like, our first exam is on Tuesday, and so this first section was all about like transporting proteins

> and stuff. And so I know that a lot of it has to do with the structure of the structure of the transporters and stuff and we learned last semester [BLiSS] like that kind of hydrophobic interactions and stuff is important and it's because of physics, like physics.
>
> —[*Int* 3]

We see Nicole explaining that hydrophobic interactions are explained by the physics she's learned and that it has an impact on the structure and function of protein transporters. We again see Nicole pointing to physics as the mechanism behind why processes explored in her biology courses occur the way they do but now she continues to make connections after she has left the first semester course. Nicole's statements describing the relevant connections between classroom activities in physics, computational modeling, biochemistry, and biology courses suggest that we can look to moments in her classroom experience in order to understand how relevant connections are built. In the next section we stay within the mesosystem to look for connections across the coursework Nicole experiences but we push beyond the cognitive view that relevance is only constructed in Nicole's mind and consider the classroom's role in helping foster and amplify relevance.

### 5.5.2 Situative perspective of the co-construction of relevance

In the previous section, we described how Nicole's beliefs on the relevance of physics to her other courses has been impacted by her perception of classroom activities. We believe this view is in line with the kinds of relevance currently explored in PER and is reflected in the design of commonly used surveys. We argue, however, that Nicole's beliefs are not the only contribution to the relevance of physics. In order to capture a more full sense of this relevance, we turn our attention to the role the classroom environment plays in helping co-construct or amplify the relevance of physics to Nicole. In what follows, we employ a situative perspective to consider the reciprocal relationship of Nicole and her classroom in forging a sense of relevance.

#### 5.5.2.1 Relevance between computational modeling and physics

13 days after we conducted Interview 2, Nicole and two other students are working in a group on an activity modeling the random walk of a protein colliding with water molecules by flipping coins. In the activity, the protein is said to move in one dimension either forward or backward depending on the result of the coin flip [35]. When Nicole's group mates (Alisa & Melanie, both pseudonyms) voice confusion and frustration, Nicole explains the point of the activity alluding to a piece of code produced in her computational modeling course that helped her understand.

ALISA: These probabilities are driving me nuts!

MELANIE: Is it the idea that it's wavering along this one line?

NICOLE: It's basically, you flip a coin. . . and if it's plus one if it's heads or minus one if it's tails. . . [my computational modeling code] makes it really easy to see.

—[*Random Walk Activity*]

Shortly after this moment we see Nicole turn her laptop toward her group mates to show them the simulation she has written for her computational modeling course. The professor notices this moment while walking around the room and suspects that the group may be off-task. As the professor approaches, Nicole explains that she is showing the group a visualization she's written in her computational modeling course that relates to this activity. The professor asks to see what the visualization does, and we see Nicole show the professor and her group members her simulation run several times. Nicole explains how changing the number of flips the program simulates impacts the distance traveled in the random walk. The professor then smiles and asks if Nicole would be willing to share this with the entire class. In the last portion of the class, Nicole projects her laptop on the document camera for her classmates to see, and explains how her simulation creates a plot that helps visualize the randomness of random walk. She runs the code several times announcing how far the random walk ended relative to its initial position. Nicole explains that if you let the code simulate a large number of flips, there is a better chance of ending up further away from where it started. The professor then summarizes why she believes Nicole's code is a good visualization of the process of random walk.

> INSTRUCTOR: So I thought this was really nice right? Because what Nicole is showing us is that, all she's showing you is that as the time increases, right? Which is the same as the number of flips, so number of flips is letting you go for a longer time, you are getting more likely to see a variation from zero. Right? So it's the same thing as that histogram plot. But this is showing it in a really nice way, like you can see where the zero is, right? And you can see where all of the variation that the steps gives you and where it ends up all in a single plot which was very nice.
>
> —[*Random Walk Activity*]

From the perspective of the ecological systems theory, this moment from the physics course embodies the reciprocal nature of participants and their settings. Nicole brings in and shares her computational modeling work as a way to show that it can make the purpose of this activity "really easy to see." The similarities between respective activities from computational modeling and physics mediate and support Nicole but we also see Nicole impacting her course environment. The professor in this course invites Nicole to share her code with the class and summarizes why she believes Nicole's visualization is valuable in understanding the learning objectives for that activity. This incorporation of Nicole's contributions into the instruction suggests that her contributions have significantly impacted and augmented that day's physics lesson. In fact, after the class, author Nair interviewed the instructor who remarked that she initially had planned to switch to a planned demonstration but revised her plans in-the-moment to make space for Nicole's contribution. The reciprocity in this moment —Nicole and her course environment impacting each other —is a critical part of the construct of relevance we want to describe and is in agreement with the features of Bronfenbrenner's (1979) ecological systems theory.

What sets this moment apart from the previous section is that Nicole's connection ***is*** relevant to physics because she has become part of that days instruction. Her knowledge and previous work from a class outside of physics is brought in, validated, and incorporated into what it means to do physics. If the classroom design did not include the flexible time and space to allow for Nicole to bring her expertise ***in***, then we may not have seen this moment play out as we had.

Stating Nicole ***believes*** physics is relevant due to these interactions is not capturing the whole of the moment. The instructor, through her actions, suggests that Nicole's contributions are relevant and useful. The classmates that listen and give Nicole their attention signal what is happening is relevant to their learning of physics. The technology utilized in the classroom allows Nicole to project her personal computer makes this type of sharing-out possible; this type of student-led presentation is a critical piece of the course's design. It is all of the classroom roles, structures, norms, and values in concert that allow for this sense of relevance to be co-constructed and amplified.

In order to connect this expanded view of relevance back to the belief structures mentioned before, we return our focus back onto Nicole's beliefs to verify that this moment was ***relevant*** to her. Author Nair, after seeing this moment play out in the classroom, followed up with Nicole over email. The following exchange happens in the very same day the events took place.

**From:** Abhilash

**To:** Nicole

Hi Nicole,

I had walked into class and noticed you were presenting work from a Jupyter notebook. I'm wondering if you could reply with a brief reflection of you presenting that to the class: - how did that happen? - how did it feel? - what are your thoughts about presenting other work in your physics class?

I just want to grab your thoughts while the memory is still fresh in your mind.

Have a wonderful day!

**From:** Nicole

**To:** Abhilash

Hi Abhilash!

When we started the coin flip/random walk worksheet, I realized that I had essentially done this in my [computational modeling] class, so I showed my group, because I thought it was a lot more easy to visualize like that than it was to physically flip a coin. [The professor] saw me doing it and asked if I would show the class. I actually enjoyed doing it, because there have been a lot of connections between the two classes, so it was fun to be able to show others the connections I had been able to make. I think showing work from other classes actually helps a lot, because it puts into perspective all the different ways physics is used.

Hope you have a great day!

Nicole believes the act of bringing in work across courses is helpful and she enjoyed showing her classmates the connections she was able to make. In the next section we look at a connection between biochemistry and physics Nicole recalls in her third interview and highlight the important features that helped support this memorable and relevant moment.

#### 5.5.2.2 Relevance between biochemistry and physics

In our third interview with Nicole, we find out that connecting across physics and biochemistry is a lasting memory for her.

INTERVIEWER: Tell me some memorable moments from the first semester.

NICOLE: Um I think one memorable moment was like towards the end when we were talking about like the water molecules and stuff, I really liked that because I felt like it related really well to Biochem, so I thought that like those two concepts like together like really gave me a really strong idea of why polar and non-polar molecules don't interact basically.

INTERVIEWER: Oh, ok, so take me to the phys– which parts were they when you talked about water.

NICOLE: Um that was the very end of the semester we basically just did-we didn't really do any like experimentation or anything we just kind of talked through a lot of it and made like giant whiteboards and drew a lot of pictures and stuff. Um but I remember like there was one specific question where I was like "we literally had an entire slide in my biochem lecture that is this word for word" So I like showed them and I'm like this is what's going on and this is like how the physics would work behind it so.

INTERVIEWER: Whoa, so you were showing your group-mates?

NICOLE: Yeah

INTERVIEWER: In physics?

NICOLE: Hm.mmm. [*nods in agreement*]

INTERVIEWER: Um it seems like a lot of times you're bringing in outside of class materials into the class, how did that feel?

NICOLE: It was nice, it was nice to make that connection between the two, because it kind of like reinforces the idea that science is super interconnected.

—[*Int* 3]

The activity which Nicole refers to above is adapted from NEXUS/Physics which asks students to use concepts of enthalpy and entropy to reason through why oil and water do not mix. It explicitly questions why oil and water mixed together isn't a favored state even though it appears more "disordered" [35]. We now turn to the in-class video to see this moment play out. Nicole is working in a group of three with classmates Melanie and Alisa; Nicole and Melanie are adjacent to each other. All three students have their heads down filling out answers to first page of the activity. Nicole finishes answering the first page and turns the page to look at the next question (#4). She then exclaims "Ooh! Number 4 I. . . " and smiles. She then quickly reaches for her laptop and powers it on. A short while later, Melanie is finished with the first page as well and confirms her answers with Nicole. She then notices Nicole's laptop screen and asks Nicole "It's biochem?"

Nicole then replies with a smile and says "Yup but it's literally the answer to number 4, so. . . " Nicole notes multiple times to classmates and to undergraduate learning assistants that the concepts in this activity are being covered simultaneously in her biochemistry course.

One learning assistant (Miles, pseudonym), who is coincidentally majoring in biochemistry, stops by Nicole's group. Miles is a case student from Year 1 of BLiSS Physics, who joined the instructional team as a learning assistant in the following year. Miles validates Nicole's connection and states that a similar realization happened for him when he was a student in the course; he had seen similar diagrams being used across physics activities and his biochemistry textbook. He, again relays his own experience by describing his former belief that the processes described in the activity were simply driven by enthalpy and describes how he now realizes he was wrong. When Nicole and her group members suggest that they are finished, Miles challenges them with a task that is not part of the activity: to consider if the process of a substrate binding to an enzyme is favorable. Through this interaction, Nicole making connections across her courses is normalized and reaffirmed by a learning assistant who has the dual status of (1) a student who has successfully completed the physics course and (2) has disciplinary expertise in biochemistry.

Over the course of two class periods we see Nicole taking the lead on writing her group's answers on white-boards, this was not common for Nicole across her entire semester in the course. Working with Melanie and Alisa was a stated preference of Nicole's and she reported that she worked much more effectively with them than other students. Whether with this group or others, Nicole typically did not take the lead on writing her group's responses and instead can be often seen on video quietly following her group. Similar to the synergy between Nicole's computational modeling course and physics, the overlap between biochemistry and physics activities was not planned. We argue that the similarity of activities is not the most significant feature in making this moment memorable and relevant.

The data from the in-class video suggests that there are several classroom structures that help facilitate Nicole bringing in relevant biochemistry knowledge into a physics activity. The classroom norms and culture encourage students to seek out any and all resources they require.

Many students use their own laptops, phones, and tablets to look up information or read class materials online; this is encouraged and not considered off-task. Nicole projects her laptop to the class to show her computational simulation of random walk and uses her laptop to bring up her biochemistry notes. The classroom culture prioritizes student ideas and building consensus over relaying the "correct answer." This affords Nicole the opportunity to take the lead and demonstrate her knowledge from biochemistry and contribute to her group's white-boards. Miles's validation of Nicole's connections are bolstered by his roles as a senior biochemistry major and a student who has successfully completed the physics course.

All of the classroom structures, norms, and roles that help facilitate and co-construct this moment cannot be described by simply measuring Nicole's beliefs. We argue that the full sense of physics being relevant to Nicole's other courses exists in her beliefs as well as the interactions between Nicole and the classroom. Pre-to-post shifts on attitudinal and epistemological surveys can be an important data point for measuring relevance but it does not capture the richness and the power of classroom elements in amplifying or co-constructing those beliefs. Using ecological systems theory allows us to identify that the mesosystem can serve as a rich space for relevance through connections across courses. Our situative approach to relevance gives us the chance to (1) capture these moments as they play out in our classrooms for a more complete sense of relevance and (2) highlight course structures and norms that be designed/iterated to impact the relevance of physics for students.

## 5.6 Discussion

In this paper, we have presented analysis that pushes beyond the cognitive perspective on relevance and uses a situative approach [67], a reader may question if exploring relevance necessitates such an expansive framework. Ecological systems theory's situative nature gives scholars the language to start identifying sites that may be formative in a student's sense of the relevance of physics. Until now, the physics classroom has been the primary focus of work on students' beliefs on the relevance of physics [4, 5, 18–20]. We argue that the other layers of systems within a student's life can play a critical role in a student's sense of relevance. In addition to allowing us to map out important contexts in students' lives, a situative perspective affords us the ability to explore the reciprocal relationship that an environment and its participants have on one another.

### 5.6.1 Relevance is co-constructed by students and their environments

One of the limitations in seeing relevance as purely a cognitive construct is that it puts the onus on students to ***believe*** that physics is relevant. When students report their belief that physics may not be relevant to their lives, there is a risk that scholars may focus on how to fix students' beliefs as opposed to addressing the layers of systems students exist within. Moving away from a deficit-view of students' beliefs, we can explore the rich ways students and physics classrooms can co-construct and amplify the relevance of physics.

Maria arguably is a student that will attempt to make connections in any classroom she is in but it is the dynamic relationship of the two courses that helped forge her sense that physics is relevant to her. The curriculum [35, 40] may have introduced the notion that physics and biology share disciplinary ideas but we argue that relevance was co-constructed by Maria, her coursework, the roles she played in those settings, and the roles the settings played in amplifying her connections. This reciprocal and dynamic nature to the construction of relevance is well suited for a situative perspective. Maria brings her biology knowledge into the physics classroom to arrive at an alternative solution path. The instructor validates Maria and asks her to share her reasoning to the rest of the class. The course allows for multiple correct answers and has the space for students' voices to be shared as experts in their home disciplines. In this moment, Maria is bringing in the outside disciplinary knowledge but it is the classroom structures and values that amplify her relevant connection.

Nicole sees connections between her physics course and her computational modeling course early on in the semester. This connection is supported by multiple moments in which Nicole brings in the work from one course to help with the other. We demonstrate through a series of interviews that Nicole's beliefs around relevance have been impacted by her classroom experiences. When we look to the classroom for evidence of this change, ecological systems theory allows us to see the role the classroom plays in co-constructing and amplifying the relevance of physics for Nicole. Nicole and the classroom's design together have constructed a moment in which physics and Nicole's disciplinary knowledge and experiences are relevant to each other.

### 5.6.2 Ecological systems theory as a motivation for holistic reforms

One of the strategies employed by scholars attempting to improve the results from survey measures is to engage students in activities to develop their abilities in reflection and meta-cognition [38, 49]. These interventions are often localized to the physics classroom and actively require students to articulate and reflect on connections between physics and their lives. The tacit message is that students do not already possess adequate reflective abilities. This deficit-view of students' abilities is problematic but it becomes especially so when considering non-physics majors. The life science students presented here are high-achieving and have sophisticated expertise in their major disciplines. They actively and regularly engage in thoughtful reflection to assess how relevant their coursework and other experiences are to them, including deciding whether physics is a course that should be taken simply "to get it out of the way."

It may be possible that a physics classroom activity requiring students to construct and reflect on potential connections of physics to their life can result in further development of students' sense of relevance of physics, which can then be captured in pre-to-post shifts on surveys. It may also be possible that repeated insistence that students should believe that physics is connected to their lives results in them reporting what they have been conditioned to report. Without careful qualitative work, it will be difficult to distinguish between these possibilities. We acknowledge that a positive result on these survey measures regardless of the strategy is probably beneficial for the perception of physics education. The aspect that concerns us is that as physics reforms proliferate across institutions, we continue to collect instructional strategies and activities to layer on top of a physics classroom and lose sight of the ecology at play. Students enter and exit a variety of disciplinary classrooms and without a systems-level view of their ecosystem, it is challenging to forge meaningful connections that persist and perpetuate beyond the physics classroom.

Ecological systems theory motivates us to move beyond attempts to design or choose the best activity to promote students' beliefs around physics. Instead it necessitates that we see students as existing in multiple interacting layers of systems. In our course, we have established several practices to ensure that students' beliefs, affect, and experiences are brought into the instructional cycle. We use an initial survey to assess which disciplinary areas our students are coming from, what they hope to do in the future, their previous experiences with physics, and to gauge their level of anxiety or fear as they enter the course. This serves as a foundation of knowledge that will help guide instructional choices but it must be noted that even with this knowledge we did not predict the connections Maria and Nicole were able to make. Planning instruction to attend to students' ecologies is less about predicting which activities will resonate and more about designing activities with space, depth, and flexibility to amplify what students are already capable and willing to do. This process promotes bringing student ideas into activities, allows instructors to position life science students as experts in their home disciplines, and provides critical validation and affective support. Moving toward holistic physics reforms that are responsive to the ecosystem present for their students has the possibility to generate long-lasting and meaningful narratives of the relevance of physics to students' lives.

### 5.6.3 The importance of providing space for students to bring the whole of their disciplinary selves in

One of the components of the students experiences outlined in this paper is the space they are afforded in bringing in their disciplinary expertise. We argue that the participatory acts these three students engaged in was critical in the construction of relevance. Maria recognized an alternative solution path utilizing her microbiology content knowledge and was afforded the opportunity to share her solution to the class. Nicole brought in her solution from her computational modeling course to show her group mates a visualization that she felt was easier to understand than the physics activity, she was invited to share this with the entire classroom. These participatory structures and a flexible content coverage schedule were important considerations to the design of our classroom. Without this responsive and dynamic environment, we imagine Maria and Nicole may not have had as positive of an experience.

## 5.7 Implications

### 5.7.1 Revisiting our tools to measure relevance

A large portion of the work on students' attitudes and beliefs in physics education research consists of reporting on four commonly used surveys. This corpus of work focuses on evaluating curriculum and pedagogy on its ability to shift students' endorsements of belief statements. This work has expanded to include differing student compositions and has been used to compare the relative success of different research-backed instructional strategies. Results from these surveys have been frequently reported to suggest that it is common and expected that students will find physics less relevant after instruction than they did before. We argue that the first issue in this chain of events is that there is no consensus for what it means for physics to be relevant. In the surveys, phrases such as "real world" and "everyday life" are used without contextualizing them into what students experience. We have previously argued that the concept of the "real world" presented in these surveys is of an abstracted sense of the natural world that does not include students' disciplinary interests [12]. If our physics students experiences are not appropriately captured within these surveys, then the measurement of relevance is limited and the interpretations of students' abilities to make connections becomes problematic. We still see the benefit of pre-to-post surveys and will continue to employ them to understand the effects of our classrooms but we must acknowledge the limitation in their ability to capture relevance. Most importantly, we must shift away from describing students in deficit-tinged language so that the role of instruction is not to persuade, demand, or force students to make connections but rather invite students to have a role in the classroom so that physics may have a role in their lives.

### 5.7.2 Expanding the goals of designing courses for relevance

The reader may wonder if the solution to creating more relevant physics classrooms is to design the next coin flip activity for the next Nicole, or the next paramecium activity for the next Maria. Much of the curriculum development in introductory physics for the life sciences (IPLS) is focused on creating interesting and engaging activities for students to authentically apply physics to explore biological phenomena. We believe that is certainly an important factor in promoting relevance; activities must be rich and authentic as to not simply provide a veneer of biological context over what is essentially a traditional physics problem [73]. We also believe that the curriculum is only part of the solution; classroom structures, norms, and roles play an equally, if not, more important role.

The data presented in this paper from the experiences of Maria and Nicole show the importance of the classroom in bringing in and valuing their disciplinary experiences. We are finding that providing space for students to bring their ideas into the classroom requires a relatively flexible content coverage schedule, norms for sharing out ideas to the larger class, and facilitation of the building of consensus. These are elements of the classroom that can be intentionally designed. As part of our larger design-based research study, we are currently in the process of articulating design conjectures for a classroom that among other things, can amplify relevance. We do not believe it is possible to predict all of our students' disciplinary interests and experiences, so we rely on building space to allow for students to share their expertise. This is important both for students and learning assistants who were former students. Positioning students as experts in the life sciences and incorporating their expertise into the learning of physics allows for a responsive course and is less reliant on a perfectly coordinated IPLS curriculum.

## 5.8 Acknowledgements

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# CHAPTER 6

# TRULY NOT AFRAID OF PHYSICS ANYMORE:TRANSFORMATION FROM FEARING PHYSICS TO AMPLIFYING ITS RELEVANCE

## 6.1 Introduction

### 6.1.1 The negative perception of physics

Physics, as a discipline, has cultivated a problematic image that scholars have been actively trying to mitigate. Commonly people have described physics as (1) evoking fear and anxiety [74–76]; (2) being irrelevant to students' lives or future career plans [18, 60–64]; and (3) being dense, abstract, or inscrutable [77, 78]. Emotional and affective stances toward physics can and do affect students ability to learn and are intertwined with students' epistemological beliefs [79, 80]. In attempts to address these challenges, a large body of work has been dedicated to developing strategies to engage students, reduce fear, and transform students' beliefs and attitudes toward physics [4, 5, 9, 10, 19, 20, 38, 51]. We add to this literature base by exploring how an ecological systems view of relevance can explain the evolution of the role of physics in a student's life.

### 6.1.2 Physics for the life sciences as an exemplar context

In order to explore these problematic perceptions, we argue that introductory physics for the life sciences (IPLS) classrooms are ideal contexts. Students majoring in the life sciences represent one of the largest proportions of students enrolling in introductory physics [11]. Additionally, disciplinary areas in the life sciences and physics are often considered to have epistemological values that are distant from one another [73]. In early interviews our case students report that biology values process-level knowledge and is less concerned with discrete mechanistic explanations that they associate with physics. This epistemological distance contributes to the sense that physics has little relevance to the disciplinary interests of life science students. For pre-health majors, the perceived irrelevance of physics is compounded by conflicting messaging; physics education scholars and policy reports insist learning physics is relevant to the study of medicine [1, 35, 43] while medical graduates and physicians disagree [12, 61–63]. The discrepancy between the views of surveyed practitioners in the cited studies and those that help create policy recommendations [1] may reflect the gap that exists between the current perception of the relevance of physics *is* and what it ideally could be.

In the past few decades of physics education research (PER), many instructional strategies have been designed to (1) positively affect students' beliefs and attitudes toward physics [8, 35, 71] and (2) present physics as relevant to students' disciplinary interests or career plans [38, 51, 81]. In spite of this large body of work, the mechanism by which these classroom experiences impact students is still under-explored. PER's current measures of success of these reform efforts include pre-to-post shifts on surveys that fail to capture the whole of the transformation in students' perceptions of physics [4, 5, 15, 19, 20]. This paper aims to articulate the transformation of a student's perception toward physics through a case study of their experiences in an IPLS classroom intentionally designed to attend to students' affect as well as value their disciplinary experiences. We push beyond evaluating the success of the course as a monolithic experience and explore the more fine-grained interactions that contribute to a transformation of the role of physics in a student's life.

In previous physics education research around students' views of physics, the focus has been around framing the problem of physics being perceived as irrelevant as just that: a perception issue that the students have. In those studies, the recommendation was for instructors to convince, coerce, or force students into believing that physics simply ***is*** relevant. We identify this as a deficit-framing of students' abilities [15]. This paper focuses on Miles (pseudonym) who is not accurately represented with this deficit-framing. Miles actively looks to make connections, and if he ultimately does not believe physics to be relevant, it is not because he has overlooked or underestimated physics.

### 6.1.3 Introducing Miles

We organize our exploration of Miles's experiences into three acts. Act I follows Miles as he experiences his first physics course. In these experiences we see fear and anxiety interacting with the utility and sensemaking tools physics provides. For Miles, physics is both frustrating and functional in gaining insights into physical processes. Act II describes the role of Miles's physics classroom experiences as a student and as a learning assistant in making relevant connections to physics. Act III focuses on Miles as an agent of change as he embraces the value of his role as a learning assistant and becomes an amplifier of the relevance of physics to students in the course.

Throughout these acts we will show how viewing relevance as a set of connections between physics and Miles's life allows us to track the transformation of the role of physics from fear to empowerment. Miles enters his first-ever physics course with anxiety and lack of confidence in his ability to do physics. After he leaves the course, he describes a drastic transformation.

> MILES: It's quite honestly, very remarkable how clear everything has become. I'm truly not afraid of physics anymore. I was very scared of physics, because it was just a way of thinking I never had to do. It was something that just didn't come easily to me. . .
>
> —[*Int* 4, *Nov.* 2017]

In this paper we will show how analyzing Miles from a ecological systems perspective of relevance helps us to see how this change occurred, tracing the growth and evolution of connections between physics and settings in his life.

## 6.2 Methodology

The work presented in this paper builds a longitudinal case study of a student as he learns physics for the first time in an IPLS course that is taught in a studio format. The course utilizes discursive structures such as whiteboards and arriving at a classroom consensus through student argumentation [39]. Since the terms IPLS and studio format can have many implementations, it is instructive to outline the features of the study context that we believe are critical in understanding this work.

### 6.2.1 Course context

The course in this study is a two-semester introductory physics sequence named Briggs Life Science Studio (BLiSS) Physics. This course is taught in Lyman Briggs College, a residential college within Michigan State University (MSU) that is focused on science and the history, philosophy, and sociology of science. The vast majority of students in the course are life science majors, and many of them are pre-health majors with plans to attend medical school. BLiSS Physics is one of multiple implementations of introductory physics that students can enroll in MSU. The creation of BLiSS represented continuing reforms in making physics at Lyman Briggs more relevant to the life science majors.

#### 6.2.1.1 Explicit focus on affect

The design of BLiSS Physics incorporates explicit support of students' affect through conversations with students that learning physics can be challenging and stressful at times. The learning objectives in BLiSS Physics include helping students leave the course with less fear and anxiety towards physics, as well as increased sense of competence in doing physics. At the start of the course, students are asked to fill out an initial survey to understand their disciplinary interests, future career plans, previous experiences with physics, and to probe their self-reported anxiety and level of preparedness for the course.

#### 6.2.1.2 Mixed instructional team

There are three sections of BLiSS Physics taught in a semester by a diverse instructional team consisting of undergraduate learning assistants (who have previously succeeded in the course), physics graduate students, and two faculty members. In any given section of the course, there are three members of the instructional team present for a maximum of 48 students. Students are invited to join the instructional team by becoming undergraduate learning assistants if they have succeeded in the course, have demonstrated a strong ability to communicate, and generally promote a positive stance towards the struggles of learning physics.

#### 6.2.1.3 Authentic biological context

Every IPLS curriculum focuses on biological contexts in which physics may be used but the implementation of these physics concepts applied to biology can vary wildly in their authenticity to how biologists work [73]. The curriculum of BLiSS Physics consists of a mixture of IPLS materials that have been previously published as well as new materials created for this course [9, 31, 35, 51].

#### 6.2.1.4 Students as disciplinary experts

One of the stated concerns in implementing IPLS curricula is the physics instructor's knowledge of the life sciences and whether it is sufficient to authentically incorporate physics into biological contexts. To alleviate some of these issues, we consulted with a biophysicist at MSU who helped articulate limits of physics models as well as introduce us to new biological phenomena that can be modeled with the toolkit of introductory physics. The resource we rely on the most during instruction, however, is the students' disciplinary experiences. This course takes place in a residential college that focuses on science (Lyman Briggs College) within Michigan State University. We can expect our students to enter the physics classroom with the knowledge and expertise of past experiences with biology and chemistry. We build structures in the classroom to support students in bringing their disciplinary knowledge into activities to arrive at richer explanations. The curricular activities, therefore, must be flexible and relatively unconstrained to allow for students to infuse their ideas into the solution.

#### 6.2.1.5 Modeling biological complexity through computation

A significant objective of the course is to demonstrate to students that modern science utilizes the power of computing to answer complex questions. Many students enter our classroom never having written in any programming language. As a way to familiarize students with using computation as a tool, we incorporate activities that ask students to construct visual simulations using vPython through an online development environment [82]. Students are never asked to write code from scratch but rather are provided minimally working programs [83–86]. Students are asked to modify or update the few lines of the program in order for the simulation to model accurate physics.

### 6.2.2 Data collection

The data presented in this paper was part of a larger design-based research effort to study the effectiveness of the transformed BLiSS Physics classroom in promoting (1) student attitudes and beliefs around the relevance of physics and (2) student self-efficacy and mindset towards learning physics. The case study of Miles (pseudonym) represents one of 40 case students that were interviewed across two years of this course. 24 of these case students were followed and interviewed at multiple times. Author Nair was embedded in the course as a researcher and instructor, and helped develop curricular materials. He was present nearly every day of instruction, managing data collection and recording field notes. Author Sawtelle was the lead developer of the curriculum materials for this class, and was a faculty instructor for 6 sections of the course in which 29 cases were embedded.

The data in this paper includes multiple data streams including an initial course questionnaire which is aimed at assessing students perceptions of, and previous experiences with, physics as they enter the classroom (see Supplemental Materials for the complete survey). There were three semi-structured interviews conducted throughout the year: near the start of the Fall semester, near the end of the Fall semester, and halfway through the Spring semester. After his time as a student, Miles joined the instructional team as an undergraduate learning assistant and was interviewed a fourth time in the middle of his first semester teaching physics.

### 6.2.3 Analysis methods

This case study utilized several analysis methods to unpack meaning from the various data streams. Initial short-response course questionnaires were categorized based on student responses around (1) anxiety or fear towards physics, (2) their disciplinary identities, and (3) their attitudes and beliefs toward physics being relevant. Field notes were written to document the emerging themes and interactions in the classroom for the purpose of giving context and life to the interview data.

Each interview was video and audio recorded, transcribed, and coded in multiple iterations. Initially codes were created to capture the different notions of relevance represented in the PER measures of student views of physics (physics being relevant for future careers, understanding the real world, everyday life, or personal interest), as well as notions that were not as frequently measured (physics being relevant to students' disciplinary experiences outside of physics) [12, 29, 33]. As the study progressed, the focus of the coding expanded to include narrative codes that captured how Miles positioned the role of physics in his life. When Miles became a learning assistant in the course, the in-class field notes also were expanded to include moments when Miles reflected on the role of physics to other students. Analytic memos were produced throughout this study to highlight significant moments in-class as well as in the interviews [29, 33].

The claims presented in this paper were developed and iterated over the course of multiple years. Claims were revised and validated through discussions and presentations at several research group meetings. Transcription and coding was completed using software including InqScribe [87] and MAXQDA [32]. This case study exists alongside analysis of many student experiences in our course; while the story of Miles presented in this paper is its own entity, the analysis methods used were shared across and shaped by the larger set of student experiences.

### 6.2.4 Theoretical Framework

#### 6.2.4.1 Relevance

The notion of relevance presented in this paper is built and adapted from past theoretical work on relevance [16–18] and past efforts to create an organizational structure of attitudes and beliefs [21]. We are specifically interested in exploring the relevance of physics, so we start from and build upon the areas of students' lives that have been the focus of multiple commonly used measures of students' views of physics [4, 5, 19, 20]. We organize a student's sense of the relevance of physics as a set of attitudes towards physics, each attitude being composed of a set of beliefs toward physics. To visualize the role of physics in a student's life, we map the connections between physics and different settings in which the student participates.

#### 6.2.4.2 Ecological Systems Theory

Ecological systems theory was initially developed to describe human development [22], we have adopted it to characterize students' lives as multiple interacting systems [15]. Previous work has limited the exploration of students' views of the relevance of physics to inside the classroom, suggesting new curriculum or pedagogical strategies to influence students' views [38, 48, 59]. We instead reverse this approach by first exploring the interacting systems that constitute students' lives, find ways to incorporate those systems into the classroom, and finally inform the design of curricula and pedagogy to allow students to bring those experiences into the classroom. We use ecological systems theory to map settings in a student's life that can impact the relevance of physics and characterize the nature of that connection.

In studying the relevance of physics, we narrow our focus to the two innermost systems, the microsystem and the mesosystem. While all systems represented in ecological systems theory are important, we identify these two systems as the most accessible in our study design and represent the systems that can be most easily impacted by experiences in the classroom. The microsystem is composed of the settings, roles, and relationships the student engages in directly. The elements within the microsystem may include, for example, a student's courses, peer network, research lab, and the roles and relationships within those settings. The mesosystem consists of the connections between settings in the microsystem. We can for example imagine that a student's coursework, peer network, or research lab may impact their views toward physics. The mesosystem will be the focus of this paper as we map out the evolving connections between physics and different settings in Mile's life.

## 6.3 Act 1: Fearful reverence of physics

When we first meet Miles, he enters our physics course in his junior year as a biochemistry major with minors in Italian and bioethics. He works in a biochemistry research lab and plans on attending a medical school and become a physician that works with children. Miles describes biology as his favorite scientific discipline. He is a first generation college student and has never taken physics before. Concurrently with the BLiSS Physics course, Miles is enrolled in an advanced biochemistry course and an organic chemistry laboratory. What caught our attention early on is Miles's trepidation and fear towards physics; he frequently described his identity as a biochemist and positioned physics outside of that identity as something with which he had little experience. In his initial course questionnaire Miles indicated on a five-point scale (Very Prepared to Very Unprepared) that he was very unprepared for the course and in a free response question asking him to describe his expectations, he wrote:

> MILES: I am very nervous because I have ZERO [emphasis in original response] physics knowledge whatsoever. Many of my peers have taken physics in high school.
>
> —[*Course Questionnaire, Aug.* 2016]

Miles's anxiety toward physics is brought up again when we interview him in the first weeks of the Fall semester. Shortly after listing the courses he's taking in the semester, he describes his hesitation in taking this course.

> MILES: I'm most nervous about physics to be completely honest, I've never taken physics

before. . . and it's just a very different way of thinking about things. . . It's interesting to see, you hear horror stories about physics. . . [my advisor] talked me into taking [BLiSS] physics because it was changing. . . so I said "OK, I'll give it a try." But I'm still nervous. . .

—[*Int* 1, *Sep.* 2016]

The anxiety Miles describes is not solely that of an achievement-oriented student worried about succeeding in an unfamiliar course. His stance towards physics is informed by the negative experiences he's witnessed in others. He explains the reputation of this course being difficult; which prompted students to take large lecture-format physics courses in which the final grade would be more predictable. [1]

Miles is aware of the negative reputation of the BLiSS physics course, and during his time as an instructor for an MCAT review program he witnessed peers struggling with physics as an obstacle on the MCAT.

MILES: I actually taught an MCAT review program at the beginning of last summer. . . I taught a few chapters of biology, and one chapter of chemistry, and then just like in the MCAT they added a new critical thinking section, stuff like that. . . physics was like the big one that they had to reschedule certain days around because the people taking the class didn't feel they had enough time to go over the physics part, and that was kind of like the first time I saw physics like right up close, 'cause I didn't know, and these tutors were pulling their hair out. These kids just looked terrible after the physics parts and they missed lunch a few days, just to do physics, and it was kind of weird but I mean you gotta do it, it's on the MCAT, and that's going to be a huge factor for med school. . . hopefully they did fine I don't know, I didn't have to tutor physics [*laughs*]

—[*Int* 1, *Sep.* 2016]

[1]Students at MSU have many introductory physics courses to choose from and often make a strategic decision on which they will be most successful in.

In light of these experiences, the perception issue that physics has cultivated is vividly demonstrated for Miles; physics stands apart from the other disciplines. He describes the negative experiences of those learning physics and is glad he did not have to teach physics. One striking feature of this narrative is that even though Miles is anxious about physics he still sees the importance of physics. It is not that Miles perceived physics to be valuable to a career in medicine but that it is required, and therefore it is a hurdle that must be overcome in order to do well on the MCAT. This stance towards physics as an obstacle to overcome aligns with many reports describing pre-health students as being grade-achievement oriented [43, 88–90]. We characterize Miles's attitudes and beliefs toward physics as fearful reverence; physics is important for his success, and yet it is intimidating and scary. As we proceed in the first interview, we see that this fearful reverence is not limited to the role of physics as a required obstacle. For Miles, physics is also important because of its role in the other disciplinary areas he studies; physics is being brought up in biochemistry and he believes physics explains everything.

INTERVIEWER: Do you see like physics popping up in your other classes?

MILES: . . . it's interesting because the only class I've seen it so far is biochem. . . we were just talking about. . . water and how like life today formed. . . [biochemistry professor] was just kind of talking to us about the concept of how it's physics - how the water, that it's unfavorable how water is being pushed out as the enzyme and substrate come together, and I just thought that was so interesting. . . I'm sure that's going to help me in seeing physics in other classes too.

—[*Int* 1, *Sep.* 2016]

Miles is seeing physics being referred to by his professor in his major discipline and is open to seeing more of these connections. Later in the same interview Miles expresses his belief that physics is fundamental by repeatedly saying "it has to be" physics. At this point Miles has not had the experience with physics for him to articulate connections beyond his belief that it must be physics, INTERVIEWER: Do you see biology, chemistry, and physics as being related?

MILES: I never really did, now I mean, they have to be. . . like I said I never really took physics so I didn't know. And I mean, it has to be physics. Like all of that has to be, every kind of movement or, we've only done movement so far. . . It has to be, I think physics is a driving force behind everything, it has to be. At least I think so. . .

—[*Int* 1, *Sep.* 2016]

We ask if Miles sees concepts from the first few weeks of physics as having connections to his other courses. He responds *"um. . . kinematics, I don't think I can see it now."* For Miles, we argue physics is ill-defined and obscure. Even with this lack of clarity, he understands physics is important for two reasons: (1) it is required for his success on the MCAT and in completing his undergraduate degree, and (2) the driving force underlying everything "has to be" physics.

### 6.3.1 Miles's initial mesosystem

We have thus far described Miles's starting set of attitudes and beliefs toward physics as he begins our course. In the subsequent sections of this paper, we will see the role of physics in Miles's life shift as he completes a year of physics as a student and moves into a role as a learning assistant. We will construct diagrams of Miles's mesosystem (i.e., the connections between physics and other settings in Miles's life) to track the changing number and quality of connections that accompany a shifting role of physics (Fig. 6.1).

Figure 1 displays Miles's mesosystem in the Fall semester during these initial interviews. Miles is enrolled in Organic Chemistry Lab and Advanced Biochemistry concurrently with physics. Biochemistry and Chemistry have multiple connections to different settings in Miles's life. He tutors the topics from these courses in an MCAT review program, and he works in a biochemistry research lab that utilizes disciplinary knowledge from both chemistry and biochemistry. Physics stands apart in Miles's mesosystem as having no positive connections to his interests or peer groups. It is also the only disciplinary course that is ill-defined; Miles does not have previous experiences learning physics to know what it consists of let alone articulate the ways in which physics connects

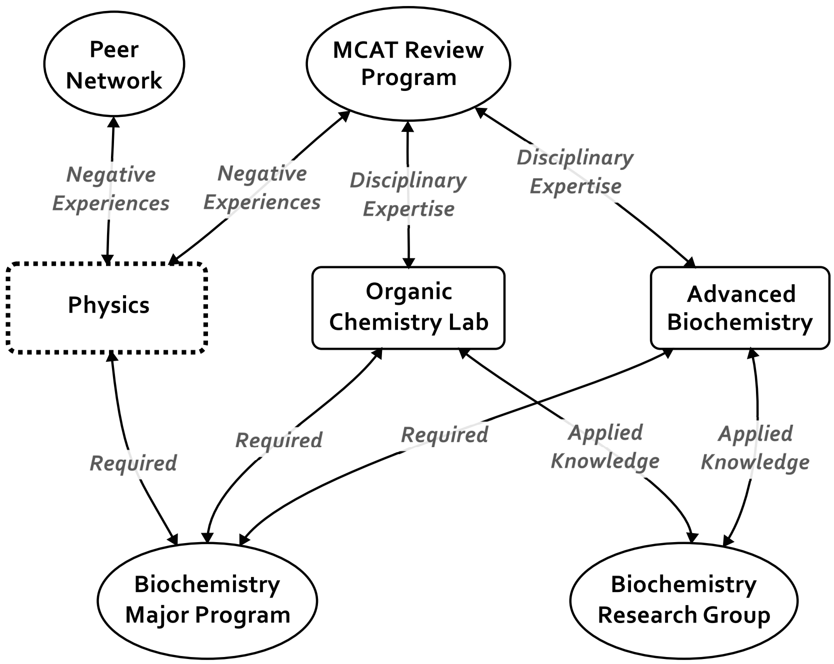


Figure 6.1: A representation of connections within Miles's mesosystem as he starts his first semester of physics. The settings represented include the courses he's enrolled in as well as his extracurricular activities. Advanced Biochemistry and Organic Chemistry Lab are two courses that are well connected to other settings; Miles works as a tutor in these topics as well as conducting research that utilizes both disciplinary areas. In contrast, physics exists as a largely mysterious entity (represented with a dotted outline) with which Miles has little experience other than knowing that physics is important and that it has a reputation for being difficult and stressful.

to other settings in his life. Miles understands that physics is important for his success on the MCAT and that it plays an important role amongst the other scientific disciplines. He also has several experiences to suggest that learning physics is a stressful and challenging experience. Physics, so far, is not integrated into Miles's life and its relevance is limited to the fact that it is an obstacle to overcome. In the next section we will see how this role of physics evolves for Miles as he progresses through the rest of the course. We will revisit Miles's mesosystem in each act to explain how physics becomes more relevant to Miles through the proliferation and increasing quality of physics connections in his mesosystem.

## 6.4 Act II: Physics as frustrating & a sensemaking tool

In this section we look at in-class data of Miles as well as two follow-up interviews, We follow Miles as he completes a unit near the middle of the Fall semester that incorporates computational simulations to explain the process of diffusion as the result of collisions on a large scale. We interview Miles shortly after the diffusion unit and again near the middle of the Spring semester. The computational sequence on diffusion is split up into two class periods. The first class period is focused on manipulating and combining equations from conservation of energy and momentum to arrive at one final expression for the change in momentum of a particle experiencing an elastic collision [91]. In the second class period, students are presented with a minimally working program [83, 85, 86] that contains the structure and syntax of a simulation of two particles colliding but without an expression for how the momentum would transfer between the particles. They are tasked with writing a few lines of code that represents the correct physics using their expression for the change in momentum derived in the previous class period. There are in total 3 simulations students are asked to complete that scale up in complexity from visualizing 2 spheres colliding in 1-dimension, to 2 spheres colliding in a 3-dimensional box, and finally to many spheres colliding in a 3-dimensional box.

### 6.4.1 Familiar frustrations with physics

In his first interview, Miles recounts several negative experiences he's witnessed while others have tried to learn physics and shares his own anxiety about his own ability to do physics. In the first day of this computational sequence, we witness Miles experience this familiar sense for what physics is: a frustrating and challenging discipline. During the start of the first day of the activity, Miles can be seen in the in-class video with his head on his hand seemingly disengaged. He had just explained to his group-mates that he was not able to relax during the weekend and he expresses frustration throughout the activity as he struggles to get expressions that agree with his group-mates (Kathryn and Amy). Miles, at times, works alone intensely to try to find where his derivation differs from the group's and the rest of the class. Throughout this entire unit, Kathryn is quiet and rarely speaks but follows along with her group's work. Amy takes the lead in the group and ends up leading the programming. During the first day, a pattern emerges in which Miles will display frustration and Amy will help and reassure him.

In the next moment, Miles is scrutinizing how to simplify his expression, and jokingly disparages himself when he does not notice it right away.

MILES: Oh, are these [terms] going to cancel? Oh these will cancel, wow I'm an idiot.

AMY: Miles, it's okay.

MILES: [*laughs*] It's so serious.

AMY: Life will go on.

—[*Day* 1*, Computational Sequence, Oct.* 2016]

Later, when Miles asks an LA for clarification, the explanation from the LA occupies approximately 5 minutes of the group's attention. After the LA leaves, Miles apologizes for having asked the question.

MILES: I'm sorry guys, [*GROUP-MATES laugh*] I am a weakling of this group. You can eat [sic] me off the island first, I've accepted it. . . [*laughs*] I have no contribution to this group, I know I'm a terrible group member, I'm just trying to understand.

—[*Day* 1*, Computational Sequence, Oct.* 2016]

Throughout the first day, moments of Miles displaying frustration is common. Though, the day is not without moments of celebration. When Miles discovers he is understanding or can explain a process, his happiness emotes very clearly in the video.

MILES: Oh this one bounces back in the other direction, this one just keeps going. Okay makes sense. It literally slows down by like point. . . [*starts smiling and nodding*] Finally getting something guys. [*gives himself a round of applause*] go Miles.

—[*Day* 1*, Computational Sequence, Oct.* 2016]

Being able to visualize a process is important to Miles; he frequently has stated in interviews that if he can visualize a process then he knows he understands it. In the last portion of class, Miles can be seen working intensely with his notebook and calculator trying to reason through his equations. The group has already produced a whiteboard with their solutions but Miles continues to work while Amy and Kathryn are waiting for the class to reconvene for a whole class discussion. When Amy checks in with Miles, he explains that he is now plugging in numbers to understand the expressions.

MILES: . . . plugging in numbers now, 'cause I'm like, I can't see it in my head, it's bothering me.

—[*Day* 1*, Computational Sequence, Oct.* 2016]

After the whole-class discussion class is adjourned and students are packing up to leave. Amy is working with Miles to help explain where his expressions were different from those presented in class. Miles's expresses his frustration through humor.

MILES: I'm about to cry myself [*shakes paper*] I'm about to throw a temper tantrum [*laughs*]

AMY: Miles, it's okay. . .

MILES: I just hate when I can't do something. I feel like this year has been consistently me not knowing how to do shit. [*mimics violently pounding his fists on the desk*] I'm outraged [*laughs*] I'm going to throw a temper tantrum [*laughs*]

—[*Day* 1*, Computational Sequence, Oct.* 2016]

While Miles is clearly using humor in the video, it is clear from his actions and his interviews that he genuinely cares about understanding the concepts. We argue that there are two main contributing factors to his frustrations.

First, this initial task of manipulating expressions has been challenging for both students and LAs in our experience. In LA prep meetings and in discussions with students, it became clear that the steps in arriving at the final expression can seem to some as unmotivated and arbitrary until they work on programming the simulation. Until they see the purpose of this expression in driving the physics of their simulation, it can be perceived as a purely mathematical exercise.

Second, when Miles can be seen intensely working on arriving at the correct expression, Miles alludes to his group-mates that he needs to be able to see it. This suggests that part of Miles's frustration stems from this activity not having a visual representation that he can use to better understand the process. We will see this ability to see processes ends up playing an important role in the second day of this sequence when students build their visual simulations of particle collisions.

### 6.4.2 Physics can serve Miles's need to visualize

The second day of the diffusion activity is centered around students inserting the expression they derived in the previous class period into the minimally working program to visualize two particles colliding elastically.

Amy is taking the lead in entering the code into the laptop while Kathryn and Miles follow along. When the group successfully finishes the first portion of the activity (two spheres colliding in one dimension) Miles and Amy verify the expected behavior by checking their intuition on several scenarios, and trying them out in the simulation. What occurs when one sphere is less massive than the other? What would happen if the less massive sphere is faster or slower than the other? After they verify their intuition, we see Miles appreciating the purpose of this activity and having a positive experience.

AMY: Okay, that's fun.

MILES: That was cool, I like this now. I feel bad for talking shit.

AMY: I like coding when it works.

MILES: I mean I don't really like to code but I like to see this stuff, so that's cool.

—[*Day* 2*, Computational Sequence, Oct.* 2016]

After Miles's group completes each stage of the visualization we see Miles express his appreciation and excitement. As the group continues to work through the activity, they discuss with an LA that they have managed to keep the particles constrained in two of the three dimensions. Miles wonders aloud what would happen if they allowed the particles to have initial velocity in the z-direction (out of the computer screen). An undergraduate learning assistant overhears his comment and encourages them to try it.

MILES: So we're doing two separate lines that just specifically define the Y. . . so then we're going to see what happens. [*Amy starts the revised simulation*]

MILES: Ok, wait. . . [*large gasp*], wait! We got them to stay.

LA: Looks good to me.

AMY: Do we have to do the x-direction, or the z-direction? . . .

MILES: [*to LA*] Isn't this so cool? I talked mad shit about this shit all the time but when it works, I live! I feel so happy. [*laughs*]

AMY: [*laughs*] He gets super excited.

MILES: I feel so happy.

LA: So the z-direction would be if they came out of the box [motioning out of the laptop screen] I think you defined it with zero z-momentum initially, right? So if you look in the code, you see it has its position in the z is zero, it's velocity in the z is zero. So it shouldn't really move in the z, unless you give it a z-velocity.

MILES: I wonder if it would be cool if we did that. . . we don't have to, we have. . .

LA: I wonder what it would look like because if it flies out, it'd be interesting right?

MILES: [*eyes wide open, pointing at the LA nodding and smiling in agreement*] Should we try it?

LA: Just see what happens [*smiles*] I'm kind of curious.

MILES: You're right, I am too, I feel the same way.

LA: It might not ever actually collide-

MILES: -we'll just check it out, check it out. [ *Amy changes lines of code and runs the simulation again, while all group members look on*]

MILES: Oh! [*grabs chest in shock*]

AMY: Interesting [*laughs*]

OFF-CAMERA STUDENT: What did they do?

MILES: It literally just. . . it attacks you! [*Amy turns laptop to show other students at table*]

OFF-CAMERA STUDENT: It attacks you?

MILES: It runs after you. Look it [*points at the simulation, entire group laughs*]

MILES: [*to faculty instructor*] We gave it a z [velocity] instead of zero [*laughs*]

—[*Day* 2*, Computational Sequence, Oct.* 2016]

When the group tries his suggestion, the code shows a surprising result and it is followed by a cascade of events marked by laughter and excitement. This moment marks a transformation in Miles's view on the value of this activity.

MILES: [*smiling widely rocking back and forth in his seat*] That's so cool! . . . that is so cool.

AMY: We're figuring stuff out guys, how exciting is that?

MILES: This is actually proactive [sic] I literally don't mean to talk shit, I'm so glad I didn't talk that much shit about it this time. . . We're doing very well, we're doing very well, I'm so happy about it.

—[*Day* 2*, Computational Sequence, Oct.* 2016]

Multiple times throughout the second day of this sequence we see Miles remark that he wishes he wasn't so negative about this activity (e.g. "I talked mad shit about this"). The first day was marked with frustration and it is quite possible that he expected the second day to be the same. In later interviews Miles would joke that he initially was "allergic" to the coding activities in the physics class, and even though Miles may not enjoy the act of writing code the second day shows Miles appreciating the activity and its ability to visualize diffusion. In addition to the physics class providing visual representations that Miles values, it also is a space in which he can bring in his outside knowledge. Next, we will see Miles bring in outside knowledge directly from his memory, surprising his group-mates.

### 6.4.3 Physics as a space to bring in outside knowledge

As students scale their visual simulation of diffusion from 2 particles to many particles, the third activity asks them to use their simulation to model collisions in living systems between water and proteins. They are asked to find and use biologically appropriate values of the relative numbers, masses, and radii of water molecules and typical proteins.

AMY: What's the mass of a typical protein? [Miles eyes stare into space, seemingly transfixed in thought searching his memory]

MILES: 137. . . 110, 110 is the mass of one residue of an amino acid in protein, so depending on the amino acid, depending on the protein that's what it would be. [Miles & Amy smile at each other]

MILES: So if you have a protein of. . . you just multiply it by 110, that is the standard weight of one residue, so one amino acid, in one protein. [group laughs]

—[*Day* 2*, Computational Sequence, Oct.* 2016]

Miles in this moment recites knowledge from his biochemistry background that is relevant to the activity from memory. The laughter among the group members suggests that they did not expect this level of detail in his explanation. This moment is in stark contrast to the first day of this computational sequence where Miles was expressing frustration at his perceived lack of understanding. In this instance, Miles gets the opportunity to be a source of knowledge in his physics class. The events during the computational sequence on diffusion are exemplary of the mixed state that physics occupies in Miles's life. It is both a source of frustration and a space in which he can make connections with outside knowledge.

For Miles, we argue that the curriculum alone is not what causes Miles to become engaged; that is to say, physics concepts presented in a studio IPLS setting are not automatically more accessible. Instead, we argue that the critical element in promoting his engagement is his realization that physics can be used to visualize what he is curious about, and is a space in which he can bring in and share his biochemistry expertise. The reader may question if Miles's positive stance toward

Day 2 is simply the result of experiencing a more interactive and visually stimulating activity and not indicative of physics providing him with a deeper more meaningful understanding. Next, we will describe how this activity served Miles's desire to understand phenomena at a deep level and that his experiences in this course have started to shift his relationship with physics.

### 6.4.4 Physics serves Miles's values for deep understanding

After the in-class moments described above, we sit down with Miles for a second interview where he describes the computational sequence as helping him see diffusion in a new way. One of the learning goals of this diffusion unit is that students shift away from the notion that diffusion "just happens" and move towards a causal explanation that involves individual collisions happening at a large scale. Miles's reflection below demonstrates that, for him, this was a novel way of thinking of diffusion.

> MILES: Honestly this activity really helped me kind of formalize a visual representation of diffusion [*gesturing turning objects in his head*] of pieces of diffusion that make diffusion, diffusion. . . all of these molecules in this tight-packed space like bouncing off each other allowed them to like disperse throughout the entire thing. . . and all the little interactions within caused it to diffuse out into the whole thing. Actually, I remember that in class, that was something that helped me think about diffusion in different way. . . I never thought of diffusion that way, I just was [in his previous courses] told that you disperse, that you disperse throughout a liquid but it has to do with things interacting and bouncing off each other.
>
> —[*Int* 2, *Nov.* 2016]

We argue that physics is becoming more relevant to Miles in that it provides him the toolkit to visualize and gain a new perspective on diffusion, a phenomena he has previously learned. Miles strongly identifies as a biochemist and has significant roots into those disciplinary communities through his research and tutoring experiences. If physics can impact these contexts with which

Miles strongly identifies, physics can potentially play a more significant role in Miles's life. Later in the same interview, we see that Miles's attitude towards physics in the MCAT tutoring program has shifted. Previously he noted how he was glad he didn't have to teach physics because it was such a frustrating experience for those learning it. He now states that he is willing to help students with physics topics and is okay with the prospect of being incorrect.

MILES: I tutor, or, I do like an MCAT program over the summer, and they have biochemistry, bio, chem, physics; all that stuff. We're just basically like LAs or whatever. So, people come with different questions all the time. Like, this past summer, physics was the only course that I couldn't help anybody with. So I feel like I would be able to help someone more-so with that. I mean, I think I would feel pretty comfortable with doing it. I mean, I'm not afraid to be wrong. So if I didn't know something, I would just say I don't know, or anything. But I would never be afraid to. . .

—[*Int* 2*, Nov.* 2016]

Miles states that he feels comfortable tutoring students for the physics portion of the MCAT, a situation that he previously described as people "pulling their hair out" and the students having "looked terrible." We take this moment to suggest that Miles is feeling more confident in his ability to do physics. We saw early on that Miles entered our course believing that physics must be important to the other sciences even though he was unable to describe specific examples. Now after a semester and a half of physics instruction, Miles can more confidently describe the importance and relevance to physics to other disciplines.

We interview Miles for a third time after he has left the first semester of BLiSS physics and is halfway through his second semester of physics. During the interview we ask Miles why he enrolled in the first semester of physics, this leads to Miles describing himself as someone who values learning.

INTERVIEWER: So, take me back. . . why did you enroll in [the first semester of physics]?

MILES: Well, I mean, it's a requirement for my major.

INTERVIEWER: It's a requirement. Okay.

MILES: Yeah. . . I really don't want to say I'm one of those people who just is going to take a class because it's required by my major. I really pride myself in thinking that I really am very passionate about learning. I would consider myself as a life learner. I will learn the rest of my life. I want to learn as much as I possibly can. I really believe knowledge is power.

—[*Int* 3, *Mar.* 2017]

Miles is engaged in a multitude of academic endeavors, and must balance the time investment of his engagement with the relative return on that investment. We believe this is emblematic of the decisions life science, and especially pre-health students, have to make. Unfortunately, in the PER literature, this sophisticated prioritization of constrained resources is presented as an unwillingness to see, or ignorance of, the importance and relevance of physics. Miles's notion that knowledge is empowering continues throughout the interview, and points to this belief as the reason he worked so hard in the Fall semester of physics.

MILES: But, I think that has to do with why I worked as hard as I did. You know what I mean? Because I really did want to understand what we were doing. I wanted to understand all of these concepts that we were learning and things like that. Because physics is why things work. You know what I mean? That's what I've learned. . . in Physics II now, and then last semester. That's why these laws and stuff are why the world around us works the way it does. So I thought that was such a valuable piece of knowledge that anybody should have. I really believe that once you have that knowledge, that that knowledge empowers you and you look at the world very differently. So that's why I really worked hard to understand everything I try to understand.

—[*Int* 3, *Mar.* 2017]

Miles's statements here connect his hard work in the first semester to: (1) valuing knowing how the world works and (2) believing physics has the ability to explain how the world works. Later in the interview Miles expounds on why he believes he is required to take physics as a biochemistry major.

MILES: I think I'm required to take physics because – I mean, we have to be well-rounded in the sciences, for one. And two, it's just a different way of thinking. I mean, how could you go through life and look at the things you look at and why, I don't understand how someone couldn't question some of those things or not want to understand why things work. So I think just practicing the skill of opening yourself up. . . and embracing new ways of thinking, no matter how hard they are. I think that's so important. And just as a person and as a student as well. I really believe that.

—[*Int* 3, *Mar.* 2017]

Miles throughout the third interview frames himself as having a strong desire to understand why things in the world work the way they do. This desire to understand the world combined with his belief that "physics is why things work" positions physics as a tool he can use to satisfy his curiosity about the world.

INTERVIEWER: How do you see physics being important to you in the real world?

MILES: I question everything.

INTERVIEWER: [*repeats*] Question everything.

MILES: I really do question everything. . . So physics would for sure apply to me trying to answer why something happened. For the longest time, I wanted to know [why] salt melts ice. I wanted to understand, "Why does this happen? Why is this a thing?" So, just little things like that. I can look around and just question any dumb thing. You know what I mean? Sunsets, like, why are those colors there? Just things like that. So I think that's. . . how it's going to apply in the rest of my life.

—[*Int* 3, *Mar.* 2017]

Miles states that since learning physics, he is now able to see physics connections to his other coursework and his tutoring in other disciplines. In the next moment, Miles explains how physics can answer increasingly deep layers of "why" questions.

INTERVIEWER: Have you seen any connections between physics and your other courses?

MILES: Oh, yeah. Yeah. All the time. I mean-

INTERVIEWER: All the time?

MILES: Yeah. I mean, and even thinking back to physics in... other classes... I'm also a student tutor, so I tutor Orgo, Chem, and then Biochem, and Bio, So, like, I was just helping someone last week with, it was spectroscopy and things like that... they were asking why that happens. So, I mean... you can give the explanation about, "Oh, electrons are jumping to higher energy states and then back down." But then they ask, like, "Okay, so what is this light? What is this light entity?"... So that gets into electromagnetic waves, and the wave lengths and the amount of energy in each wavelength, and things like that... It's almost like I have been learning physics all my life, and I just haven't really known it. Some of the equations haven't been in a physics classroom... "Okay. I'm still associated with chem," ..Physics, I've been seeing all my life. It's just now [I'm] practicing it and understanding the variables and stuff like that. So I see it [physics] all the time in my classes now.

INTERVIEWER: Gotcha.

MILES: ... it's easier for me to identify physics now. For sure.

—[*Int* 3, *Mar.* 2017]

The experiences that Miles recounts in his interviews suggests that the two semesters of learning physics has had a profound impact on his life. We ask Miles if our physics course has changed his interest in physics.

INTERVIEWER: Do you think the first semester course changed your interest in physics?

MILES: Yeah. Yeah. Because it really – because like I said, I'm very attracted to understanding the way things work, and physics is that. Physics is literally that. So I was very attracted, I became very attracted to physics. I mean, if you brush away all the frustration and like, how difficult that the – errgh! sometimes, about it.

MILES: I really am interested in physics. That's why, it's almost like I keep learning more in-depth stuff, whether it be biochem, whether it be physics. I feel more comfortable understanding the real world. You know what I mean? And so I think – yes. After taking physics... my passion to understand physics really became heightened. I want to explore these different concepts and what-not. So, yes. I think so. Very confidently, yes.

—[*Int* 3, *Mar.* 2017]

We argue that this last quote is emblematic of how physics is characterized in Miles's life, a mixed-state: it is both the source of frustration as well as a sense-making tool that he can use to better understand other disciplines and the world around him. Miles experiences physics as a way to visualize diffusion as well as a space in which his outside knowledge is relevant. Miles articulates connections between physics and multiple settings in his life: his everyday life (sunsets, salt melting ice), his other disciplinary courses, and his role as a tutor. This is in contrast to Act I in which Miles's recognized the importance of physics but the role of physics was largely an unspecified anxiety that physics was a required hurdle in his path.

### 6.4.5 Growth of connections in Miles's mesosystem

If we look to Miles's mesosystem (Fig. 6.2), we can now see that physics has connections to many aspects of Miles's life. It provides the explanatory power needed to unpack disciplinary ideas in his other courses, physics helps him construct explanations as he's tutoring others, and serves as a way to understand the light from a sunset or why salt melts ice. In Act I we described how Miles largely described physics as being outside of his expertise; in Act II we have made the argument that his physics course is a space where he brings in and shares his expertise. Physics aligns with his

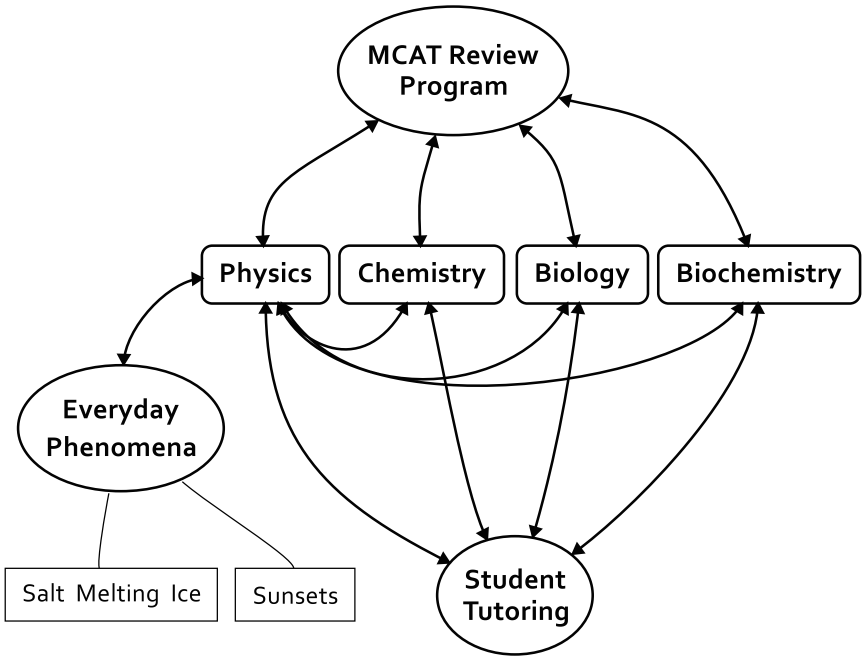


Figure 6.2: A representation of connections within Miles's mesosystem as he finishes two semesters of physics. When compared to his mesosystem in the previous section (Fig. 6.1), physics has many more connections to other settings Miles engages in including his job as an MCAT tutor and as a tutor at the university for multiple life science courses. Miles now points to physics as providing a new view on the world around him as well as helping him construct deeper explanations of concepts in life science courses.

personal interest in understanding underlying mechanisms and provides him a toolkit to understand phenomena he's previously learned in a new light. Overall, physics has become more enmeshed in Miles's life and the mesosystem provides a map of the connections being made. In the next Act, we will see Miles move beyond his role as a learner of physics and into the role of a teacher of physics as he becomes a learning assistant that promotes the relevance of physics to others.

## 6.5 Act III: Miles as an amplifier of the relevance of physics

As Miles neared the end of his second and final semester of physics, he was identified by the instructional team as a student who would be a good candidate for the role of undergraduate learning assistant (LA). He was encouraged to apply, and even though Miles was initially hesitant, he would apply and join the BLiSS Physics instructional team in the following Fall semester. After a few months of teaching as an LA, we interview Miles for a fourth time and discover that the transition into teaching physics marked a significant change in his confidence.

MILES: My whole perspective of physics has just changed... I never would have thought it would have changed, ever... I was very apprehensive about becoming an LA, just because I wasn't confident on some of my physics background and making those connections and helping students understand these connections. Because I was not confident on that. But to be honest with you, the past, probably the past month, I have felt so confident in the classroom. Just, I don't know, it just, it's more, it's just different. It's very different, seeing everything again.

—[*Int* 4, *Nov.* 2017]

Teaching physics marks a significant transformation in Miles's view of physics, and in this final act we will explore what it means for Miles to become an amplifier of relevance. In Act 1, we see Miles share multiple examples of how his beliefs and attitudes towards physics was shaped by the experiences and words of others. He describes how his peers often avoid BLiSS physics because of its difficulty and opt to take a different course for a more predictable grade outcome. Miles also witnessed as an MCAT tutor the stress students went through when having to prepare for the physics portion of the exam. The belief that physics is a difficult obstacle to overcome may perpetuate if Miles were to re-voice or otherwise support them with examples from his own experience. Instead, we see Miles share examples of how useful and relevant physics has become to him. He does not perpetuate the notion that physics is irrelevant but instead amplifies its relevance to others.

### 6.5.1 Reinforcing connections of students

It is the middle of the Fall semester and students are working on building explanatory models for why oil and water do not mix. Miles is walking around the classroom checking on groups in his role as an LA. The three students in the group are Nicole, Melanie, and Alisa. Nicole has just realized she has done parts of this activity in her biochemistry course and has brought up slides from that course on her laptop.

NICOLE: I did this in biochem-

MILES: I know! Did you take 461 or 401? I know there's like, that picture [*points down the classroom*] is literally in our, I took 461, that's in our biochem book and it's literally the same situation, like it literally explains it.

MELANIE: We did the oil and water thing in my chem class last semester.

MILES: Did you talk about it in terms of entropy though?

MELANIE: Yes

MILES: You did? Damnit, you should be like really confident on this.

MELANIE: The problem made me very angry at the time but now I understand it.

MILES: I know, when I first did this activity I was convinced it was enthalpy, I was like 'nope, it's enthalpy-driven, it is not entropic, this is enthalpy' and I was completely, like completely wrong. Also, if you guys know it, like if you've already done it. Try to explain why this is favorable. [*draws new situation on whiteboard, not visible on camera*] so this is the substrate for an enzyme and this is the enzyme. So why is this favored when this system is more ordered than this system?

—[*Oil and Water Activity, Nov.* 2017]

Miles in this clip reinforces Nicole and Melanie's connections to other courses as well as use stories of his own previous misconceptions to present physics as the place where he gained a more complete understanding. We do not argue that this is an uncommon or unique interaction between a learning assistant and students but we do argue that the intersection of Miles's roles in the classroom is particularly effective at communicating the relevance of physics to others. He is a biochemistry major who has previously succeeded in this course and he is positioned by the faculty instructor as a disciplinary expert.

### 6.5.2 Miles is positioned as an expert in the classroom

In the next class period, the faculty instructor is creating a summary page of takeaways from the oil and water activity on the document projector and has just finished answering a question asked by a student off-camera.

FACULTY: Also this might be an important thing. I don't actually know, does anybody know about the relative magnitudes of breaking these hydrogen bonds between forming these hydrophilic connections? [*Faculty looks around classroom, no one answers*]

FACULTY: I don't know.

MILES: They're about the same.

FACULTY: [*looks at Miles*] They're about the same? OK, [Miles] is saying they're about the same, I trust him [*smiles*] so the question would be how many do we end up with in this process.

—[*Oil and Water Activity Consensus Building, Dec.* 2017]

In this brief moment, the instructor poses a question that she doesn't know the answer to and asks if someone in the class knows the answer (a fairly typical move in this IPLS class). When no one replies, Miles provides his response and the instructor re-voices it and states that she trusts him. This moment of recognition as a knower of outside knowledge as well as the previous example of Miles working with students and positively reinforcing their connections are just singular examples of the types of interactions Miles has throughout his time teaching. He repeatedly uses the lessons he's learned from his time as a student in the course to engage and motivate students in learning physics, and he consistently serves as an expert for the instructor to rely upon in the classroom. Why does a student like Miles end up being a promoter and amplifier of the relevance of physics? In the next section, we interview Miles near the middle of his first teaching semester and see the importance of the connections he's been able to make in his mesosystem.

### 6.5.3 Increased confidence and clarity of connections

Miles, in his role as a learning assistant, has the opportunity to go through the entire first semester curriculum with the benefit of (1) having finished a year of physics and (2) shifting his priority from completing activities to understanding and conveying the main purpose of activities. In the fourth interview, we ask Miles to reflect on the past three semesters: two as a student, and the current one as part of an instructional team.

MILES: So I noticed, I for sure noticed that while teaching this semester. That I'm just really starting to understand how everything's finally connecting. You know what I mean? As a student in first semester, I really could not see that. I think I really struggled with, I even said that in a lot of the interviews I had. I wasn't able to visualize why we were learning these equations by these, all these White men who were like visionaries. You know what I mean? Like, why would be learning all that stuff?

MILES: So I'm finally starting to understand all of that stuff. . . I'm also in PChem [Physical Chemistry] right now. . . Even when I was just studying for my last PChem exam, it was like these equations that used to just scare the hell out of me, in that it just looked like a bunch of letters thrown around. It was more intimidating then. . . I couldn't even put forth understanding because . . . it's almost like I didn't care as much. But it's almost, now looking back at all of this, and looking at how much I actually do know and applying it in different places, like PChem, for instance. It's almost inspiring that the people who made these equations, and the same people who frustrated me when I wasn't applying myself, just how differently they saw the world. You know what I mean? It's just very inspiring, in a way. . .

—[*Int* 4, *Nov.* 2017]

Miles contrasts his attitude towards physics in the first semester to his current view and uses his view of physics equations as a point of comparison. Equations previously were intimidating and Miles describes he didn't understand why he had to learn them. We see this description as paralleling Miles's visible disengagement at the start the computational sequence on diffusion. He notes in the above transcript that one issue was that he wasn't able to visualize the purpose of the equations. Similarly, in the in-class data, it wasn't until the simulation showed the power to visualize ideas that he found the activity to be useful and interesting.

In Miles's ecology, he now has a new role in the physics classroom as a member of the instructional team. In Figure 3, we see that in his mesosystem, connections to physics are spreading to new settings, notably Physical Chemistry.

INTERVIEWER: You mentioned that there are some connections and applications to P. Chem. Can you say more words really quick?

MILES: Yeah... what I've been seeing mostly, is because the first whole half of PChem, we treat everything... with classical mechanics. So, like, Boltzmann constant and things like that. I've seen the Boltzmann constant before, in second semester specifically... Then I just understood... especially how, like, the Arrhenius equation. It describes the fraction of molecules that can have enough energy to react.

INTERVIEWER: Wow.

MILES: You know what I mean?

INTERVIEWER: Yeah.

MILES: So, and that incorporates temperature, for instance. So, I was finally starting to understand how temperature – well, I mean... We live with it. We check our phones for temperature and things like that. But... I finally was able to visualize that relationship between increase in the temperature, increases the probability of these molecules reacting, and blah, blah, blah, blah, blah.... my brain almost was grip-, trying to grab on to things that I knew.

—[*Int* 4, *Nov.* 2017]

When Miles is learning concepts in physical chemistry, he is reaching for ideas learned in his physics classes. To the reader it may be obvious that physical chemistry and physics should share many disciplinary ideas but we argue that the views of many life science students and working professionals that physics was irrelevant to their science preparation suggest that it isn't an obvious or natural connection [12, 60–64]. Physics, due to its pervasive reputation, can be intimidating, which was certainly true for Miles before he took physics. When courses are intimidating and perceived as a hurdle to overcome, many students will have the desire to compartmentalize that course as a bad memory. Here we see Miles actively looking to physics as he learns new ideas, a classic example of what it means for physics to be relevant [18]. Miles's disciplinary connections between physics and other disciplines serves to be an important part of his role in the physics classroom as a learning assistant.

### 6.5.4 Powerful impacts of a growing sense of relevance

For Miles, the transformation he experiences is not limited to an increased number of cross-disciplinary connections but has a significant impact on Miles's relationship with physics [36]. In the first act, we describe Miles's apprehension and anxiety toward physics. In this final act, we see that this relationship has changed. In the passage below, Miles engages in a reflection on his journey with physics.

> MILES: It's quite honestly, very remarkable how clear everything has become. Like, I'm truly not afraid of physics anymore. Like, I was very scared of physics. Because it was just a way of thinking I never had to do. It was something that just didn't come easily to me, and so maybe subconsciously I was trying to resist it a lot. That's maybe why I struggled quite a bit when it came to trying to learn physics in a studio style. I really don't know. . . But it's almost like, "Why don't we all think like this?" now. You know what I mean? It's just such a logical way of understanding things that I think we just glaze over in some of our classes. You know what I mean?
>
> MILES: I was very apprehensive about becoming an L.A., just because I wasn't confident on some of my physics background and making those connections and helping students understand these connections. Because I was not confident on that. But to be honest with you, the past – probably the past month – I have felt so confident in the classroom.
>
> —[*Int* 4, *Nov.* 2017]

### 6.5.5 Reflecting on the evolution of Miles's mesosystem

As we look at the Miles's mesosystem in this final Act, we see that physics has become much more securely connected and integrated into his life. Physics connects to disciplinary courses like Physical Chemistry. Physics is now connected to his tutoring and learning assistant roles in a positive way: physics is a discipline he can teach to others as opposed to a source of distress. Physics is also helping provide deeper answers to the questions he has about the world around him, where previously, it was an inscrutable area of study for Miles. These numerous connections sprouting in his mesosystem firmly attaches physics to have a role in Miles's life. Through these connections, physics is relevant to Miles.

## 6.6 Discussion

Students reporting that physics ideas connect to experiences in their lives and the world around them is certainly the goal of many reform efforts in PER. What we describe here goes beyond a story of a student "seeing" the relevance of physics and shows the powerful impact when a student forges connections with a discipline they previously feared. Using ecological systems theory as a way to understand students' lives helps us center our exploration on the student. We can build from the experiences students bring with them into the physics classrooms and look for ways to leverage their rich backgrounds in the learning of physics.

We argue that the transformation in the relationship Miles has with physics leaves powerful lasting impressions on his life. He not only believes that physics is relevant to him, he is actively promoting the relevance of physics to others. Leveraging students' ecological systems in the classroom helps us to shift away from a focus on convincing students that physics is relevant. Instead of searching for compelling curricular contexts, we can design classroom experiences that treat students as more than novice physics learners. This design choice relies on framing students as able and willing to seek out meaningful connections across their experiences.

Miles's experiences through these three semesters create a rich story, and one can explore it using many lenses; each lens is only a projection into a reduced plane of analysis. We chose to look through the lens of relevance to help articulate the process of a student starting his journey through physics fearful of the discipline and ending with him promoting and amplifying the relevance of physics to others. There is no current consensus on how to make a physics course more relevant, which may be unsurprising since we are only approaching a consensus for what it means for physics to be relevant at all [9, 10, 12, 51, 92].

For Miles, his physics learning experiences served his desire to understand cross-disciplinary concepts deeply, make sense of everyday phenomena, and his self-stated need to visualize concepts before understanding. Physics was a space in which outside knowledge from his biochemistry major was valued; it was where he shed the intimidating label of a novice physics learner and be seen as a knower of important pieces of knowledge. As Miles transitioned from student to LA we see him deeply integrated into a space which he previously had no experience with. He serves as an expert in the classroom that demonstrates confidence in his ability to do physics and convey the relevance of physics to a multitude of disciplinary experiences.

Miles is representative of the vast majority of students in our classroom in that they are successful in their home disciplines and have made a significant investment in learning science. In that light, it is foolish and deficit-tinged to argue for convincing or forcing students to "see" the relevance of physics [43, 48]. It implies students like Miles will not make meaningful connections on their own if given the opportunity. It is no longer tenable for physics instruction to rely on the cultural reputation of physics being fundamental as a sufficient argument for why physics is relevant. This isolating stance is intimidating and anxiety-inducing for students like Miles. If classrooms focus on shifting the framing of students' roles from novice learners to members of a learning community with valuable knowledge and expertise, students can become promoters and amplifiers of the relevance of physics.

## 6.7 Implications

We argue that in order to make physics more relevant to students, classroom designs need to provide students with the agency and space to bring themselves and their experiences into interaction with physics. When designing BLiSS physics, we understood that there was no way to predict or cater to the diversity of backgrounds present in our student population. To mitigate this problem, we focused on developing classroom experiences that had flexibility and space to allow students to: (1) use physics to uncover insights in familiar contexts from other coursework, (2) recognize that bringing in and valuing their outside experiences is a critical part of doing physics, and (3) design experiments to answer their own questions. In the following sections we describe the implications of such a design.

### 6.7.1 Framing physics as fundamental is detrimental to promoting relevance

IPLS classrooms are by design cross-disciplinary spaces where students' disciplinary ways of knowing from biology and chemistry come into contact with the norms of what it means to do physics. This interaction between the epistemological values of different disciplines can potentially lead to tension or grandstanding if a physics instructor leads students to believe the knowledge from their other courses is an incomplete story or that in the physics classroom they will learn what "really" occurs [93]. This notion that physics is somehow a more fundamental scientific discipline than others is pervasive and troubling.

For pre-health majors like Miles, the insistence that physics simply is relevant to them [43] runs counter to their own experiences working with doctors [12] as well as counter to a large collection of research in the medical community making the case for physics being irrelevant to the success of doctors [15, 60–64]. We argue that framing physics as fundamental or the ways of knowing in physics as being a distinct enterprise to students' previous experiences works directly against physics becoming more connected and enmeshed in students' lives.

### 6.7.2 Positioning students as disciplinary experts is a powerful pedagogical shift

Students in our IPLS classroom arrive with a wealth of experience in science in the form of coursework, research, and service. Miles initially describes himself as having "ZERO physics knowledge whatsoever" and in many physics courses he may very well be treated as a novice. The

BLiSS physics classroom values Miles's disciplinary knowledge and expertise and considers him an expert. In previous work, we have described other instances in which students' outside knowledge being valued in the BLiSS physics classroom led to an increased sense of relevance [12, 15].

In a mirrored fashion students' experiences and knowledge are relevant to doing physics and the toolkit of physics is relevant to answering questions students care about. Believing that physics can be a tool used to understand phenomena students are interested in can be a powerful way for students to see physics playing a role in their lives [12, 13, 15, 31].

### 6.7.3 Discomfort of teaching without having all the answers

Teaching in a classroom with this amount of flexibility can seem uncomfortable, especially for physics instructors who are accustomed to being the principal experts in the room. There will be moments in which the physics faculty will not know the answer to a question students bring up from disciplines outside of physics. Physics instructors may not be knowledgeable in the complexities beyond the reduced biological models constructed in introductory physics. In our design, this concern is alleviated to some extent by having LAs from outside disciplines in the classroom and relying on our own students as experts in their home disciplines.

In Act II, the faculty instructor posed a question for which she did not have an answer. What followed was a moment for Miles to step up as an expert and to be recognized in front of the entire class as someone the faculty instructor trusts. We argue that teaching without knowing all of the answers and having to rely on students for pieces of knowledge is much closer to an authentic community of learners constructing knowledge together. At the end of Miles's journey in our classroom physics no longer stands apart from the other disciplines in his life —it becomes well-connected to many aspects of Miles's life. Physics is no longer an inscrutable discipline that others say is important and relevant, instead physics is enmeshed in how Miles understands disciplinary ideas in his home discipline.

## 6.8 Acknowledgements

We thank the members of the ANSER group for thoughtful discussions around this work. We thank the PERL@MSU group for their engagement and reflections during group meetings where this work was presented. This work was funded by the Lyman Briggs College and the Department of Physics and Astronomy at Michigan State University. We thank Angela Little for continually highlighting the value of our work to the community. We thank Benjamin Geller for encouraging us to push forward as we both explored the murky space of relevance. Lastly, and most importantly, this work would not exist without Miles. We are grateful for the insights he's provided and the trust he's placed in us to tell these stories.

# CHAPTER 7

# DISCUSSION

## 7.1 Current understanding of relevance

The studies presented in this dissertation are all focused on the relevance of physics. The notion of relevance I have developed has two traits, it (1) is embodied in a relationship between a student and physics and (2) can be measured or observed as connections between physics and the settings in students' lives. In moments where students find physics to be relevant, they are finding meaning in the physics ideas and practices they have learned in a specific setting. Ecological systems theory allows us to select settings of different grain sizes to support the specific research question we are interested in.

### 7.1.1 Our choice of settings

For our study of relevance, we have mostly discussed the settings of disciplinary coursework and research. One can, however, choose to look at student experiences through different settings altogether. For example, in Chapter 4.2, we discussed the case student Sam whose friendship with her friend supported her thinking of and reasoning with physics concepts in her everyday life. One could take this same lens and apply it to the case students of Miles and Maria, who were friends during the course and became LAs at the same time. Depending on the choice of systems, you would tell a different story about the contribution of those connections to furthering a sense of relevance. We made a specific choice to focus on the settings that (1) were readily accessible within the larger design-based project and (2) allowed us to start the process of articulating the implications of classroom design. Our choice of settings has implications for the breadth and diversity of connections we describe. Within this flexible framework of relevance, pushing beyond the setting of a classroom would yield rich and interesting results on how other settings are promoting or hindering a student's sense of relevance.

### 7.1.2 Our choice of systems

In addition to restricting our settings to the domain of a student's academic life, we chose to narrow our focus to the micro- and mesosystem of ecological systems theory [22]. Our narrowing of focus is not intended to convey that the other layers of systems are not important or consequential. In fact we see the effects of these outer layers of systems permeating throughout the meso- and microsystem. For example, since this study is implemented within the United States, it is infused with the cultural values and ideologies of this country. We see all classroom interactions to be influenced by and reproductions of values and ideologies. For example, domestic and international students will arrive in our classroom with different cultural values and ideologies that will impact how they engage with the environment and their peers. IPLS courses navigate the intersection of physics and biology, each of which has its own epistemological values and culture. We made an intentional choice to focus our attention on the nature of connections across settings and acknowledge the many directions for future work. For example, exploring how BLiSS physics interacts with the culture of physics that the course is situated within. Do the design features impact how students perceive the culture of physics?

I chose to focus on the micro- and mesosystem specifically as it represented the minimal complement to understand and analyze case students' statements on how physics is relevant to and meaningful in areas of their lives. The micro- and mesosystem also represented the systems most readily probed by our study design which did not follow students outside of the classroom environment. An exploration of the influences of the exo-, macro-, and chronosystem would likely necessitate a different study design but would add richness to our understanding of how indirect settings, values and ideologies, or the passage of time would impact a students' sense of relevance.

### 7.1.3 Revisiting early cases with our current view

In looking back across the studies presented in this dissertation, there are several avenues that we could revisit equipped with the knowledge of ecological systems theory.

In chapter 4.1 we were introduced to the case student Beverly who stated that physics was not relevant to the practice of medicine because of conversations with physicians she shadowed. Near the end of her participation in our study, she had switched away from a pre-medical track. An ecological systems view of Beverly would help us articulate the changes that may occur when students experience a shift in the academic trajectories, and the effects of that shift on their perception of the relevance of physics. It's quite possible that Beverly's shift in career paths would have left observable changes in her mesosystem. Beverly had many discussions with her family about the dangers of being in a small car versus a larger car if there were an accident. Since BLiSS physics explicitly has this scenario as a lab investigation, another avenue to pursue would be to unpack how these moments in class shifted how she engaged in conversations with her family on these topics. An open question is whether these in-class activities became relevant in these discussions with family. How do physics activities around the dangers of the world impact conversations with family that may hold different views?

In chapter 4.2 we explored how Sam's friendships were a source of connections between physics and her everyday life. In her interviews, she remarks that she only thinks of these physics concepts when she's around specific friends or groups with certain majors like engineering. If we revisited Sam with an ecological systems view and define our setting to be more specific than her peer network, it would equip us to explore how different friend groups contribute to or hinder connections to physics. It is not unreasonable that students will have different peer and social groups that fulfill different needs in their lives; this is analogous to how physics can be thought of fulfilling needs in students' lives. Understanding how students' friendships impact their sense of relevance would add an important layer to our understanding.

## 7.2 This work relative to the ways PER has reported on relevance

This dissertation has explored the notion of relevance and built a framework with which researchers can make meaningful, holistic interpretations of students' views of relevance. I described how this framework provides a much more complete picture of relevance than what attitudinal and epistemological surveys can measure and it maintains a strengths-based view of student ability.

This work is a re-envisioning of the way we consider and judge the relevance of physics. Previously, researchers have been certain of the ways physics is relevant, and have asked students to endorse those statements. Those endorsements are then interpreted as value statements of students. Those that agree with the "expert" views are successes for a course design, while those that agree with the "novice" views are deemed students that were not reached with the instruction. Survey after survey, year after year, PER has reported and accepted the fact that students' beliefs around the relevance of physics will be negatively impacted by instruction.

Our approach questions what is previously thought to be well-known, that physics is relevant for all students. Instead of asking how the student feels about the presumed truth that physics is relevant, we start with students' lives and experiences and ask where physics fits in. In each chapter we have challenged the ways PER has interpreted or understood students' views on the relevance of physics.

In Chapter 4.1, we showed how phrases like "real world" are relatively abstract, and to be frank meaningless. In chapter 4.2 we show what is required for a student to connect physics to everyday experiences, and demonstrate the importance of support networks in a student's life. In Chapter 5, we formalized a process to approach the exploration of relevance and demonstrate its descriptive power in understanding the relevant connections two students make. Finally, in Chapter 6, we revisit the main motivating purpose to our entire enterprise. Through a case study, we re-assert how finding relevance in a discipline you once feared can be a transformative experience.

Throughout all of the student experiences within this dissertation and the others not discussed, the most important realization is that students' outside experiences matter. Physics instruction can no longer afford to treat the learning of physics as being distinct or special. For students majoring in the life sciences who never plan on becoming physicists, it is crucial that instruction invites, integrates, and values their experiences for students to regard an introductory physics sequence as more than just a hurdle to overcome on the path to their major.

In the end, relevance is not a stretch goal or an extra consideration for those looking to build a stronger connection with students. Relevance is far from optional —it is the primary challenge for physics education. As major programs increasingly question the value of a requisite physics course in the preparation of their undergraduate students, physics programs are at risk of losing their primary funding mechanism —the education of non-physics majors. In serving the needs of these students, it is no longer defensible to plan instruction disconnected and detached from the students in the classroom. Relevance is a mechanism by which instructors can engage and motivate students in the classroom. In almost every case presented, we see a recurrence of a pattern in which students recall physics through key moments of relevance. Maria, Nicole, Sam, and Miles all have relevant connections crystallized into their memories that remain powerful touchstones as they continue their journey. Students' affective characteristics are part and parcel of their experience learning physics. Through these four cases we have shown that there is a resiliency of knowledge when you learn in an engaging way and make genuine connections to your life.

If the cases presented were not sufficient to convince the reader of these claims, these patterns exist amongst many of the additional cases collected in this project but not presented in the primary chapters. Alisa and Melanie are members of a neuroscience research group that uses physics concepts to study neuron signaling in the brain. Alisa emailed me to tell me of all the physics she is seeing and how the con-focal microscopy techniques explored in BLiSS are re-appearing during her study abroad experience in Europe. Leslie is a student who was initially resistant to physics because she felt physics activities overly simplified the complexity of biology. After leaving the physics sequence, she studied electricity production in fish species and sent an email to discuss how she will be learning how to perform a technique called qPCR in her research lab that uses concepts from the second semester. The list of case students who reflect on their time learning physics positively is too long to discuss even in a dissertation. These students consistently reach out to me mention that they thought I would be proud or excited to know about the connections they were seeing.

This dissertation may appear to be one of identifying an issue with PER, constructing a theoretical framework in response, and showing its application. That is far from the whole story; this dissertation is about the power of establishing meaningful connections with students in a classroom.

Treating students as being more than novice physics learners and instead treating them as knowers, providing space and time for students, and inviting students into leadership roles in the classroom are ways to transform how physics instruction views its purpose. The priority isn't transmission of piece-meal knowledge —I am arguing for a re-imagining of what it means to teach physics to non-physics majors. Instead of showing them where they fit into the landscape of physics, we should be asking where physics may fit into their lives. If we revisit the resolution of the story I shared at the start of this paper, of a high school physics student questioning the purpose of physics, we find that the answer was staring at us all along. When I have exhausted all of my logical arguments, I relied on asking her for a favor, relying on the rapport and relationship I had built in the classroom. Physics continues to serve the needs of only a select few in our society; co-constructing relevance with students by inviting their experiences into the enterprise of learning physics is a reliable mechanism to not only convey knowledge but overcome the troubling and intimidating perception of physics.

# CHAPTER 8

# IMPLICATIONS

The reader may throw their hands up and wonder how difficult it will be to predict the right context for the right students. Planning for every possibility can be an exercise in frustration. To this worried reader, I want to once again remind them that the classroom practices presented in this paper make the life of an instructor much simpler. Your challenge isn't to predict or gather students' interests and plan activities accordingly. Your challenge is to let go of control, let go of the identity as the sole expert, and let go of suffocating content coverage. Let it all go, and trust those students that are in your classroom. Your main responsibility is to open a supportive space for students to bring themselves in and connect to their outside experiences. Physics has a perception issue for those outside of the discipline as well as a representation issue for those inside the discipline. Inviting and supporting students from outside the discipline in developing relevance can be a path forward in addressing both issues simultaneously.

This entire dissertation is an effort to understand students' views about the relevance of physics. The interpretations from surveys around the relevance of physics have for too long been a stain on the reputation of physics students. Students are capable and willing to make connections in a physics classroom if given opportunity and guidance.

In the future we plan to articulate how the design of the BLiSS classroom promotes student outcomes utilizing conjecture-mapping [68]. For now we can describe a select number of design elements that have fostered students building strong connections to physics and promoting their views that physics is relevant.

**Mixed instructional team** The members of the instructional team consist of a variety of academic titles including faculty, graduate student, and undergraduate learning assistant (LA). This has created multiple levels of knowledge and experience. We often find that students may be hesitant to ask the faculty member a question; the presence of an LA helps mitigate this issue. In addition, most of our LAs are not majoring in physics, so the instructional team has a mixture of disciplinary expertise to draw upon and connect to.

**Avoidance of superficial biological contexts** When designing or adapting activities for BLiSS, care is taken to ensure that activities represent authentic lines of inquiry that are representative of the interests of biologists. We do not use spherical chickens or cows in BLiSS physics and instead position physics as having a toolkit of representations and practices that can be of use in a variety of contexts. This often means that we cannot avoid biological complexity and have to move forward with argumentation and reasoning in the absence of a clean analytic solution.

**Computation to tackle biological complexity** Throughout the course we use computational activities to help students analyze and visualize complex phenomena that would not be possible by hand. We use these opportunities to connect to computational biological models that increasingly represent modern biology research.

**Course implementation is responsive to student affect** It is not an accident that BLiSS physics is named after an emotion. Attending to student affect is a central premise of teaching BLiSS physics. Students' affective responses to activities can impact day-to-day planning as activity sequences are extended, short-circuited, or modified. At many points in the course we are faced with multiple options of equally feasible activities to run. Often this choice is discussed in terms of the class climate overall. A typical consideration would go as follows: Should we do the lab activity that works very well at giving students clean intuitive results? Or should we do the activity that has less direct lead-in to the next unit but has historically caused students to erupt in joy? The instructional team puts a heavy emphasis on acknowledging frustrations and celebrating successes as being part of the teaching practice. Throughout the in-class experiences presented in the paper you will notice instructor and LA teaching moves focused on positively supporting students' affect.

**Students positioned as experts in the room** BLiSS physics emphasizes knowledge construction through argumentation and consensus-building. Students are encouraged to bring in their outside expertise and the course has time and space built-in to allow for students to share. Setting aside time to allow for students to share their expertise comes at the cost of content coverage; we do not attempt to cover every topic traditionally taught in a first semester physics course. We attempt to focus on areas of physics that have great overlap and relevance to the life sciences. This design element is perhaps the hardest to implement because it requires the possibility that the faculty member doesn't know all the answers. In fact, we see this as a strength of the design. Students recognizing that they authentically contribute to the shared knowledge is a powerful mediator of relevance. Maria, Nicole, and Miles all have moments in which their outside knowledge contributes to a richer shared understanding.

If we can focus on experiences to promote students believing physics is relevant to them, we may see the problematic public image of introductory physics classrooms destroyed. As more and more students believe that physics is relevant to their lives, physics can perhaps finally give up its prized status as being distinct from or "purer" than other disciplines and become just one of many fields to pursue. If we reform our classrooms to be spaces where students feel welcomed and valued, there is no limit to the transformations we will see as students enter the world equipped with a toolkit of physics.

**APPENDICES**

# APPENDIX A

## REAL-TIME VISUALIZATION OF EQUIPOTENTIAL LINES USING THE IOLAB

This paper represents an example of the cross-pollination that occurs when research and curriculum design impact each other. This activity was designed in the second iteration of BLiSS, and it was an effort to implement a modification of a commonly used exploration of equipotential lines. The impacts noted in the student quotes as well as from interviews yet to be published signal to us that this was a meaningful experience for many students because it was intuitive to them, easy to approach, used commonly found materials, and gave students responsive and accurate data. Activities like this one are examples of classroom experiences explicitly designed to engage students and promote positive affective responses.

# Real-time Visualization of Equipotential Lines Using the IOLab

**Abhilash Nair and Vashti Sawtelle,** Michigan State University, East Lansing, MI

Drawing equipotential and electric field lines is an activity commonly found in most second-semester introductory physics courses. Unfortunately, current commercial lab offerings are expensive and do not afford the opportunity for real-time graphical visualization of the trends in voltage in different regions. In this brief article, we describe a flexible alternative that utilizes the Interactive Online Lab (IOLab) device and easy-to-acquire supplies to create an experiment that yields robust results and has resulted in a positive response from our students.

## A traditional equipotential lab

The current Field Mapper Kit from PASCO retails for $160 and requires a Digital Multimeter ($59 from PASCO) and a Power Supply ($210 from PASCO). The total cost for each setup is $429, which is not including the recurring costs to replace the conductive ink pen ($49 each) and the conductive carbon paper ($45 per 50 sheets).[1] Setups using carbon-impregnated paper have been described extensively.[2-5]

There have been efforts to bring down these recurring costs, particularly for the conductive ink. For example, Benimoff described how to use copper foil tape,[6] and others have resorted to constructing shapes from machined aluminum and securing them to the carbon paper.[7] Binder et al. have shown a modification that utilizes a rotary motion sensor and a computer interface to arrive at detailed plots of the electric potential.[8]

Our design aims to tackle many of the issues addressed in previous efforts in a single experimental design. We replace the conductive ink, eliminate the need for a benchtop power supply, and provide for real-time monitoring of the electric potential using a computer.

## The IOLab

The Interactive Online Lab (IOLab) system is a device developed by the Physics Education Research group at the University of Illinois at Urbana-Champaign.[9] The IOLab is a cart that costs approximately $100 and serves as a sensor box; it connects wirelessly via a wireless USB dongle connected to a computer. Accompanying the cart is a free software package that records, plots, and keeps a history of previously recorded data automatically.

The IOLab is capable of making a variety of measurements including force, acceleration, velocity, displacement, magnetic field, rotation, light, sound, temperature, pressure, and voltages. The designers have outlined many mechanics-related investigations, but the roster of second-semester experiments is lacking.[10]

In our studio physics for the life sciences course (BLiSS Physics), we check out an IOLab to each student at the beginning of the semester. Having access to an IOLab enables the students to make measurements inside and outside of the classroom and have all of their data available on their personal computers. We find that the IOLab is particularly supportive of our flexible studio classroom space, where traditional fixed benchtop lab setups are not feasible. In our classroom, students have taken advantage of the flexibility of the IOLab to creatively design and conduct lab investigations both in and out of the classroom. Nevertheless, we believe that any affordable sensor system that has the potential to record and plot potentials in real time can be used to achieve our goals. The real-time monitoring of voltage is a concrete hands-on experience that is richer than measuring and recording voltage values with a multimeter.

## Cost breakdown

As an alternative to commercial offerings, we describe a design for an equipotential lines lab that includes an

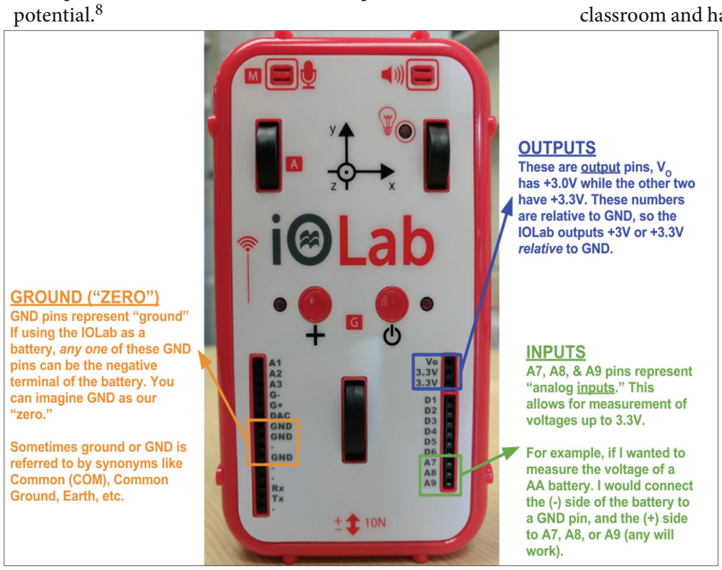


**Fig. 1. A guide given to students to help identify the different inputs and outputs present on the IOLab.**

IOLab device, steel bars, and water. This approach utilizing water is not novel[11] and has been widely used by teachers and demonstrated in EM modeling workshops. We believe that substituting an IOLab in place of a multimeter affords the students the opportunity to visually observe the changes to the potential as they move the probe across different regions of the setup. This allows students to quickly check their understanding as well as improvise new experimental designs.

The cost of one setup in this lab includes:

- IOLab ($100)
- 22 AWG solid-core wire (approx. $0.06 per foot)
- 3-cup rectangular Pyrex container ($7.39)
- (2) 6-in steel bars (3/16 square rod, $1.13)
- (2) D-cell battery holders ($3.50)
- Printed sheets of grid paper
- (2) test leads with alligator clips – $1.50

Altogether we approximate one setup to cost less than $115. In this design we use one IOLab as a voltmeter and the power is supplied by two D-cell batteries. We have also used a second IOLab as a voltage source with success[12]; we found that using the IOLab as both a power supply and a voltmeter helps students to think beyond single-purpose pieces of electronic lab equipment and helped to illustrate to students that voltages can be outputted as well as read-in using the same device. The details of using two IOLabs are beyond the goals of this article, so we focus here on using the IOLab as a voltmeter. In this activity there is a hidden cost of a laptop or desktop computer for the IOLab to communicate with. We see this issue as mitigated by the increasing numbers of students who arrive in a classroom with either a classroom set of computers or with their own personal laptops. Without a computer, one can still use this setup and replace the IOLab with a multimeter, but that will lack the opportunity to plot the voltage from the probe in real time.

## Affordances of this approach

The IOLab has been used to conduct a variety of first-semester mechanics activities (see IOLab website and related YouTube channel).[9] We offer this second-semester experiment to supplement the roster of force and motion labs of any classroom that adopts the IOLab. This activity provides students an opportunity to have authentic experiences—from cutting and stripping their own wires, to making electrical connections to Arduino-like microcontroller header pins. It has the potential to demystify popular maker-technology in the physics classroom. The IOLab has explicit labels on the expansion pins, and the students have to reconcile what each connection means for the device. One example of such a reconciliation is discovering what electrical ground means, which can be a subtle but useful tool for students understanding that potential differences are relative differences in voltage with respect to a common zero.

The IOLab, like most microcontrollers, uses floating inputs. The consequence of a floating input is that if you ask the IOLab to measure the voltage on any input with nothing connected, it will report a voltage that is not zero. In our design this is an opportunity to have conversations about what zero means in electrical circuits, and why conventional voltmeters will report 0 V when nothing is connected. A classroom that wants to avoid these discussions can employ a pull-down resistor13 to bring the floating input to zero volts or simply ask students to only record when their probes are in the water.

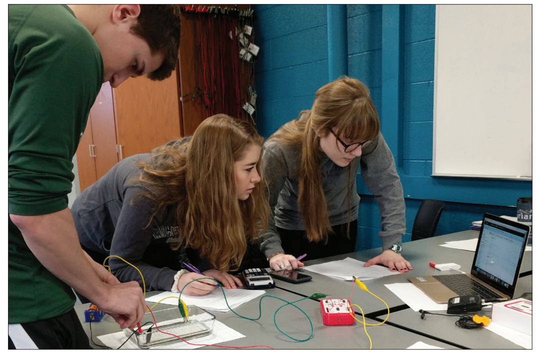

Fig. 2. A student manipulates a probe in the water while his group mates monitor the changes in voltage on the laptop.

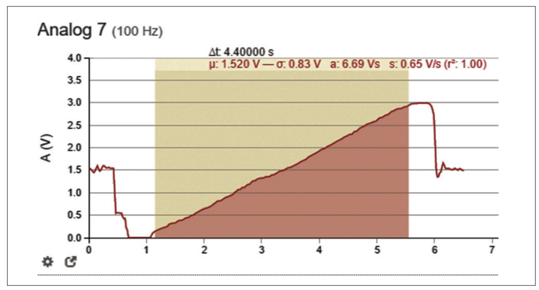


Fig. 3. Actual data recorded in the IOLab software by students exploring the slope of potential vs. time, a visualization that is not easily generated without real-time voltage monitoring.

Using water, glass kitchen containers, and simple metal pieces, students are brought into the exploration of a standard but difficult-to-visualize concept. These easily accessible materials can help to lower the bar for participation in working with electronics and understanding fundamental physics. When using carbon-impregnated paper, conductive ink, or mounted machined metal pieces as found in the traditional equipotential lines experiments, students may be led to believe that exploration of electric fields and electric potentials is confined to specialized laboratory equipment. We hope using commonly found equipment reinforces the idea that electric fields and electric potentials exist even in the most common of situations. In our course, students were motivated to study the effect of moving the parallel steel bars closer together. By attempting to move the probe at the same pace in each setup, they quickly arrived at two plots (one of which is shown in Fig. 3). At a glance they were able to conclude that if the bars are closer together, the graph of the potential vs. distance will have a larger slope than if the bars were further apart.

The quality of the data collected by students was robust and multiple students remarked that this was a fun and engaging activity.

> "The whole experience made a lot of sense, and the results we got proved it, which was just really satisfying to see. This made so much sense to me because it feels like the most logical and natural results, the results that I would've expected. It was like my natural intuition about what was happening made sense, which again was super satisfying. This feeling is what encouraged me to take the lead… today was such a good day for me!"
> –*Angie* (Human Biology Major)

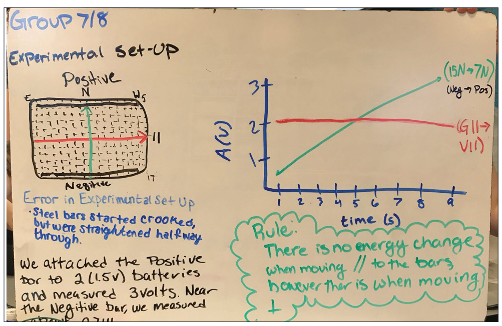


**Fig. 4. A group's whiteboard summarizing their results. They plot the voltage trend as the probe moves parallel and perpendicular to the parallel plates.**

Students being able to quickly visualize trends in voltage for the parallel plate setup has transformed this common activity from a quiet affair of measuring and recording voltage values in a table into one in which we see students get activated and engaged. The ease with which students are able to adjust their setup and see results plotted allows for increased improvisation and experimentation. Ansell and colleagues have discussed using the IOLab as a way to facilitate experiments in the "dorm room."[14,15] Similarly, we believe if students have an IOLab available to them, they are able to continue to explore electrostatics outside of the classroom. As low-cost sensor devices become more affordable and widely available, we see an opportunity to break physics explorations out of the constraints of a well-resourced laboratory and into the hands of students.

## References

1. PASCO scientific, http://www.pasco.com.
2. D. Loyd, *Physics Laboratory Manual,* 4th ed. (Cengage Learning, 2008).
3. J. D. Wilson and C. A. Hernández-Hall, *Physics Laboratory Experiments*, 8th ed. (Cengage Learning, 2015).
4. J. A. Phillips et al., "Beyond the point charge: Equipotential surfaces and electric fields of various charge configurations," *Phys. Teach.* **55**, 71–73 (Feb. 2017).
5. W. B. Lynch, "Electric field plotting apparatus," *Phys. Teach*. **19**, 342 (May 1981).
6. A. I. Benimoff, "The electric fields experiment: A new way using conductive tape," *Phys. Teach*. **44**, 140–141 (March 2006).
7. R. D. Smith "Electrostatic field plotting apparatus," *Am. J. Phys.* **58**, 410 (April 1990).
8. P-M Binder et al., "High-density electric potential plots," *Eur. J. Phys.* **36**, 035029 (2015).
9. IOLab Wireless Lab System, http://www.iolab.science .
10. "Mat's Favorite IOLab Activities," http://www.iolab.science/documents/favorite_experiments_20160221.pdf.
11. R. B. Khaparde and H. C. Pradhan, "An experiment on equipotential curves," *Phys. Educ*. **27**, 27 (2010).
12. The IOLab is capable of outputting 3 V or 3.3 V and can measure voltages up to 3.3 V. We've found that just 3 V across parallel bars is sufficient to create a clear and measurable pattern of equipotential lines.
13. Pull up resistor / Pull down resistor, Resistorguide.com, http://www.resistorguide.com/pull-up-resistor_pull-down-resistor/.
14. A model for open-ended "dorm room" physics experiments is available at https://www.aapt.org/docdirectory/meetingpresentations/WM17/Ansell%20AAPTWM17%20talk.pdf.
15. Katie Ansell and Mats Selen, "Impact of experience and equipment on student responses to open-ended dorm room experiments," https://ws.engr.illinois.edu/blogs/getfile/78/24442.

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# APPENDIX B

## COURSE QUESTIONNAIRE

Starting on the next page, we include the questionnaire given to students at the start of the 2017 Fall semester. The goals are to learn about students' disciplinary interests, future careers, and disciplinary experiences. It also asks students to self-report their levels of preparation and anxiety as they head into our course. The questionnaire was initially designed in MSU's LON-CAPA system in the first year but was modified and implemented in Qualtrics for the second iteration.

MICHIGAN STATE UNIVERSITY

**Default Question Block**

**What is your first name?**

**What is your last name?**

**What is your MSU PID number?**

**Which section of Lyman Briggs Physics are you enrolled in?**

MWF 10:20 AM - 12:10 PM

MWF 12:40 PM - 2:30 PM

Tu/Th 9:10 AM - 12:00 PM

Tu/Th 1:50 PM - 4:40 PM

**What is your current or intended major?**

**Is there a science course, field of study, or career you strongly identify or associate with? Describe why it appeals to you.**

**Do you think the area of interest (from the previous question) affects how you view physics? If so, how?**

**Select all the science courses you have taken in high-school or college**

| | |
|---|---|
| Standard high-school introductory biology | Standard high-school introductory physics |
| AP biology or college-level introductory biology | AP physics or college-level introductory physics |
| Standard high-school introductory chemistry | Introductory biochemistry |
| AP chemistry or college-level chemistry | Introductory organic chemistry |

**Describe briefly, your previous experiences with physics.**

**How prepared do you feel for physics in the Lyman Briggs College?**

**Do you expect to see connections between what you learn in this course and your other science courses?**

**In your section, name one person you would feel comfortable working/sitting near (optional)**

**In your section, is there anyone you would feel uncomfortable working with? (optional)**

**Please indicate your level of agreement with the following statements**

| | Strongly agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Strongly disagree |
|---|---|---|---|---|---|
| I expect my professors to talk about how biology, chemistry and physics relate. | O | O | O | O | O |
| To be successful in this course, I don't expect to have to bring in ideas from my other science courses. | O | O | O | O | O |
| Drawing on my science knowledge from other courses will help me in this course. | O | O | O | O | O |
| My other science coursework is too different to be useful in physics class. | O | O | O | O | O |

| | Strongly agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Strongly disagree |
|---|---|---|---|---|---|
| Time should not be taken out of biology courses to present physics. | O | O | O | O | O |
| Time should not be taken out of physics courses to present biology. | O | O | O | O | O |
| My biology background helps me solve problems in physics class. | O | O | O | O | O |
| What I learn in physics will be beneficial to me in my future career. | O | O | O | O | O |

**How challenging do you expect Lyman Briggs Physics to be? Why?**

**In order for me to understand physics concepts, I need to:**

**(rank with 1=most needed & 5=least needed)**

| | 1 (most needed) | 2 | 3 | 4 | 5 (least needed) |
|---|---|---|---|---|---|
| Design experiments | O | O | O | O | O |
| Conduct experiments | O | O | O | O | O |
| Understand how the lab equipment works | O | O | O | O | O |
| Read books, articles and online sources | O | O | O | O | O |
| Use computers to analyze data | O | O | O | O | O |
| Use computer programs to simulate physical situations | O | O | O | O | O |

| | 1 (most needed) | 2 | 3 | 4 | 5 (least needed) |
|---|---|---|---|---|---|
| Do quantitative problems | O | O | O | O | O |
| Work with other people | O | O | O | O | O |

**In order for physicists to understand physics concepts, physicists need to:**

**(rank with 1=most needed & 5=least needed)**

| | 1 (most needed) | 2 | 3 | 4 | 5 (least needed) |
|---|---|---|---|---|---|
| Design experiments | O | O | O | O | O |
| Conduct experiments | O | O | O | O | O |
| Understand how the lab equipment works | O | O | O | O | O |
| Read books, articles and online sources | O | O | O | O | O |
| Use computers to analyze data | O | O | O | O | O |
| Use computer programs to simulate physical situations | O | O | O | O | O |
| Do quantitative problems | O | O | O | O | O |
| Work with other people | O | O | O | O | O |

## Please indicate your level of agreement with the following statements

| | Strongly agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Strongly disagree |
|---|---|---|---|---|---|
| Models are exact representations of the physical world. | O | O | O | O | O |
| A good model must include all of the details of the situation. | O | O | O | O | O |
| All models involve simplifications. | O | O | O | O | O |

| | Strongly agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Strongly disagree |
|---|---|---|---|---|---|
| A simple model is not useful for understanding a physical situation. | O | O | O | O | O |
| Most simplifications in physics are done without a good reason. | O | O | O | O | O |
| You need more than one model to *completely* understand a physical situation. | O | O | O | O | O |
| Biologists rarely use models in their work. | O | O | O | O | O |

**Have you ever studied or learned a programming language or written a computer program? (examples may include: Java, Python, C++, C#, Visual Basic, JavaScript, MATLAB, Mathematica, or others)**

Yes

No

**Please describe your experience with programming.**

**Have you ever used a computer program to plot, model, or analyze data?**
**(examples may include: Excel, MATLAB, Mathematica, Maple, LabVIEW, LoggerPro, or others)**

Yes

No

**Please describe your experience with using a computer to plot, model, or analyze data.**

**What role do you think computers play in the process of doing science in your major, area of interest, or future career?**

**The following questions will ask you to reflect on a computer program such as the one below**

```
GlowScript 2.1 VPython
##Setup our view of the scene
scene=canvas(center=vector(5,0,0))
## Setup the particle and a reference point for the particle (i.e., the ground)
particle = sphere(pos=vector(0,1,0), radius = 0.5, color = color.red)
ground = box(pos=vector(5,0,0), length = 10, width = 1, height = 1, color=color.white)

## Assign the particle a fixed velocity
particle.velocity = vector(1,0,0)

## Creates an arrow to visulaize the particle's velocity vector
vArrow = arrow(pos=particle.pos, axis = particle.velocity, color = particle.color)

## Set up the time variables for the while loop
delta_t = 0.01
t = 0
tf = 10

## While loop to iterate over the time interval
while t < tf:

    rate(100) ## Keeps animation slow enough to view

    ## Time step to predict location of particle in a time delta_t
    particle.pos = particle.pos

    ## Keep the arrow representing the particle's velocity
    vArrow.pos = particle.pos
    vArrow.axis = particle.velocity

    t = t + delta_t
```

| | Strongly agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Strongly disagree |
|---|---|---|---|---|---|
| I am afraid of writing computer programs. | ○ | ○ | ○ | ○ | ○ |

| | Strongly agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Strongly disagree |
|---|---|---|---|---|---|
| I do not have the skills to write a computer program. | O | O | O | O | O |
| I feel capable of reading and understanding a computer program. | O | O | O | O | O |
| I feel capable of using resources from the web to help me write a computer program. | O | O | O | O | O |
| I am interested in using a computer program to work through problems in science. | O | O | O | O | O |
| Making mistakes when writing a computer program is part of the learning process. | O | O | O | O | O |
| Using computer programs to do science is not a skill I will need in my future. | O | O | O | O | O |

---

**Rate the following on a scale of 1 to 10.**

| | Least | | | | | | | | | Most |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 9 | 10 |
| How much anxiety do you feel about this course? (1=least anxiety & 10=most anxiety) | | | | | | | | | | | |
| How capable do you feel about succeeding in this course? (1=least capable & 10=most capable) | | | | | | | | | | | |

---

**Is there anything else you would like to tell me heading into this semester?**

# APPENDIX C

# ELASTIC COLLISION IN 1-DIMENSION

Earlier in class we investigated what happens when carts collide on a frictionless surface with various masses. In this exercise we want to work on quantitatively representing those results.

**Our assumptions:** We're going to model these two carts as two point particles so that they are a better approximation for molecular collisions. These molecules will only interact with each other, gravity is not important (because they are very small) and we don't need to consider friction, viscosity or air resistance. The air track contains only two carts, is level (so we can ignore gravity) and the air eliminates friction as the carts slide, so this is a pretty good model for molecules. Lets assume both molecules will collide head-on and we know the initial velocities ($v_1$ and $v_2$), which are both in the x direction. Watch (or try) as the two carts collide from opposite sides.

1) Recall with your group what we discovered from the collision lab. What did we learn about momentum?

2) Now discuss what we know about energy. In the case of the two carts colliding on an air track, what types of energies do we need to put in our energy budget?

3) Write down the two equations for conservation of momentum and conservation of energy.

These equations can be solved for the final velocities for each cart, make sure everyone in your group understands the basic idea of how the solution may go (you do NOT need to derive these equations).

$$v_{f1,x} = \frac{m_1 - m_2}{m_1 + m_2} v_{i1,x} + \frac{2m_2}{m_1 + m_2} v_{i2.x}$$
$$v_{f2,x} = \frac{2m_1}{m_1 + m_2} v_{i1,x} + \frac{m_2 - m_1}{m_1 + m_2} v_{i2,x}$$

4) Now let's see how we can check the reasoning on that answer. From our rules from the earlier class - how should our velocities compare if the masses are the same? If one mass is much larger (4x) than the other? Check to see if your answer holds for these two extreme cases.

5) Let's check our reasoning in a different way. Explain in words what the expression for two carts of equal masses says. And the unequal masses?

6) Let's take the unequal masses condition to the extreme. What if the heavier cart were 100x more massive than the lighter cart? 1000x?

This is similar to a ball (or molecule) colliding with a wall. The wall has an infinitely high mass and no velocity before the collision so the final momentum of the molecule is equal and opposite to the initial momentum.

7) Find the final velocities if $m_1 >> m_2$. (Careful! You'll have do some approximation work in these expressions!)

A water molecule (MW=18) collides with the protein lysozyme (MW~14000).

8)Is the mass of lysozyme large enough to treat it like a wall?

9)What would be the smallest protein molecular weight where we can assume $m_1 >> m_2$?

# APPENDIX D

# MODELING CHEMICAL REACTIONS - HANDOUT

# Modeling Chemical Reactions: 1-D collisions

We will be thinking about the physics of chemical reactions in this course. In later parts of this course we'll examine the conditions necessary to break bonds and form new ones, but to start with we want to consider how molecules even have the opportunity to react with one another. For example, consider a common chemical reaction like adding hydrogen chloride gas to water:

$$HCl(g) + H_2O(l) \leftrightarrow H_3O^+(aq) + Cl^-(aq)$$

Remember, molecules are always moving (in liquids or in gases). So for a reaction to occur, the reacting molecules need to collide. To decide whether these colliding molecules will react we need to know about the kinetic energy each one has at the end of the collision.

## Part 1 - Determining Momenta Exchange in a Particle Collision

Determining whether a chemical reaction will occur when particles collide is a relatively simple process, but requires a careful choice of system and approach to the analysis. In this first part of the problem we will think about how the choice of system affects our analysis.

1) First let's define two different possible systems for this set-up. Draw system schemas for (a) the situation where only one HCl molecule is in the system, and (b) the situation where both the water molecule and the HCl are in the system.

2) Looking at the expressions below, which system are they describing? (Recall you just derived these in the 1-dimensional elastic collision problem.)

$$v_{f1} = \frac{m_1 - m_2}{m_1 + m_2} v_{i1} + \frac{2m_2}{m_1 + m_2} v_{i2}$$
$$v_{f2} = \frac{2m_1}{m_1 + m_2} v_{i1} + \frac{m_2 - m_1}{m_1 + m_2} v_{i2}$$

Choose one and calculate the final momentum. Which molecule is this momentum expression describing?

3) Now subtract the initial momentum for the same object from both sides of the equation. Simplify the equation to be in terms of initial momenta and the masses. This is the change in momentum for that object

4) What do you expect the change in momentum for the other object to be? Do the algebra on the other equation to check your guess. (Hint: Consider the ratio of the masses for the water molecule and the HCl molecule.)

## Part 2

Just as we simulated the motion of one ball using vPython a few weeks ago, we can simulate a 1-d elastic collision, that represents the collision of the water molecule and HCl molecule, that you have solved for earlier.

1) Go here and copy the code, then paste it into your Glowscript account.

2) Run the code. Does the physics seem correct?

3) Can you identify the line that needs to be changed?

4) Using the equations you derived earlier for an elastic collision, what is the momentum transfer for each ball? Where should this go in the code? (Remember VPython works in three dimensions, so you'll need to specify the direction of the momentum.)

5) Run the code and check that momentum and energy are conserved before and after the collision.

6) Try running the code for the correct masses of the water molecule and the HCl molecule. What happens as you change the velocity?

7) Try different initial velocities and different masses for the two balls. What general rules can you develop for how mass affects the final velocities? Can you extend this to rules about chemical collisions?

# APPENDIX E

# MODELING CHEMICAL REACTIONS - MINIMALLY WORKING PROGRAM

```
GlowScript 2.1 VPython
## Setup the both the red and lavender balls a reference point (i.e., the ground)
red_ball = sphere(pos=vector(-5,1,0), radius = 0.5, color = color.red)
lavender_ball = sphere(pos=vector(5,1,0), radius = 0.5, color = vector(0.5,0,0.5))
ground = box(pos=vector(0,0,0), length = 10, width = 1, height = 1, color=color.white)

## Assign each ball a fixed initial momentum
red_ball.velocity = vector(1,0,0)
lavender_ball.velocity = vector(-2,0,0)
red_ball.mass = 5
lavender_ball.mass = 2
red_ball.momentum = red_ball.mass * red_ball.velocity
lavender_ball.momentum = lavender_ball.mass * lavender_ball.velocity

## Creates an arrow to visulaize the ball's velocity vector
vArrowR = arrow(pos = red_ball.pos, axis = red_ball.velocity, color = red_ball.color)
vArrowO = arrow(pos = lavender_ball.pos, axis = lavender_ball.velocity, color = lavender_ball.color)

## Set up the time variables for the while loop
dt = 0.01
t = 0
tf = 10

#Calculate and report the kinetic energy and momentum.
red_ball.kinetic_energy = 0.5*red_ball.mass*dot(red_ball.velocity,red_ball.velocity)
lavender_ball.kinetic_energy = 0.5*lavender_ball.mass*dot(lavender_ball.velocity,lavender_ball.velocity)
```

```
total_kinetic_energy = red_ball.kinetic_energy + lavender_ball.kinetic_energy
total_momentum = red_ball.momentum + lavender_ball.momentum
print("Initial K.E. = " + str(total_kinetic_energy))
print("Initial momentum = " + total_momentum)

# Keep the scene from expanding
scene.autoscale=False

## While loop to iterate over the time interval
while t < tf:

    rate(100) ## Keeps animation slow enough to view

    ## Calculate the separation between the balls
    diff = red_ball.pos - lavender_ball.pos
    separationRB = mag(diff)

    ## Test if that seperation is less than the joint radii of the balls
    ## Assumes head on, elastic collison
    if separationRB < red_ball.radius + lavender_ball.radius:

        # Yes, it is.  Only collide if they are moving toward each other
        nextposR=red_ball.pos + red_ball.velocity*dt
        nextposB=lavender_ball.pos + lavender_ball.velocity*dt
        if mag(nextposB-nextposR) < separationRB:
            # Time to colide!

            ## Calculate the amount of momentum in the x-direction that is transferred between the balls
            delta_p = 0
```

```
            ## Update the velocity of each ball with the transferred momentum
            red_ball.velocity = (red_ball.momentum + delta_p*vector(1,0,0))/red_ball.mass
            lavender_ball.velocity = (lavender_ball.momentum - delta_p*vector(1,0,0))/lavender_ball.mass
            red_ball.momentum = red_ball.mass * red_ball.velocity
            lavender_ball.momentum = lavender_ball.mass * lavender_ball.velocity

    ## Euler step to predict location of the ball in a time dt
    red_ball.pos = red_ball.pos + red_ball.velocity*dt
    lavender_ball.pos = lavender_ball.pos + lavender_ball.velocity*dt

    ## Keep the arrow representing the ball's velocity
    vArrowR.pos = red_ball.pos
    vArrowR.axis = red_ball.velocity
    vArrowO.pos = lavender_ball.pos
    vArrowO.axis = lavender_ball.velocity

    t = t + dt

#Calculate and report the kinetic energy and momentum.
red_ball.kinetic_energy = 0.5*red_ball.mass*dot(red_ball.velocity,red_ball.velocity)
lavender_ball.kinetic_energy = 0.5*lavender_ball.mass*dot(lavender_ball.velocity,lavender_ball.velocity)
total_kinetic_energy = red_ball.kinetic_energy + lavender_ball.kinetic_energy
total_momentum = red_ball.momentum + lavender_ball.momentum
```

```
print("Final K.E. = " + str(total_kinetic_energy))
print("Final momentum = " + total_momentum)

```

# APPENDIX F

# 3D COLLISION: KEEPING PARTICLES IN A BOX - HANDOUT

Returning to our chemical reaction from the last problem,

$$HCl(g) + H_2O(l) \leftrightarrow H_3O^+(aq) + Cl^-(aq)$$

we know that it's not realistic to model a reaction as just two balls colliding. The remaining computational problems in this segment are going to help us develop our computational model to better represent a scenario of (a) many molecules moving around randomly in any direction and (b) confining those molecules to a particular region (as if we're doing this reaction inside a test tube or a cell).

### Letting the molecules go in any direction

In order to develop a realistic model of diffusion of many molecules, we have to let the balls move in 3 dimensions. As we showed with 2-d collisions, how two objects collide depends on the angle at which they hit each other (head-collision vs. glancing blow). The same is true in 3-d and makes the momentum transfer that you calculated for 1-d much more complicated. Therefore we have included that line already in the code you will work on.

1) Go here and copy the code, then paste it into your Glowscript account. Look at the code and compare it to the 1-d collision code. What lines of the code represent the 3D part of the collision? Which particle (A or B) is red?

2) Run the code, what do you see? (To look at the simulation from different directions, right click and drag the view to rotate) Will the balls ever collide a second time? What could we do to make them collide more than once?

### Confining the molecules to a particular region

3) To keep the balls contained in the box you see on the screen we need to make the balls bounce off the walls. To figure out how to do this, treat the wall as a very massive as compared to each molecule. Using the expression from 1D collisions, how would the final velocity compare to the initial velocity of each particle after it bounced off the wall?

$$v_{\mathrm{f1},x} = \frac{m_1 - m_2}{m_1 + m_2} v_{\mathrm{i1},x} + \frac{2m_2}{m_1 + m_2} v_{\mathrm{i2}.x}$$
$$v_{\mathrm{f2},x} = \frac{2m_1}{m_1 + m_2} v_{\mathrm{i1},x} + \frac{m_2 - m_1}{m_1 + m_2} v_{\mathrm{i2},x}$$

4) Now looking at the code, how will we know when a ball is near a wall and will need to bounce off? (Hint: Take a look at line 73-74).

5) Now edit the code so that the particles are forced to keep colliding with one another.

# APPENDIX G

# 3D COLLISION: KEEPING PARTICLES IN A BOX - MINIMALLY WORKING PROGRAM

```
GlowScript 2.1 VPython
## Asign a radom position to the particles.  Since the center of our viewing is the origin
## of a coordinate systeem and random values returns in the interval [0,1], 0.5 is taken from the random value.
## Since the box is from [-1.5,1.5] in x, y, and z and the radius of the particles is
## 0.5, the positions can range from [-1,1] in x, y, and z.
posRx = 1
posRy = 0
posRz = 0
posOx = -1.0
posOy = -.1
posOz = 0
## Setup the particle and a container for the particle
red_ball = sphere(pos=vector(posRx,posRy,posRz), radius = 0.5, color = color.red)
lavender_ball = sphere(pos=vector(posOx,posOy,posOz), radius = 0.5, color = vector(0.5,0,0.5))
container = box(pos = vector(0, 0, 0), length = 3, width = 3, height = 3, color = color.white, opacity = 0.1)

#Give the particle random velocities, masses, and momentum
vRx = -1
vRy = 0
vRz = 0
vOx = 1
vOy = 0
vOz = 0
red_ball.velocity = vector(vRx,vRy,vRz)
lavender_ball.velocity = vector(vOx,vOy,vOz)
red_ball.mass = 5#*random()
lavender_ball.mass = 5#*random()
red_ball.momentum = red_ball.mass * red_ball.velocity
lavender_ball.momentum = lavender_ball.mass * lavender_ball.velocity

## Set up the time variables for the while loop
dt = 0.01
t = 0

## While loop to iterate
while True:

    rate(200) ## Keeps animation slow enough to view

    ## Calculate the separation between the particles
    diff = red_ball.pos - lavender_ball.pos
    separationRO = mag(diff)
    direction = norm(diff)

    ## Test if that seperation is less than the joint radii of the particles
    if separationRO < red_ball.radius + lavender_ball.radius:

        # Yes, it is.  Only collide if they are moving toward each other
        red_ball_direction=dot(red_ball.velocity,direction)
        lavender_ball_direction=dot(lavender_ball.velocity,direction)
        if red_ball_direction <= 0  and lavender_ball_direction >= 0:
            # Time to colide!

            ## Calculate the amount of momentum that is transferred between the particles
            delta_p = 2.*dot(red_ball.mass*lavender_ball.momentum
                           - lavender_ball.mass*red_ball.momentum,direction)/(red_ball.mass+lavender_ball.mass)*direction

            ## Update the velocity of each particle with the transferred momentum
            red_ball.velocity = (red_ball.momentum + delta_p)/red_ball.mass
            lavender_ball.velocity = (lavender_ball.momentum - delta_p)/lavender_ball.mass
            red_ball.momentum = red_ball.mass*red_ball.velocity
            lavender_ball.momentum = lavender_ball.mass*lavender_ball.velocity

    ## Euler step to predict location of particle in a time dt
```

```
red_ball.pos = red_ball.pos + red_ball.velocity*dt
lavender_ball.pos = lavender_ball.pos + lavender_ball.velocity*dt

"""
Determines if red_ball is going to reflect off the wall during
this step, and returns the appropriate velocity if it should.
"""

if abs(red_ball.pos.x) > container.length/2 - red_ball.radius:
    red_ball.velocity.x=red_ball.velocity.x

t = t + dt
```

# APPENDIX H

## 3D DIFFUSION: TRACKING PROTEINS - HANDOUT

# Simulating 3D diffusion: Tracking Proteins

Now that we can simulate the motion of 2 balls in a box, we can add as many as we want. However, they can't all start in the same place. Se we have to make a list of particles to keep track of them all, give each a different starting position and velocity and check whether each pair will collide in a time step. We also have to check if each ball will collide with a wall. This is a lot of tedious bookkeeping that computers are really good at. For this problem we will be working with the finished code to see how a large number of balls interact with each other.

### Adding more molecules

1) Go here and copy the code, then paste it into your Glowscript account.

2) Look at the differences between this code and the one for Simulating a 3-d collision. Discuss with your group what the additional lines of code do. Make sure you understand what a"for" loop does.

3) Now run the code and observe what happens. What is the best way to describe the motion of the balls?

### Modeling proteins in water

Consider a typical cell (e.g. E. coli, yeast). These cells have many molecules within them, but two primary molecules are the proteins and the water. Find a reliable source and determine the ratios of the protein to water molecules in terms of (a) mass, (b) size, and (c) concentration.

4) Looking at the code you will see there are two "for" loops in which we create a list of particles. This lets you make two different kinds of balls. How can make these two groups different? What are the dimensions we can vary? Can you change the balls so that we can tell which is which when we run the simulation? Try playing with the different parameters in each group and see what happens.

5) Now let's make this a simulation - using your numbers from above, create a simulation of a few proteins (3-5) with a lot of water molecules. (Note: To run this code on our computers we have a few limitations - you can only make the masses about 5x different and we cannot make the total number of balls more than 100. How much do the proteins move compared to the water?

6) In real experiment we can watch the motion of proteins by making them fluoresce (emit light), such as happens with Green Fluorescence Protein. Here is a movie of such an experiment (left panel).


However you can't see the water molecules. Edit the code to make the group of water molecules invisible and run the code. Is it easier to watch the trajectory of an individual ball? Can you figure out how to follow the trajectory visually? How would you describe it?

# APPENDIX I

# 3D DIFFUSION: TRACKING PROTEINS - MINIMALLY WORKING PROGRAM

```
GlowScript 2.1 VPython

listOfParticles = [] # List of all particles

N = 20 # Number of small particles
M = 20 # Number of large particles
t=0
dt = 0.01

container = box(pos=vector(0,0,0),length=80,width=80,height=80,color=color.white,opacity=0.1)
Graph = series(color=color.red)
## Create all the particles
## Focus here
for i in range(0,N):

    posx = 80*(random()-0.5)
    posy = 80*(random()-0.5)
    posz = 80*(random()-0.5)

    vx = 100*(random()-0.5)
    vy = 100*(random()-0.5)
    vz = 100*(random()-0.5)

    newparticle = sphere(pos=vector(posx,posy,posz),radius=1)
    newparticle.visible = True
    newparticle.mass = 1
    newparticle.velocity = vector(vx,vy,vz)

    listOfParticles.append(newparticle)

for i in range(0,M):

    posx = 80*(random()-0.5)
    posy = 80*(random()-0.5)
```

```
    posz = 80*(random()-0.5)

    vx = 100*(random()-0.5)
    vy = 100*(random()-0.5)
    vz = 100*(random()-0.5)

    newparticle = sphere(pos=vector(posx,posy,posz),radius=1,color=color.white,make_trail=False)
    newparticle.mass = 1
    newparticle.velocity = vector(vx,vy,vz)

    listOfParticles.append(newparticle)


## Simulate Random Motion (just like week N)
while True:

    rate(500)

    for particle in listOfParticles:

        particle.pos = particle.pos + particle.velocity*dt

        if abs(particle.pos.x) >= container.length/2-particle.radius:

            particle.velocity.x = - particle.velocity.x

        if abs(particle.pos.y) >= container.height/2-particle.radius:

            particle.velocity.y = - particle.velocity.y

        if abs(particle.pos.z) >= container.width/2-particle.radius:

```

```
                particle.velocity.z = - particle.velocity.z

        for i in range(0,len(listOfParticles)):

            for j in range(i+1,len(listOfParticles)):

                diff = listOfParticles[j].pos - listOfParticles[i].pos
                distance = mag(diff)

                if distance <= listOfParticles[i].radius + listOfParticles[j].radius:

                    nextpos1 = listOfParticles[i].pos + listOfParticles[i].velocity*dt
                    nextpos2 = listOfParticles[j].pos + listOfParticles[j].velocity*dt

                    if mag(nextpos2 - nextpos1) < distance:

                        direction = norm(diff)

                        mv1 = listOfParticles[i].mass*listOfParticles[i].velocity
                        mv2 = listOfParticles[j].mass*listOfParticles[j].velocity

                        ptransfer = 2.*dot(listOfParticles[i].mass*mv2
                                          -listOfParticles[j].mass*mv1,direction)/(listOfParticles[i].mass

                    +listOfParticles[j].mass)*direction
```

```
                listOfParticles[i].velocity = (mv1 + ptransfer)/listOfParticles[i].mass
                listOfParticles[j].velocity = (mv2 - ptransfer)/listOfParticles[j].mass
    t=t+dt
    #Graph.plot(t,listOfParticles[1].velocity.x)
```

# APPENDIX J

## INSANE IN THE MEMBRANE PART 1: OIL & WATER

# Insane in the Membrane- Part 1: Oil and Water

First, imagine a box full of two types of non-interacting gases such as helium (He) and neon (Ne) in equal amounts.

1. Draw a picture of how you would imagine they would be distributed in a box.

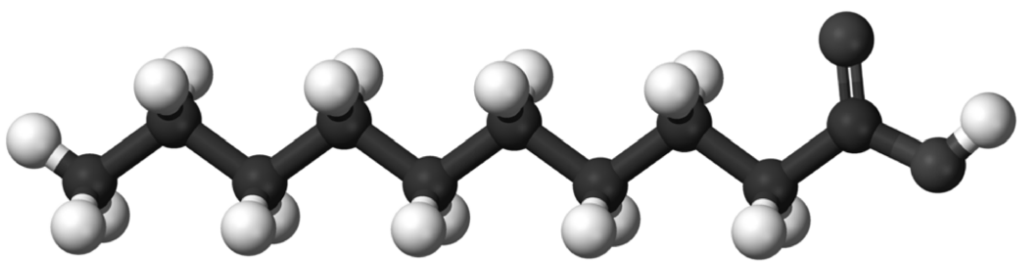
2. Based on what you know about entropy, can you justify why this would be the state that you observe?

In your study of biology, you've probably encountered "hydrophobic interactions": some non-polar molecules, or non-polar parts of molecules, seem to be repelled by water. This phenomena plays an important role in the structure of proteins, and next week we'll see how it relates to the formation of lipid bilayers: the membranes that form the boundary of all cells (as well as some organelles within cells). You've also encountered hydrophobic interactions in everyday life when you've observed that oil doesn't mix with water; they separate when you try to put them together.

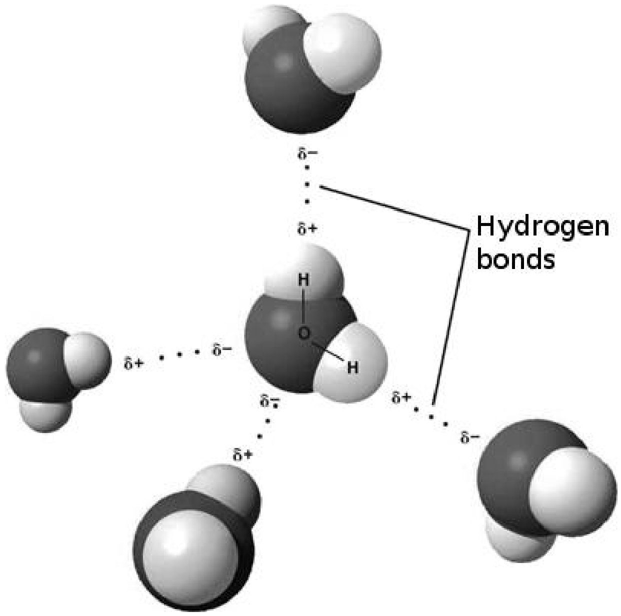
Today you'll use the Second Law of Thermodynamics to understand where this interaction comes from.

3. Draw (in a way that makes sense to you) what it would look like at the molecular level (a) for oil and water to mix, and (b) for oil and water to separate (don't worry about correctly representing the molecular structure of the oil, you can just use squares for oil molecules and triangles for water molecules.)

Oil molecules are basically long hydrocarbon chains. These are non-polar molecules. The picture below shows an oil molecule with a carbon backbone (dark circles) and hydrogen atoms (white circles) coming out off of the backbone.



Water, in contrast, is a polar molecule: the electrons are closer to the oxygen atom than to the hydrogen atoms, and the molecule is bent so that both hydrogens are to one side, so the hydrogen end is positive and the oxygen end is negative. This results in hydrogen bonding: the reason that water is a liquid at room temperature (even though hydrogen and oxygen are gases). The picture below shows water molecules forming hydrogen bonds with one another where the large red circles represent oxygen, and the smaller white circles represent hydrogen.




4. Oil molecules can appear to get "stuck" inside surrounding water molecules (and, since an oil molecule is considerably larger than a water molecule, quite a few water molecules are required to surround a single oil molecule). Using what you know about hydrogen bonding between water molecules, draw a picture showing a hydrogen-bonded "cage" of water molecules within which an oil molecule is apparently stuck.

5. What effect does the formation of these hydrogen-bonded cages around oil molecules have on the entropy of the whole oil/water system (as compared to the situation where nothing "sticks" to anything and everything moves around freely)? Why?

6. Compare what will happen to the entropy of the whole system in the following two scenarios: A) if the oil molecules are all clumped together and the clump is surrounded by water and B) if the oil molecules are spread out evenly throughout the water, each individual oil molecule surrounded by water?

7. Explain from the perspective of entropy and the Second Law why it is that oil and water are likely to separate.

8. Your answer to question #2 may have suggested that oil and water would mix due to entropy, but in #7 you found that maximizing entropy would indicate that oil and water separate. How can you reconcile these two different answers?



Vashti Sawtelle, Ben Geller, Julia Gouvea, and Chandra Turpen 2/1/12

# APPENDIX K

# INSANE IN THE MEMBRANE PART 2: LIPID BILAYERS

# Insane in the Membrane- Part 2: Lipid Bilayers

**How did life originate?**

Many of the early models of life's origins proposed by biologists included as a crucial step the formation of **proto-cellular compartments** that could serve as distinct / discrete environments in which chemical reactions could take place. However, the exact structure and mechanism of their formation remained unknown.

In the 1960s laboratory experiments demonstrated that **phospholipids** could spontaneously assemble into bilayer membranes forming bacteria-sized containers (vesicles). Later experiments demonstrated that such vesicles could also form under simulated early-Earth conditions. Such experiments paved the way for a line of research investigating how these self-assembling membranes could have functioned in the evolution of living cells.

But how exactly does spontaneous membrane formation work? What are the mechanisms that drive this process? It turns out that an **understanding of the combined effects of energy and entropy** can help us make sense of this phenomenon.

1. Last week you explored the *entropic* contribution to hydrophobic interactions (the entropic reason for why oil and water don't mix). With your group, write out an explanation for why oil and water don't mix that relies only on the *entropic* arguments you made last week. (This explanation is incomplete because it does not yet take *energy* into account.)

Phospholipids have a phosphate ion at one end, and the rest is a hydrocarbon chain (like oil). The hydrocarbon end is the "hydrophobic" ("afraid of water") end. The phosphate end is the "hydrophilic" ("water-loving") end.

2. Gibbs free energy ($\Delta G = \Delta H - T\Delta S$) is a way of quantifying the (sometimes competing, sometimes additive) effects of *both* energy *and* entropy. You can think about what happens when you put hydrophilic molecules into water, and what happens when you put hydrophobic molecules into water, as resulting from both an energetic contribution (in this case, electrical potential energy) and an entropic contribution. Answer the following questions for the process ofoil separating from water that we looked at last week:

- What is the sign of $T\Delta S$ for the system during the separation? How do you know?
- What interactions contribute to $\Delta H$ for the system during the separation? What is the sign of $\Delta H$ for each interaction that contributes to the overall $\Delta H$? (Remember that $\Delta H$ is due to electrostatic interactions, so you are being asked to identify the various electrostatic interactions that one must consider.)
- It turns out that the quantitative value for $\Delta H$ upon separation of oil and water under standard conditions is quite close to zero! Why might that be plausible?
- What is the sign of $\Delta G$ for the separation of oil and water under standard conditions? What does this tell us about the separation?

3. As you know, not all substances behave like oil: some substances are soluble in water and dissolve quite easily. Think about ions (such as phosphate, or sodium chloride, or whatever) that tend to be soluble in water, whereas oil is not. Answer the following questions for the process of sodium chloride dissolving in water (the system is the water plus the salt):

- What is the sign of $T\Delta S$ for the system during the dissolving process? How do you know?
- What is the sign of $\Delta G$? How do you know?
- What is the sign of $\Delta H$ for the system during the dissolving process? How do you know?
- How does this salt water system differ from the oil/water system?

4.  Using Gibbs free energy, explain what makes some molecules (or parts of molecules) hydrophobic and others hydrophilic.

5.  Explain why changing the temperature of the system can determine whether a substance dissolves in water or does not.

6.  Putting all this together, explain how phospholipids can spontaneously self-assemble into a lipid bilayer.  Why this particular shape?  (Why not a monolayer, or a trilayer?)  Note that the individual phospholipid molecules are still free to move around within the bilayer, like a two-dimensional liquid; they're not bound together like a solid.



Ben Dreyfus, Vashti Sawtelle, Ben Geller, Julia Gouvea, and Chandra Turpen 1/30/12

# APPENDIX L

# TRANSCRIPT: MARIA INTERVIEW 1

1 Maria: and then meetings till 4, and sometimes I work

2 I: jeez, where do you get the time?

3 Maria: i dunno, 9am apparently

4 I: {laughs} {silence}

5 I: So what classes are you taking right now?

6 Maria: Obviously I'm in physics and then I have prokaryotic physio, intro to epidemiology, and epidemiology biostatistics.

7 I: Whoa

8 Maria: yeah, a lot of science is happening

9 I: whoa, i might ask you to repeat those words you said, it sounds fancy.

10 Maria: {laughs} it's just epi for the minor

11 I: Yeah, and then this is just an audio recorder cause sometimes the, the video dies on us. um...it's happened before, and that bottle of water is yours.

12 #skipping ahead, just introducing interview here-0#

13 What do you think you want to do with a microbio degree?

14 I want to do research probably infectious disease yeah.

15 So you want to solve the Walking Dead?

16 {laughs} yeah, we'll see that one is a little tough.

17 Do people make that joke a lot?

18 No actually, that's the first one. I'm surprised actually yeah.

19 I: {laughs}

20 Um...so, do you have anything right after this interview?

21 I have a 10:20, but it's in (Fee?), so it's right across the street.

22 I: So now I'm going to ask you a very general question, tell me a little bit about yourself.

23 {laughs} OK, um...I dont know where to start. I went to high school in Ann Arbor a big high school, I actually grew up in Northern Michigan, a small town. Came to MSU, microbio major, epidemiology minor, member of some clubs on campus, i work in a research lab, i'm tutoring, i dont know what else you want to know. I like photography in my free time, yep. i watch a lot of TV to destress, I'm a big fan of TV shows, Netflix.

24 Um..what kind of clubs are you in?

25 So I'm the co-founder and co-president of American Society of Microbio and then fundraising chair for N7 which is a public health, infectious disease club, and then I'm doing Briggs ambassador, which is the tour guides for Briggs.

26 That's a lot of stuff, wow. Fantastic, what research lab do you work in?

27 Dr. Joan Rhodes in fisheries and wildlife, so it's water microbiology.

28 What do you do there?

29 Um...right now I'm just being trained in all the different assays we run, so assays for viruses that infect ecoli, so we look for that in the water, um...concentration of enterococci in the water, learned that one yesterday, stuff like that.

30 I: Very cool. Um..describe a little bit about your high school experience.

31 So high school was interesting because I moved the summer between the 8th and 9th grade I moved from a tiny town where I lived my whole life, i knew everyone, to ann arbor, which was giant for me, um... it was cool cuz i mean growing up north you don't get a lot of diversity, you're with the same people, like nothing changes. and my high school, my high school graduating class was about the size of the high school, the whole high school up north, so it was hard to transition to that big environment but once i did i really enjoyed it. um... a lot more course offerings, like i took latin for two years cuz i had a gap in my schedule, so ... fun.

32 awesome, what science classes did you take?

33 um...i took, we had like a weird like accelerated track, um...for our sciences that everyone was required to take, um...so i took like accelerated bio they called it your whole freshman year and then accelerated physics for two semesters, but you took it as a sophomore so you didn't have any calculus so you know i just, forces and energy not a lot of the math to it. and then um... let's see, chemistry regular, and AP bio, {in low voice} stats i think i did for a (second?)

34 wow, so you've had bio, chemistry, and physics before, wow that's great.

35 and so, what got you interested in bio or microbio?

36 um...i've always just kind of liked bio like i grew up north, like my family really likes going hiking, all of my vacations when i was little was like to (IO ROyal?) we went to montana you know like hiking and outdoors. so i've always kind of liked that. but then like a little bit I remember in high school like when we got to like genetics and like you know diseases like that's really cool but that's where we left it and i came to college thinking i was going to do like sustainability res...like stuff like that, um that's kind of what i aimed my freshman year at and then at the end i was like you know what's really cool, we have a microbiology major so i'm gonna go for it.

37 I: Do you think that the biology concepts came easier to you?

38 S: Yeah, yeah it's i think the applications are maybe a little easier to see. Yeah.

39 I: OK, so do you know what kind of research you want to do?

40 S: Um...beyond like infectious disease not really, i've been pretty interested in infectious disease in the water microbiology i've been in so i think that's kind of cool, um... like i went to Nicaragua freshman year and like you can't drink the water like anywhere even at your hotel, don't drink from the tap, don't brush your teeth from the tap, water is a serious issue in a lot of places in the world that we don't think about. so, i think that might be cool to do.

41 So i know Briggs students often have like a choice in the physics classes they can take. They can take like the college of natural sciences version or the briggs version. Is there a reason you picked the briggs version?

42 um...i know physics isn't really my thing. and i know a lot of my university classes like, like my orgo class, i never talked to my professor, i never went to the help room, but with briggs i knew where everything was, i knew the professor's office would be right here, i knew the help room is in east, all my resources i knew where they were. so i figured i'd need help and i knew where to get it.

43 why do you say that physics isn't your thing? just curious.

44 I just, for the longest time i wasn't, like i didnt really think i was good at math, and i didnt really like math, so i've kind of steered away from anything related to math. and so, like the last time ive had physics was sophomore year of high school and you know we really just talked about like work and motion and i seem to remember vaguely and i just dont think they did a very good job of connecting it back to everyone's interests. like it was just theoretical pure physics. so, not my thing in that aspect.

45 did you do well in the course?

46 yeah, i got an A.

47 how come uh... if, so i'm curious so the difference between "i'm not a physics person and the math kind of is" but then

you did pure physics right? theoretical physics, i'm curious how those two jive, how were you able to do well?

48 Um... I mean i just apply myself so i always do well, like i'm not gonna, just cuz i don't like it doesn't mean i'm gonna like just let it fall away um... I mean i found now especially after taking calculus 1 and 2 like i actually enjoyed that, which was strange to me, i actually enjoyed the theoretical math and i didn't think i would, so i think physics this time around might be a little better. but um...yeah, just as far as like i guess it's hard for me to conceptualize so that kind of steers me away from like, i have to think a little harder about it.

49 Did you have expectations of what the physics course in Briggs would be like?

50 Um... not really, cause i knew it was its first year so it was like its, who knows, um... but i kind of figured it would be a little more like integrating different sciences just because they know that like we're all science majors but we're prolly not physics majors, where i kind of figured the university one would be just here's your physics, get it out of the way, move on with your life. so...

51 Now i'm going to ask you some general questions, um...about what you did in class and stuff, uh... so i want your interpretation of it so um... describe what you did in class yesterday.

52 what did we do in class yesterday? so it started with a board meeting, so we talked about the previous class's activity where we did just the experiment so we kind of talked about what we did but because we had a lab report we didn't go as in depth as we normally do into the concepts and then we worked on a conceptual worksheet about the reading and then a quantitative worksheet about the reading. and that was it.

53 how did that feel?

54 it was good, um...sometimes like with the readings on d2l, that's not my favorite format for readings so, i tend to like not retain it as much so um... it took me a moment to like you know remember what was going on in the worksheets and stuff.

55 what about the formatting on d2l is kind of

56 i'm not like a big like, i don't like reading things on the computer so i like, i think printing them out may help me, so as long as it's a lower number of pages it's prolly what i'll do from now on after the first few weeks in.

57 So is this pretty typical of what you do in that class?

58 Yeah, yeah, i mean some days are like i said the experiments, you have to do the experiment first then you can have a day where you kind of tie it all together.

59 what happens in these board meetings?

60 So... um... typically you either talk with 3 or 6 people, you focus on one question, it's supposed to really get to the bottom of what you were doing and kind of like tie it all together, like what's the point, what's the physics. um... you talk within your group and then as a class you kind of build the lecture on our own. um... kind of like sounding off of each other to cement the ideas.

61 can you say more about building the lecture together?

62 yeah so, usually, um... the professor is like prompting us, you know it's never straightforward but we usually get to the point in the end, so we you know you start from just kind of what you did, and from there you try and draw out the physics in each person, you know usually each group has something a little bit different, so each element comes together.

63 hm...are there ever any disagreements?

64 um... there have been a few times, which is kind of to be expected because we're trying to grasp like what we did in that, we all come with like different background of like physics is hard because you see it in the real-world, but that's not always you know what you think is going on is not necessarily what is actually happening, so there's sometimes things like that like um... i know like yesterday when we're doing the quantitative stuff like some people thought it should be negative and other people are like "no" the number should be forward (cause it has to be in) perspective to this, so just like hashing that out but it's never you know, it's just so that everyone understands, we usually come to a conclusion.

65 do you feel it's productive?

66 yeah, for the most part yeah. it can be a little confusing when there are disagreements and you're trying to, if you don't actually have an opinion and you're trying to learn it and then you're being told these two things and you're not sure which one is right, so, by the end you get it but as you're going through it's, it can be a little confusing.

67 so how do you keep uh... hm... so you said there are moments where these two ideas seem to be conflicting or still up in the air, um... is it always um... do you always get to a resolution.

68 not always, um... sometimes it goes kind of i think beyond the scope of what we're supposed to be grasping for that day, so the professor will be like "i want you to hold on to that but just know that like it's important that those things are there but, you can kind of not focus on that for now, you don't need to you know concern, be really concerned with the answer.

69 OK, um... can you describe a typical week, so you meet 3 times, Monday Wednesday Friday, what's the sequence of events?

70 I'm trying to remember, it's only been a few weeks {laughs} so i mean usually there's some activity that we do um... kind of like the first day that's um... not for this week because we had a lab report this week but um... it's usually a little less, like it's um... just something to kind of get your ideas out there and start figuring it out and then like, like last week um... we did an activity and then i think it was on wednesday we watched like the videos and really like saw it in like practice, like we used bacteria which i thought was cool. and um... and then on friday you know it's really like getting it all together like sometimes there's worksheets on wednesday or friday and usually the board meetings happen after the major experiment and we really start putting down our definitions and all that stuff.

71 so you said you liked the video analysis, what did you like about it?

72 uh huh, yeah, i mean i kind of knew like after the first day it was hopefully going to be like this where you know like i'm a microbiology major, i know physics is important for what i want to do but like physics like i was taught in high school has nothing, like i cannot make that bridge by myself like that. it's too conceptual, too theoretical, but this was you know like here's where you would apply it like what concepts to use specifically in microbiology

73 that's awesome, do you have any thoughts on why you think, i'm curious, why you think the course is structured the way it is.

74 i mean it definitely reminds me of a high school course a little bit and um... you know like you're given that time and we're there for lecture and lab, so it's like high school you know where you don't have separate classes for everything, so it lets you like explore and kind of, kind of in a bubble, get to see and explore what you're doing you know like there can only be so many conclusions, you kind of get to draw it for yourself and see it, then we do like a real application, something that's a little more concrete but more complicated and we're able to from those two kind of figure out the defintions and things that would be in a textbook. we're basically figuring out what the textbook would say. based on our experiences.

75 wow, uh... where do you think the learning happens? if you had to pick a point

76 um... i would say that there's definitely a lot like the first day when you first experience it, but that's maybe more of the like the experiencing it and maybe the learning happens more of the second and third day when you take those concepts and you really start to like get into them and know how they apply where they apply.

77 is there a specific activity that you would do on the second and third day where you think the learning is happening?

78 Hm... um... for me it really helps with the worksheets where i'm able to take what i did in a specific like activity like yesterday like what we did in the collisions, we're doing an experiment, like i knew why we were doing but being able to look at different like situations conceptually and then quantitatively really showed that i had understood it and could apply it. for me that's like, it means you've learned it so...

79 that's great, so you mentioned the video tracking um... as one example of something from bio coming in, have you encountered anything else from bio in this course?

80 um.... i'm trying to think, uh... not that i can remember but it's also like what week 4? so um... yeah.

81 do you find yourself finding physics in any of the other courses? biochemistry or epidemiology?

82 um... i mean i can see it in some of my past courses, like my past epi course was really focused on like um... osteoarthritis and um... forgetting it now, bone osteo, he spent so many weeks on it cause that's what his research was in. so stuff like that i can definitely see how you would be like focused on like the physics of it all, like what causes the

fractures what can we do to prevent them and things like that. i could definitely see that um... not so far in like prokaryotic physio, but i'm feeling once we get to flagella and pillae and things that are moving, maybe a little more.

83 Alright i want to pick your brain on this, do you see biology chemistry and physics as being related?

84 Yes.

85 can you tell me more?

86 yeah, so... {laughs} i mean i have to take biochemistry next semester and i'm in prokaryotic physio right now and i'm just looking at the board like yeah {makes pointing gesture} learned that in orgo, learned that in orgo, like you know you have your amino acids which are your basic building blocks for living things and you know nucleic acids when it comes down to it, that's chemistry. like we like to think that's biology but it's really not {laughs} and um... so it's i think it's a little easier for people to see the relationship there. physics is so you know, i've seen the cartoons where it's like purity and stuff and physics is way at the end and i think it's a little harder for people to see that physics is kind of the basis of some of the other fields like. why are things moving that way within the cell. why can the cell do that? well, it's physics. actually, we talked about lateral motility within the cytoplasmic membrane in um... in microbio, and i'm pretty sure my professor's words were something like the thermodynamics and the physics of the you know the cytoplasmic membrane are a glorious chapter in microbio! {laughs} it's like alright. but definitely with that sort of stuff, anytime anything is moving, or even just you know the thermodynamic things, things you don't think about, it's physics. you just experience it everyday, so maybe you don't realize it. so.

87 that was great, you gave me a lot of good similarities. um... do you see any differences between the three?

88 um... yeah for me i think it's a lot easier for me to see biology applications like especially like intro bio just out in the real-world, you know you can go out and sample squirrels or whatever people, i see people watching squirrels so much this week, for class. and then i think for chemistry you know it's a little harder to conceptualize for me, i have to think down a little more, um... to what's happening but then i think physics is kind of like yeah, it's a sliding scale of ability to conceptualize. physics i have to think a little more about and kind of come up with an everyday example to use the theoretical stuff.

89 when you say conceptualize you're meaning connecting to the real-world.

90 yeah.

91 ok. what physics concepts have you covered so far in class.

92 uh...we started with kinematics, so position, velocity, acceleration and now we're on to momentum.

93 so do you see connections between those physics concepts and your other subject classes?

94 um...these are a little more basic but i mean i know it's going to apply somewhere, you know you can find velocity of a bacteria like we did actually in our activity and stuff like that. and you know how different things affect their velocity and stuff like that, but so far it's pretty basic, so...

95 cool, do you ever find yourself thinking of physics outside of the classroom?

96 other than when my professor said it was glorious i thought about this class, not so much

97 and uh... do you ever talk to your family or friends about physics?

98 no {shakes head} other than my friends that are in the class i don't know who.

99 no, do you think you'll need physics for what you want to do in the future?

100 um...it depends cause i really like epidemiology so that's a little more um... real-world, but if i get into the lab sort of aspects of really going down to the cellular level of microbiology, i can see it playing a role.

101 very cool, is physics relevant to you?

102 um... i think in this course it may be a little more, cause of the connections otherwise i would probably say no. {laughs}

103 alright so i'm going to ask you this question and it may or may not bring something to mind. so what comes to mind

i say diffusion?

104 um...things going in an out of a cell membrane.

105 tell me more.

106 um...so like yesterday i had an exam on these cell envelopes of prokaryotes and you know we had to memorize like the proteins that allow for passive diffusion of solutes into the cell, that's their main way of getting nutrients and things. it's the basis kind of lof life, like of things being able to diffuse across the membrane. so that's...

107 so how do they diffuse?

108 so i assume it has to do with physics [smiling, laughs] usually concentration is what it's based off of. so if it's going against the concentration, you're usually putting energy in.

109 ah ok, so going from high concentration to low concentration is?

110 easier.

111 easier, ok. and where do you think um... you learned all these ideas about diffusion?

112 um... i mean they definitely covered it in like chemistry, i think it was like maybe the second semester where we talked about gases diffusing and things like that. um... you definitely talk about it in your kind of biology classes, they just tell you things are going to go from high concentration to low concentration. um...and you just kind of accept that as a fact. makes sense kind of in your mind so...

113 what other things have you learned about diffusion? you told me about diffusing across membranes, and high concentration to low concentration, what else?

114 thinking back to my chemistry 2, it's like 2 years ago. we talked about diffusion of gases into a space.

115 ok, are there still things that you dont understand or you still have questions about, about diffusion.

116 um...i mean i think it would probably be nice to know why it happens, you know you don't really think about it, well of course it happens, you know it goes from high to low.but there has to be a reason. you know like know we just kind of accept it as a fact because we see it every day, but with like you know why does an apple fall from a tree, there is a reason for that. so...

117 how would you say you're doing in the course so far?

118 um... i think it's going ok. i've been able to complete like the online homeworks and stuff, we've only gotten i think like 1 homework grade back so...

119 is the homework the way you judge if you're doing well or not?

120 usually, if i'm able to apply it and understand it then yeah. then i'm probably good for... concepts.

121 are there classmates you talk about this course with?

122 yeah, so my roommate is in it so. {laughs}

123 that's convenient

124 yeah my roommate and my friend, who's also my neighbor is in it and um... i mean it's briggs so i know a lot of the, even if i don't know the people in there, i'm like yeah we've definitely had a class together so... get people a little more comfortable talking to each other.

125 do you have any examples of when you've talked about this outside of class?

126 i mean i've done the homework with my roommate a few times, uh.... the same way with my neighbor, like we've talked about it like "i couldnt get the answer to #4, like how did you do it?!" stuff like that so...

127 and so i've got a very general question, um..., are there any other things i should know about the course or about you,

anything you want to share?

128 that's about all i got yeah {laughs}

129 ok, {finishing remarks thanking student and asking if it's ok to follow up}

# APPENDIX M

## TRANSCRIPT: MARIA INTERVIEW 2

# TRANSCRIPT OF AUDIO FILE:

# MARIA-INTERVIEW2-11.09.16

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*The text below represents a professional transcriptionist's understanding of the words spoken. No guarantee of complete accuracy is expressed or implied, particularly regarding spellings of names and other unfamiliar or hard-to-hear words and phrases. (ph) or (sp?) indicate phonetics or best guesses. To verify important quotes, we recommend listening to the corresponding audio. Timestamps throughout the transcript facilitate locating the desired quote.*

**BEGIN TRANSCRIPT:**

INTERVIEWER: It’s a similar kind of chat to before. Just kind of chat about your class, see how things are going. Okay to close the door?

RESPONDENT: Yeah.

INTERVIEWER: Okay. Yeah, they’re the same. Too many. That’s for you to keep. And I don’t have an audio recorder so I’m just going to use my phone, just as a backup. How are things going?

RESPONDENT: Well, in general.

INTERVIEWER: Yeah.

RESPONDENT: In this class they’re going fine.

INTERVIEWER: In this class they’re going fine? What makes you say that?

RESPONDENT: I think I have the top score on both exams.

INTERVIEWER: Congratulations.

RESPONDENT: Yeah.

INTERVIEWER: Wow.

RESPONDENT: Yeah, the lab report is fine so that’s the main component, really, of the class.

INTERVIEWER: How does the class feel so far?

RESPONDENT: It’s all right. It can be frustrating at times.

INTERVIEWER: Yeah.

RESPONDENT: But overall, at the end I guess it seemed to be okay, with exams. So.

INTERVIEWER: What's frustrating about it?

RESPONDENT: I think it just can be like you're not sure what you're supposed to be learning. And it can be hard to figure out what you're supposed to focus on and what's important.

INTERVIEWER: Can you describe a specific moment that this happened?

RESPONDENT: I know it can happen during, especially the activities. Where you're trying to design it, and you're not really sure where you should be focusing or what concepts you're supposed to be really using, or what, sometimes you're not even, I'm not even sure what I really know. And then I go back and I'm like oh, that's what she wanted us to see. [0:01:42]

INTERVIEWER: I see. Where do you, why do you think that's happening? This kind of not knowing?

RESPONDENT: I think –

INTERVIEWER: And you're talking about the lab investigations?

RESPONDENT: Yeah, well –

INTERVIEWER: I mean, let's start with, okay.

RESPONDENT: The ones she'd do (inaudible at 0:01:53) you can get through. And they're kind of guided. I think it's just, it's a different structure that we, as college students we spent years learning how to learn from lectures. I went to more of a high school class structure, where you get the activities and you run it. I think you can just be, like there's less direction, so it can be harder to orient yourself.

INTERVIEWER: Gotcha. But it seems like you're doing well. You're excelling.

RESPONDENT: Yeah.

INTERVIEWER: Is there a secret?

RESPONDENT: I really like math and I'm a logical thinker. So I think physics is heavily based on that. And it's kind of like, when I see physics problems, more so than biology problems or something, it's a logic answer. There's a right answer. It's a logic problem to me.

INTERVIEWER: I see. Had there been problems in class that were kind of like, you were able to logic through it?

RESPONDENT: Yeah, I think they're just kind of like a puzzle, in making sure you have your pieces. And they all match up, like your energy and your work and everything, they should all fit together. [0:03:08]

INTERVIEWER: Are there activities that you see more math-like?

RESPONDENT: I guess like the worksheets we do.

INTERVIEWER: The worksheets, okay.

RESPONDENT: There's, like the conceptual goes along with it, to make sure that your math checks out. But to me, it's like okay, they gave me force and they gave me this other component. From that, I can find that. Just going off what I know I can find, I can logic through it.

INTERVIEWER: Okay, cool. Well, that's exciting to hear, that you're knocking these tests out. You're doing well on lab reports. That's amazing. Are you enjoying the class?

RESPONDENT: Yeah. (chuckles). It can be a lot of work. Just because you have to be there every day. You're always doing something. The activities can take a lot of thought process to go through. But this class has more homework than my other classes. But it is like four credits, so I think that kind of accounts for it. [0:04:04]

INTERVIEWER: Okay. Great. So today, the way we're going to structure it, is I have some activities that you've done in class, okay?

RESPONDENT: Okay (laughs).

INTERVIEWER: You're not going to have to do them.

RESPONDENT: Okay. (laughs).

INTERVIEWER: But I'm going to ask you to put your thoughts on them, and see what you think. So here's the first one. This is the investigating collisions. So I'm curious.

RESPONDENT: The first one will be good, right?

INTERVIEWER: Yeah, I think so. You can look through it, just remind yourself of what you did in class. Do you remember that one?

RESPONDENT: Yeah, yeah. It's been a while.

INTERVIEWER: What are your thoughts on? [0:04:41]

RESPONDENT: So, with this one, it was more like she gave us a scenario, which I think helped a lot of people. Because some of our other ones are just conceptually building an equation. Where this one, people were able to, like I was able to use just your intuition. Like, the SUV's going to be more massive. You probably heard about crashes between things like that. I think it helped for some guidance there. Which I think for the first activity was probably beneficial.

INTERVIEWER: So why do you think the instructors have you work on activities like this?

RESPONDENT: I think it's different to be told something than to actually find it and prove it in the real world. Because with physics, you know, it's all around you. It's not something that you have to go anywhere to see. So it's easy to do just in the classroom and see where these things came from. Sometimes numbers on a piece of paper don't really make sense. Some long equation is actually a pretty simple concept to prove. [0:05:47]

INTERVIEWER: And did you feel that after doing this investigation that you found out something?

RESPONDENT: Is this the momentum one? So yeah, I think so. I don't really remember momentum from my high school physics classes. And I think especially when we're talking about things like the collisions, I think later with the forces one, what you think is happening isn't what always is happening. Like with the equal and opposite forces.

INTERVIEWER: Tell me a little bit more there. So what is the situation where what you think is happening is not what's happening?

RESPONDENT: Especially with the forces one we did, building off of this one. I think everyone in the class, especially if you haven't taken physics, you would just assume. Because we did the momentum collision, that the SUV would exert more force. But they're exerting equal and opposite forces on each other. Which isn't something you can really see in your daily life. Like, you don't measure forces. But you know, the momentum and things are things we can see. We can see a change in speed. So I think that one was definitely one where people were like, oh, okay. [0:06:59]

INTERVIEWER: Do you find activities like this valuable?

RESPONDENT: I think in the long run, yeah.

INTERVIEWER: In the long run.

RESPONDENT: They can be frustrating while you're running them. Because I know with a lot of them, the technology won't work or we'll find out we didn't set our thing up quite right for it to do what we want it to do, and we're scrambling to get our trials together, and keep up before the end of class comes, and we only have half an experiment. But going over them, afterwards, is helpful.

INTERVIEWER: Okay. And how do you go over them? You yourself or in class?

RESPONDENT: In class. Taking apart and seeing, because no group usually really does the same thing. So seeing, I think it wasn't this one. The one where we were going about finding the energy equation. I was actually really surprised at the different ways people thought about it. Like I would never have thought to do some of the processes they did. But it made sense to me.

INTERVIEWER: I see. Do you remember the specifics of it? [0:08:01]

RESPONDENT: I remember it was, we were proving that it was, what is it, one half MGH, that, no, just MGH.

INTERVIEWER: MGH, yeah.

RESPONDENT: And then we were also doing one half the kinetic energy. So the way people went about showing that it's a one half relationship, or it's a velocity squared relationship.

INTERVIEWER: I see.

RESPONDENT: So it's just kind of the different angles people took on, finding the components.

INTERVIEWER: So why do you think that's a good thing, to do it different ways?

RESPONDENT: You definitely see different thinking processes. Like you said, I would never have thought to do some of the things, like people did just even at analysis. And other people had really creative ways for coming up with the one half mass. And it makes you think about the problem in different ways. So it increases your understanding for sure.

INTERVIEWER: And did that line up with your, you said when you have math type problems that you're able to kind of logic, did the logic all match up?

RESPONDENT: Yeah.

INTERVIEWER: Okay. So curious, you mentioned math, and that the math comes a little easier for you. Do you think it played a role in activities like this?

RESPONDENT: I think activities like this are more, I think that's why I find them sometimes frustrating, is they're more conceptual based. And you usually go about proving the math, or proving that you can use the math. So they're more of a thought process than straight logic. [0:09:36]

INTERVIEWER: So do you see conceptual based things and math as being different?

RESPONDENT: Sort of. I know, like math plays a role in the conceptual, but kind of in my head, yeah, I deal with them separately.

INTERVIEWER: So what do you think, if you were to give me more words on what you think math is. If it's outside of the conceptual.

RESPONDENT: So I usually think of math as the process. So I really think of it in terms of equations, and I'm going to use this one, and plus into this one. And it's really like a straight process, or a concept I guess I would think of it more as a web. And the different connections to things. And that's not to say there's not connections with the math, but I think of it linearly, like I think of energy then to this then to that, whereas I think of more of like a…

INTERVIEWER: I see. So you're identifying the process of using those equations as math.

RESPONDENT: Yeah.

INTERVIEWER: Okay. Cool. Do you think biology and chemistry plays a role in these types of activities?

RESPONDENT: Yeah. (chuckles)

INTERVIEWER: You laughed.

RESPONDENT: Yeah, I laughed. Because so I'm in prokaryotic physiology.

INTERVIEWER: Okay.

RESPONDENT: I'm a microbio major.

INTERVIEWER: Yeah.

RESPONDENT: And we, the number of times physics comes up is a little…

INTERVIEWER: Really. [0:10:58]

RESPONDENT: Yeah. Because we were talking about the movement of flagella. And how some parts are using the torque and what does the work, and different things like that. I'm like, this is physics. And then we were talking about the strength of the cell wall and the different components, and what's resisting and the inside forces, and what's really providing the protection in terms of physics. So we never go into details, but the words are like, it's there. You know it's physics.

INTERVIEWER: And then you're seeing that connected here?

RESPONDENT: Yeah, I think when we talked about the diffusion lab, that we had talked about that previously, in that class, the diffusion across the cell membrane. And you know, viewing it as smaller elastic collisions.

INTERVIEWER: And how about in investigations like this?

RESPONDENT: Investigations like this tend to, like these seem more like pure physics to me. So I associate them less with the concepts. But then usually we take what we learn from these and apply it, and that's when things make more sense. [0:12:05]

INTERVIEWER: Okay. So I've got a very interesting question here. So I'm curious what you think. Do you think activities like this represent what it means to do physics?

RESPONDENT: In my mind, yes. But I guess like pure physics. What I imagine them doing, like when Newton was developing the concepts. I think especially like at MSU, I know it's more like applied physics. So I think, something like this lab, where it was taking a scenario, that's kind of how I think of work in physics, is modeling real world, where I think a lot of our other activities are modeling the core concepts.

INTERVIEWER: Okay. Tell me a little bit more. I think I need a little more clarification. [0:12:54]

RESPONDENT: Okay, so this one we were investigating a specific scenario. Like in the one where we were proving the equations, that's, I think of that as a core concept physics lab. And I don't, when I think of people doing work in physics, I think of them more as applying it.

INTERVIEWER: Okay. So you're saying that investigations like this one are more like physics to you, because they're modeling a real situation.

RESPONDENT: Yeah.

INTERVIEWER: Whereas other lab activities that are more developing the equation, that they feel less like physics.

RESPONDENT: In the real world, I guess.

INTERVIEWER: In the real world. Okay. So are you seeing physics as being one or the other, or both?

RESPONDENT: Both.

INTERVIEWER: Both. Okay. And what do you think physicists do, which one?

RESPONDENT: I think, in terms of, I know it's probably a lot like other fields where you have your academics who are doing kind of pure, or just deriving things. And then you have your applied. I see that a lot in microbiology. Like, finding out things just to know them, and then finding out things to apply to the world.

INTERVIEWER: Gotcha. So, I'm curious. Do you think activities like this, these investigations, have equipped you to answer questions outside of the physics classroom? [0:14:13]

RESPONDENT: I think the problems I encounter are a little more complex than what we've gotten to now. We're really still on the basic level. But, I know when, last week we were doing something with, oh, (inaudible at 0:14:37) on our paramecium. And I could see when we were working through, I could see how the pieces of that, because I had been thinking about doing an honors option of coding a model for flagellum movement, and I could see how the pieces of that aligned. Like what you would need to do to apply that to other microorganisms.

INTERVIEWER: And do you find that doing the kinematics of the flagella is something that's an interesting question for you?

RESPONDENT: Yeah. I don't think I have the tools for it yet, with the whole helical and dealing with that.

INTERVIEWER: I don't know anything about flagella, so tell me.

RESPONDENT: So, it's when –

INTERVIEWER: You can draw, yeah.

RESPONDENT: Yeah, I'll draw it. I'm not sure that's a marker for, so you have your microbacteria. The flagellum is going to be the tail thing. And it moves in a helical wave. It spins. So there's a motor embedded in the cell membrane. So they like, rings, and it uses ATP to cause conformational changes that spins it.

INTERVIEWER: Whoa.

RESPONDENT: It gets, and how they decide when they're spinning it which direction is a whole, it's crazy. [0:15:54]

INTERVIEWER: So is this what you're doing for your honors project?

RESPONDENT: No. Because we had to, we had another project planned. Found out the videos we had wouldn't work. So last minute we put together something else that we knew we could get done in time. So we're analyzing, my partner and I really like hockey. So we're analyzing hockey shots.

INTERVIEWER: Great.

RESPONDENT: But, I know, if there's one next semester, I might end up doing that.

INTERVIEWER: Okay. Do you think physics would help you solve that?

RESPONDENT: Oh yeah.

INTERVIEWER: Because you mentioned that the physics you're learning is basic, but that the problems that you encounter are complex.

RESPONDENT: Yeah.

INTERVIEWER: So you think the physics you have is sufficient?

RESPONDENT: I know the motion is a little bit different, and that probably has a specific subset of kinematics that deals with that. Which I'm sure if I were to look up material, I think I could understand it. I don't think it's necessarily something we're going to learn, especially this semester. But I don't think it would be beyond my realm of understanding. [0:16:57]

INTERVIEWER: Gotcha.

RESPONDENT: And I think the part where we dealt with the time steps (ph) and how to find those sort of things that are important for modeling something like this, that's definitely something we've learned.

INTERVIEWER: So the problems that you've mentioned, the analysis of the hockey and the flagella, I'm curious if you see other problems outside of kind of school. That you feel equipped to answer now.

RESPONDENT: Well, I know for our honors option beforehand, we wanted to analyze what made a gold medal in gymnastics like a gold medal. We were pretty interested in it. But none of the videos worked. Like the NBC or anyone like tape, they're not stationary, and whatever. But things like that, because it's all movement, so you figure physics should be able to explain why one is better than the other. Like if her hands are out here, how's that affecting her speed? Is she able to twist and things like that.

INTERVIEWER: I see. Interesting. And you decided the videos weren't? [0:18:02]

RESPONDENT: Yeah, the videos won't work.

INTERVIEWER: I’m actually interested, that would be a really interesting question. So, now I know you do some lightboarding.

RESPONDENT: Yes.

INTERVIEWER: So I’ve got here, I think these are called consensus boards? There’s three of them. Yeah, this is the order.

RESPONDENT: Okay, yeah.

INTERVIEWER: So first I just want to get your general thoughts on.

RESPONDENT: I think the whiteboarding as a concept is good. Because it’s a time when we all come together, we make sure we all understood what we’re doing. We see what other people are doing. It’s instructor based, so other people are chiming in but it’s directed along a path that the instructor kind of has set. So it helps you really make sure this is what I need to know, this is what I need to get out of this. Do I understand it. I think just because this is the first year and I know it’s been mentioned that the technology isn’t necessarily there, because it can be hard to see what she’s writing and she’s going back and forth. Especially because we’re doing the whiteboarding and then this, she can’t display both. Which, I don’t know how you fix that. But I think it would help. A lot of people. So. [0:19:19]

INTERVIEWER: So why do you think, so I’m going to, so you’ll see a pattern in my questions. I’m going to bring out activities and we’ll go through a series of questions.

RESPONDENT: Okay.

INTERVIEWER: So why do you think the instructor’s having you work on these activities, like this.

RESPONDENT: Like the whiteboarding?

INTERVIEWER: Yeah.

RESPONDENT: So I think it really makes sure that you understood what you were doing. If you have to actually write it down in words, like what did you do. What did you get from it. And then I think it enables you to share your thoughts with everybody else, instead of her just saying oh, you got it, good. You share with everybody else, they can see what you bought. They can make sense of it. And then she can use your work as a path to kind of highlight all the important things and the activity is showing. [0:20:06]

INTERVIEWER: So it seems from your description, you’re almost highlighting it as instructor led. But it seems like, on the surface, it seems like it’s student led.

RESPONDENT: Yeah, it definitely is. Like she has the knowledge to make sure that the discussion goes in the right direction, it doesn't get off track. But the actual track, the actual pieces are the students talking. So it's kind of, she nudges it along in the right.

INTERVIEWER: Do you think this is valuable?

RESPONDENT: Yeah, I think so. Because I think his is the time when you, well, I think this was happening, but I'm not even sure that's what is supposed to be happening. And then you come together and like all these other groups got the same thing. And this is why, and this is what we can get out of it. So I think it really cements that, what was happening in the activity. And, any deeper level conceptions, how it connects to other things. [0:21:05]

INTERVIEWER: I know some students expressed frustration at not knowing the right answer.

RESPONDENT: Yeah.

INTERVIEWER: I'm curious if those frustrations are continuing, or if they've subsided.

RESPONDENT: I think each time we approach a new topic, it builds up again. Right now we're dealing with more forces, which follow a similar pattern to what we've been doing. I think each time, when we first started forces, or when we first started energy, we're like what is happening? Because I think a lot of people, I know they didn't take physics in high school. And then I think because they are student led, the whiteboard sections, and like I said physics doesn't always line up with what you think you visually see, that may only explain one phenomenon. But really the broader pattern is something different. People will speak out based on their intuition of what's happening, and people will be like oh yeah, that makes sense. I see that. But that's not actually what's happening in the broader sense. So then they have to backtrack off of that understanding and go down another route. [0:22:14]

INTERVIEWER: Gotcha. And do you think that's done effectively?

RESPONDENT: I think, at the end of the day, I think most people know what's the right answer. But I think it can be very frustrating, because in their other classes the professor says this is so and they're like ah yes. And they're not used to having to consider multiple options and then choose what they, what's right.

INTERVIEWER: How do you see math playing a role in these whiteboarding activities?

RESPONDENT: I think this really pulls out how to generalize them, in terms of math. So I think math is used to generalize what we learned in most activities.

INTERVIEWER: Can you give me an example?

RESPONDENT: Like all of this. Here. Where you know, we're talking about –

INTERVIEWER: It's the sum of the forces.

RESPONDENT: Yeah, so this is the force is equal to the mass times acceleration. And I think that's what we were measuring, maybe.

INTERVIEWER: Oh, okay. [0:23:19]

RESPONDENT: And this one, yeah. That looks like that's what we were measuring. So some people show that the force was dependent on mass, and some people show it was dependent on acceleration. And I think, yeah. Because this is the one where we tied two together, so we also showed it was a vector. So direction mattered. And then this whole, if it's acceleration you can also write it like that.

INTERVIEWER: So this is where you see the ideas coming together.

RESPONDENT: This is kind of where I see the concepts turn into something that I can put on a linear list and approach a problem. [0:23:55]

INTERVIEWER: Okay. So do you see biology and chemistry coming out of these whiteboard meetings?

RESPONDENT: I think yeah, because we tend to do, well, maybe not in the actual whiteboard meetings. But when we write these equations, usually within the next session we'll go to some application, where these are what you're using to solve it. You're not really using the application to get the equations, you're using the…

INTERVIEWER: I see.

RESPONDENT: So I think it's important that the whiteboards come first, and cement everything, and then you can go on and use that.

INTERVIEWER: I see. So you're seeing the biology and chemistry more of the application once you've…

RESPONDENT: Yeah.

INTERVIEWER: Okay. So I've got a question. So the process of whiteboarding, and this kind of consensus building, do you think that's what it means to do physics?

RESPONDENT: I think it's important to do it after you think you've done the physics, to come back and make sure that it lines up with everything else. You know that you're really seeing what you expected to be seeing. Or if you're not seeing what you expected, why. What could explain that. And, in science you don't get to just declare something so because you saw it. So kind of a consensus and making sure it makes sense to everybody else. That they don't see any holes in your thought process. [0:25:24]

INTERVIEWER: So you said after you do the physics. What does that mean?

RESPONDENT: So kind of like how we run an application. You run an experiment and then you come back and look at your results, and try and pull out what you've done. I think it's important to do it beforehand. Like if you were to run one after this, go back and look and see, okay, this is what I'm basing it off of. This is what I expect to happen, based on what I've come to a consensus on. And making sure that, so, before and after.

INTERVIEWER: So you would see this kind of activity of putting your thoughts down on a whiteboard, talking with classmates, as something that's after doing physics.

RESPONDENT: Yes.

INTERVIEWER: Okay. All right, now I've got a question. So whiteboarding. You've done it many times. Do you think it has equipped you to answer questions outside the classroom? That skill?

RESPONDENT: Outside the classroom? Yeah, because kind of like I said. It gives you a general, usually we come to some general statement, that applies to more than just the scenario we were looking at. So if you come across a scenario, you're going to use these generalized statements to make sense of it. So anything you come across, we're going to be, you're not going to, it can be hard to relate back to an exact, like with the fusion. We related it back to the collision of the SUV and the car. But when you're thinking about the two, you're not going to, you're like oh yeah. That's like when two cars crash into each other. You're like oh yeah, that's when it's an elastic collision. And two things, their velocities are changing and their momentum is changing. So I think it's the concepts we took out, and we're able to come up with generalized statements for. Then you apply them. [0:27:19]

INTERVIEWER: Do you find yourself doing this kind of generalizing and pulling out the important stuff in other places?

RESPONDENT: Yeah. I think that's one of the reasons that physics, the class seems to be going well. Is that that kind of follows my logic process, is like I pull out what I need to know. I focus on generalized statements that I can make from it. And that's how I learn, I guess. So I figure out what I need to know, how it applies just in a general sense. I don't want to memorize specifics, if I can memorize an overarching thing that then can go into different…

INTERVIEWER: I see. I see. So in your conceptual versus math analogy, I think you've mentioned, conceptual is a web, and then math is more linear, like a process.

RESPONDENT: Like a process.

INTERVIEWER: So I'm curious where this fits in, on what end of the spectrum.

RESPONDENT: It's kind of like the bridge.

INTERVIEWER: A bridge, wow, that's such a good, yeah, a bridge.

RESPONDENT: Because it's really taking the concepts and giving me the parts I can use in my linear process.

INTERVIEWER: Okay. Great.

RESPONDENT: Look at that metaphor coming out.

INTERVIEWER: Do you, I'm just curious. Do you whiteboard in other classes like this?

RESPONDENT: Like, as a class? [0:28:44]

INTERVIEWER: Well, just what you do in physics class. Do you do a similar thing where you work in small groups and you whiteboard, and then you kind of build?

RESPONDENT: I know in my HPS classes, it was more based on discussion and then orally presenting what you came up with. Not really writing down. And also my classes are, you know, a hundred people. So not as a class. I do tend to whiteboard things on my own, as a study tool.

INTERVIEWER: Oh, really?

RESPONDENT: Yeah.

INTERVIEWER: Did you do it before the class?

RESPONDENT: Yeah, I used to do it in orgo a lot.

INTERVIEWER: Oh, okay.

RESPONDENT: To write down and yeah, that's a subset of this.

INTERVIEWER: So you were already doing all this.

RESPONDENT: Yeah. Yeah, I was kind of a fan of whiteboarding.

INTERVIEWER: Okay, fantastic. All right, the next thing I have. I've got two things, actually. These are some in-class worksheets. One is, so I've got this one.

RESPONDENT: Okay.

INTERVIEWER: And then I've got this one. Now these are two different types of things that you've done in class. First, I loved your thoughts on multiple, yeah. [0:30:01]

RESPONDENT: So this one I viewed more as a conceptual understanding. But I think you were able to take applications out of it. So, like mathematically. I like to think of them in terms of derivatives. I know a lot of people that, I've worked with, have been like what, no. No. That's miserable. But I think I like math, I like calculus. So I do my acceleration as a derivative as velocity, and it helped to see that you can do force as a derivative of velocity, as long as you know it's a relationship and not an actual quantity.

INTERVIEWER: What does that mean, it's a relationship, not a quantity.

RESPONDENT: So it's like, so if you were to draw your graph with no numbers, it would be correct. But if you were to put numbers on it, like this does not equal the exact derivative. Whereas acceleration, numbers and without numbers, it will be right. So then it's a patter. The pattern's correct and, no, the activity we did after this I think we saw that, where we had to pick graphs based on a relationship. And you could pick your acceleration and your force graph as the same. But there's no numbers. [0:31:17]

INTERVIEWER: Gotcha. Gotcha.

RESPONDENT: So I think this helped connect concepts. And then maybe how you would use it in other situations. I think a question like this was on the exam. Like, if the mass were to change, which of the graphs would change. And, you were able to, you had to just draw qualitatively the, you know, you could draw the same graph for acceleration or force, because you had the mass for numbers. But then if she asked you which one changes by mass, you had to know, your connections between the graphs to each other and then the graphs to the equations.

INTERVIEWER: Gotcha. Okay. How about the paramecium one?

RESPONDENT: I like the paramecium one. [0:31:59]

INTERVIEWER: You liked it.

RESPONDENT: Because I'm a microbiologist. So I was like, this makes so much sense. Because I think actually she, when you had to take the density of it, I thought of it in a way like, she actually had me tell it to the class. Like she hadn't thought of it that way. But I know as a microbiologist, the paramecium is going to take in its surroundings, like osmosis. And a cell is 99% water as it is. So I knew I could take the paramecium's density approximately as water. Which is not how, she saw it as like oh, it's floating in the water, so the densities have to be relative. But I would never have thought of it that way.

INTERVIEWER: That's really cool. Do you have more thoughts on that one?

RESPONDENT: Yeah, I liked this one. I think it connected kind of the logical steps of using the mathematical formula as just, without numbers. Which I like, manipulating them like that to see what you can do with them. And then we used it as an application, and it kind of, I'd been thinking about this problem, and I had no idea how to go about it. But I think it kind of showed, it's a similar idea of movement in a cell. So you need to do the, we found a time step (ph) and things like that. That's pertinent to other things. Like anything with microbiology, you're going to need to find a time step. [0:33:17]

INTERVIEWER: Gotcha. Is that a common thing? The time step, is that a thing that you guys talk about in microbio?

RESPONDENT: Yes, so, when I said that this, the process of it moving, and deciding which direction it's going to spin? So that decides if it moves forward or if it just tumbles because the wave is heading towards it. So, it does that, like couple thousand times a second. It evaluates its surroundings and decides which direction its flagella should be moving. So yeah. It's definitely like, they move on a different scale than us.

INTERVIEWER: I see. That's great. So you saw the connections right away.

RESPONDENT: Yeah. Definitely.

INTERVIEWER: Do you see differences in the two types of activities? [0:34:02]

RESPONDENT: I viewed this one as more of a bridge between the whiteboard and this. I see this as taking the concepts, but also thinking about how they relate to the math and just an actual scenario, where this is just, this is a scenario that you've learned.

INTERVIEWER: I see. So for each one, do you find it valuable?

RESPONDENT: Yeah. I think it's valuable in the order that we do it. That this is kind of a bridge between the concepts, and then this one can, especially for me, if it's biology-related, I really make sure I know what's going on. I know, so my friends are like the chemistry-orientative (ph at 0:34:46) ones. So.

INTERVIEWER: Okay. And so why do you think the order's important? Is it that they cover different things, or?

RESPONDENT: In my head, kind of how I do the concepts and then the math separate, it creates an actual flow between them. And a bridge to make sure I know that I'm doing it right. It's like an intermediate step to double check that the bridge is going to work. And they're not going to apply them wrong here. And it's just more practice with the concepts, I think. In a not experimental form. Practice with concepts and kind of logic-based problems.

INTERVIEWER: Okay. Hm. Do you think math plays a role in these? I know you described the derivatives –

RESPONDENT: Yeah, it does for me. But I know for a lot of people, they think of it more broad concept than I would. You know, I look at this and you know, the slope's there and it changes there, so it's got to do this, just based on what I know or the derivative's going to be. And a lot of people say okay, the velocity starts out here, and it hits zero so it has to be slowing down. Things like that. And how they know acceleration and velocity relate to each other, more conceptually maybe? Yeah, I was helping a friend do graphs like this, and I was like yeah, do you want to do derivatives? She's like no, why would I want to do that. I'm like oh, that's how I do it. So I'm not sure I can help. [0:36:18]

INTERVIEWER: Gotcha. And how about that one? Is there math in that one?

RESPONDENT: Definitely. So, it's more like, I think I guess conceptual math. Like a bridge where you're not putting numbers in. But I still view it as a logical process, and seeing what you can do with the equations, how you can manipulate them to give you what you want when you actually put numbers in. Which is part of the process I like, if that makes sense.

INTERVIEWER: I think it does.

RESPONDENT: Like seeing the relationships between all the variables was kind of a key point in this, and how you could manipulate the equations to, if she had just given us this question down here, we would have all been like, we don't have the tools for that. We don't know how do to that. But I think this process was really showing us, you can with some guidance manipulate the equations, see what's going on, and all of a sudden you have a new tool. Or really it's just your old tool in a new form. [0:37:17]

INTERVIEWER: Gotcha. And when you said conceptual math, you mean, it's the same kind of linear process but with variables instead of specific numbers?

RESPONDENT: Yeah, yeah.

INTERVIEWER: Okay.

RESPONDENT: And not really applying it to a specific scenario. But it's still a math problem I had.

INTERVIEWER: And so it's clear that you see the microbio in that paramecium one. But in general, when you do in-class kind of worksheets, do you see biology and chemistry playing a role?

RESPONDENT: I can see how, if I were to find a biology problem, how I might use those. But when I'm actually doing them, not really. Because it's hard. We do a lot of like, it's a box. This is what happens to the box. But I think the idea, kind of like going back, when we were doing the SUV and car, I wasn't thinking about biology at all. Or any of the labs where we used the (inaudible at 0:38:13) lab. But the concepts then, like we use them in biology and I can use them and go back and be like that's what happened in that scenario. And I know that's what happens and I know it's going to happen here. Even though they seem totally different.

INTERVIEWER: So I've got a question. So you mentioned that we work with boxes, ramps or whatever. So, but curious. So when you see a problem like this, does it strike you as a microbio problem or a physics problem?

RESPONDENT: It strikes me as both.

INTERVIEWER: Both.

RESPONDENT: Especially, I think in the reading we had one about the physics of swimming animals, like the aerodynamics versus e coli that are in water have different forces acting on them and that explains the shape. And I've always kind of been interested in the merging of fields. Like, that's been interesting to me, to see how physics can explain a biological concept. They're like, we can explain in biology, be like yes, this fish, it's going to be different than this. But really the driving, like if you were to look evolutionarily, why it has to be that way. I think physics gives the best explanation. [0:39:20]

INTERVIEWER: Why do you think physics gives the best explanation?

RESPONDENT: Because it's how different things in the world interact. So that's really going to drive everything. How the fish has to interact with the water is going to drive its shape. There are certain things that are going to work, and certain things that aren't, based on the laws of physics.

INTERVIEWER: Is there specific things that has that makes it able to answer?

RESPONDENT: I think definitely the generalizability to take it to such a high level. And then be able to just trickle down to any really scenario you need. Because it's looking at the core interactions of the world, and really getting it down to what's affecting what. At a level that none of the other sciences really can.

INTERVIEWER: Interesting. So you said take it to a high level. What do you mean?

RESPONDENT: So, force equals mass times acceleration. That explains so much about the world. That explains to you things falling due to gravity, you know. It explains kinematic movement. So. [0:40:32]

INTERVIEWER: Interesting. So you think physics is unique in its ability to explain that kind of why?

RESPONDENT: I think we had a reading where it was like you can take physics down to the simplest level, and that works. Where in microbiology, if you think of the simplest level as a cell, you're still, all of a sudden it becomes very complex. Like you can't really get to that simplest level.

INTERVIEWER: How about chemistry?

RESPONDENT: I don't know as much about chemistry. (laughter). I mean, I think you can get it down, you know if you look at biology, you're like, well, this simplest level is way too complex. Well, your next move is to go to chemistry. You can explain what's going on in the cell with chemistry. But you can't really explain what's going on between the chemicals. Like, that's an interaction that physics gets to explain.

INTERVIEWER: Ah, gotcha.

RESPONDENT: So it's kind of like, how simple do you need to go? You're going to switch the sciences.

INTERVIEWER: So you're saying like, kind of the size of the smallest unit that you're studying.

RESPONDENT: Mm-hmm. And they don't have to be that way. Like, you can have really big chemistry concepts that are macroscopic. But if you're trying to get to the simplest level.

INTERVIEWER: So in microbio, when you have flagella like that, would physics help you answer that?

RESPONDENT: Oh, for sure.

INTERVIEWER: Yeah?

RESPONDENT: Just the movement, yeah. So you have the chemistry interactions that get you the movement, that happen inside the cell. And then physics can kind of explain the chemistry interactions. You have enzymes binding the things, and it's all great. I have to memorize them. And then, the actual movement of the flagella is driven by a conformational change, and a change in energy, and how that works. Chemistry uses energy, but it can't really explain energy the way you would need to show how that energy goes to movement for the cell.

INTERVIEWER: I see. What, I'm curious where this thought originated. How did you start realizing that physics kind of has that power to explain why, those interactions? [0:42:45]

RESPONDENT: I've always kind of thought of physics as more of a conceptual, like, being able to explain things. Because it takes it to such a simple and mathematical, you can model with it. But not really until taking this class and getting the tools, like, sure, you can see something and be like oh, yeah, physics probably explains that. But I don't know physics, so why would I think about it that way. I don't have that tool. But I think taking this course, the microbiotic course alongside physics, where things like work and torque and force are coming up, and I feel that I know about. That helps you see.

INTERVIEWER: That's awesome. So prokaryotic physiology, that's where the fun's at.

RESPONDENT: Oh, not really. [0:43:37]

INTERVIEWER: So these types of problems, do you think that's what it means to do physics?

RESPONDENT: I think so. The physics I'd be interested in doing is something like this. Like the merging of, too late in my career, my parents would kill me if I switched my major. But, I think if I were to look at physics, I think I'm interested in how it relates to the macroscopic biological world. I know other people do other things, but this is the physics I like.

INTERVIEWER: And how about that?

RESPONDENT: I mean, these are relationships we already know. But I know, especially when you look at thinking outside of our world. We know a lot about the physical interactions on our world. But I think physics, oh my God, physitists (ph). Oh my God. I can speak today. Are doing work like this on a more conceptual level for things outside of our world, trying to model how forces are working in the universe. And we don't necessarily know their relationships. Somebody has to find those. So that's, it can be applied then to modeling the galaxies and things, but someone has to go and actually figure out how we're going to model it. [0:44:53]

INTERVIEWER: I see. And you see that as helping.

RESPONDENT: Yeah, yeah, I see looking at the relationships and trying to see how one equals the other and stuff like that.

INTERVIEWER: So, the physicists that answer the kinds of questions that you're interested in, do you think that's a, hm. Do you see yourself ever wanting to do that?

RESPONDENT: I mean, so I get interested in a lot of things. And when I did the reading on swimming animals and shape, like yeah, that's something I'm interested in. And someone was like, you have to do physics. I was like well, if I'm going to do that.

INTERVIEWER: So do you think in your future as a microbiologist you'll be in physics?

RESPONDENT: I definitely could, depending on what level I'm looking at, of interaction. [0:45:50]

INTERVIEWER: Okay, cool. And, I think you might have touched on this already. Kind of these activities, these in-class activities, have they helped you answer questions outside of the classroom?

RESPONDENT: Yeah, I think definitely, like this one, yeah.

INTERVIEWER: So now when you see a problem like that, are you thinking of things that you could apply from physics?

RESPONDENT: Mm-hmm.

INTERVIEWER: Okay. All right, I've got another activity. So many activities. This is the modeling 1-D collisions.

RESPONDENT: Yeah, okay.

INTERVIEWER: So first I'd love your thoughts on it.

RESPONDENT: Okay. I remember this part being extremely confusing.

INTERVIEWER: Extremely confusing.

RESPONDENT: Yeah.

INTERVIEWER: How come?

RESPONDENT: I don't think, like it was clear that the steps in the instructions were trying to lead us to a place, but I don't think like me or anyone really in our group really knew that place we were trying to get to right away, or were like, why are we doing this? If you don't really know your end goal, you don't know if your intermediate steps are really going to get you there. So you don't know if what you're doing is really correct. So I think it was very confusing to model. It was something that we knew, you know, a change in momentum and things like that. But I think when we saw it like this, I got kind of frustrated. And I didn't realize it was really something, it seemed completely foreign. At the end of the day, when we got to the code and modeling it, it made sense, and that was just like it's just an elastic conclusion, and we're just trying to figure out how its velocity changed. Like when you see why you're doing it, you can kind of come up with it. But at first it was very confusing. [0:47:31]

INTERVIEWER: So when did it stop being frustrating?

RESPONDENT: When we got say bounce balls into each other and we were so proud of our code, and it worked, and we used –

INTERVIEWER: Was that exciting?

RESPONDENT: Yeah, yeah, I think it was fun.

INTERVIEWER: Had you done any coding before that? Really? Okay.

RESPONDENT: I mean, I think we did one coding activity before this. But like, I do not know what I'm doing when it comes to coding.

INTERVIEWER: But you feel that you could do this?

RESPONDENT: In terms of conceptually? I could probably figure out what I needed. I mean, Python has its own language. And that part is separate, but if someone were to be there, I'd be like this is, you're going to do this, you just type it in the way Python needs it to be in, I think it would do it.

INTERVIEWER: Do you find activities like this valuable?

RESPONDENT: I think so. Because I think it was, I think it, like I'll use this as an example, between the bridge, between the car and the SUV colliding. And being able to generalize something from that. Where here's something where we took that generalizing out and applied it over here. Like you would never think of this, the water hitting, I can't remember what we did. HCl or something. Necessarily as a collision, or like relating that to the car crash. But really it's the same concepts at play. [0:48:52]

INTERVIEWER: So how do you think mathematics has played a role in activities like this?

RESPONDENT: I think it's what lets us generalize. So we can take the relationships we found in one activity, come up with an overarching variable form of that. Take out the numbers. What do those numbers mean? Well, that one's mass, that one's velocity. Make sure that our relationship is modeled based off what we saw. And then we can take that model and apply it somewhere else.

INTERVIEWER: Can you identify where you put the math here? Like, what parts would you say is (crosstalk at 0:49:34) –

RESPONDENT: So –

INTERVIEWER: Math-like?

RESPONDENT: We had to, there as some serious algebra happening. I had to strain my brain. So we drew a system schema, which is more conceptual. Then we had to look at what we said was happening in our system schema. So that's when the math started to come in. I think it was like a, how the velocity would be changing after the collision. And that's where we used the math. And then we had to make it into one formula which was just algebra. And then, it was in a form that was really usable to us.

INTERVIEWER: Gotcha. So it's the equation manipulation. [0:50:16]

RESPONDENT: Mm-hmm, yeah. Because we never really had numbers. We inserted, it was just manipulation.

INTERVIEWER: I'm curious, now that you've talked about physics explaining the interactions on smaller levels, where you see the biochemistry (inaudible at 0:50:34) this?

RESPONDENT: I mean, this is going to be a chemical reaction. Does it react or does it not? And then on a biological scale, you're looking at things like osmosis and diffusion through a membrane, different concentrations, all that's playing a role.

INTERVIEWER: So you're seeing like, those are the connections that you see from this activity?

RESPONDENT: Directly from this activity, yeah. Because we were modeling.

INTERVIEWER: What does it mean to model something complicated like that?

RESPONDENT: I think it means to use physics to show how you could, how it happens in the world, and then how you could model it so that you can manipulate it, and see how it might affect something else.

INTERVIEWER: Okay, so being able to manipulate these things.

RESPONDENT: Yeah.

INTERVIEWER: Okay.

RESPONDENT: It's hard to manipulate things in the real world. If you can set up something that represents it, then you get to play with it.

INTERVIEWER: Okay. Do you think activities like this, like the coding, the 1-D dimensional, do you think activities like this represent what it means to do physics? [0:51:39]

RESPONDENT: Hm. Yeah, I know, like especially like this part where you're trying to figure out how you would represent it. We're using physics equations. And they're really figuring out how to use our physics concepts. Does every physicist code? Probably not. But it's definitely an easy bridge between finding out all of this. Well, it's great. What are you going to do with that? Plug it in by hand every time? So I think the coding is a good instrument to use, the physics. So you can really get the full value of what you've done.

INTERVIEWER: That's very interesting. Coding is an instrument.

RESPONDENT: Yes. (inaudible) other people that code.

INTERVIEWER: Say that again?

RESPONDENT: Don't tell the people that code.

INTERVIEWER: No, no one's going to. No. So, you're seeing the physics in this activity being kind of the equation manipulation, so would you consider part two as physics? [0:52:52]

RESPONDENT: I think yeah. It's showing how the physics works. Because the physics, like this part is kind of modeling interactions. And then part two is showing you the interactions in real time. So it's like seeing the physics in the moment. Observing what you've represented, the numbers.

INTERVIEWER: Do you think activities like this have helped you answer any kinds of questions outside of the classroom? Or (inaudible, crosstalk at 0:53:25)

RESPONDENT: Yeah, I think this one was more a generalizing one. And then it also had the visualizing components. You could really see what was going on, more than having to try and conceptualize it yourself. It was right there on the screen, which I think was helpful to really see what you did mathematically, what it equates to in the real world. Like the movement of the different things. So yeah, I thought it was useful.

INTERVIEWER: And I've got one more. This was the last part of the diffusion. So this is where, I think it was called 3-D diffusion.

RESPONDENT: Yeah, and that was where we had the box, I think.

INTERVIEWER: Yeah, this was the second box.

RESPONDENT: With the lots of molecules and they were moving all over the place.

INTERVIEWER: So do you have thoughts on that?

RESPONDENT: I mean, I think yeah, so that one, people actually used their, just kind of outside knowledge to really apply the physics and make sure it made sense to them, and gave them a connection to something they already knew, to double check. Because I think we talked a lot about like, well, how do you know the protein is so massive. Well, you know, I have knowledge that proteins have molecular weights that are this high. And that that's going to affect how it interacts with water. I think that was useful for me and other people in the class. So I liked that part of it. (inaudible at 0:54:57) with this. Yeah.

INTERVIEWER: So, I've asked you this question before, but I'm curious what you'd think about it now. When I mentioned diffusion, what comes to mind?

RESPONDENT: So, now what comes to mind is elastic collisions, really. And whether or not they're more likely to occur. Because that's really what we were modeling, and that's what we used to model diffusion, was the individual interactions, molecules colliding. And we used the elastic collisions, equations that we really got from our SUV car lab and some of the subsequent ones. So.

INTERVIEWER: What did you mean by more likely to occur?

RESPONDENT: So there's more molecules. They're more likely to occur. There's less space.

INTERVIEWER: I see. So, could I ask for a definition of diffusion? [0:55:57]

RESPONDENT: Diffusion is I think maybe the likelihood of an elastic collision occurring, going from more likely to less likely.

INTERVIEWER: Okay. The likelihood of elastic collisions happening from more likely to less likely.

RESPONDENT: So if they're more likely to happen, you're going to diffuse down to where they're less likely. So high concentration to low concentration.

INTERVIEWER: High concentration to low concentration, okay. Could you describe the process of diffusion?

RESPONDENT: So, it's individual collisions happening on a large scale, generally. You have diffusion, you usually have thousands of molecules interacting. And as they interact, they're going to spread out until they hit another one. So if one doesn't hit another one, they start to spread out further and you start to get this spread. In a lower concentration, they're spread out over more space and are less likely to collide. [0:57:04]

INTERVIEWER: And how do you think the idea of diffusion connects to molecules or situations?

RESPONDENT: Like for me, I don't know how the macrobiologists do this. But for me as a microbiologist, it's really easy to see what things like, we talk about how the cell has different transport systems, depending on how likely the concentration is to be high. So diffusion, things that have a high concentration, they're just, passive diffusion through the membrane. Because it's such a high concentration, they're likely to spread that way and be able to go inside the cell where it's less concentrated. That's a natural flow. Things that are low concentration outside the cell, the cell needs to come up with a new strategy to really take up those nutrients.

INTERVIEWER: A new strategy. Tell me more. [0:58:01]

RESPONDENT: There's, we talked about facilitative diffusion, different things. So, they'll come up with high affinity binding proteins.

INTERVIEWER: Whoa. [Now there's] (ph at 0:58:12) lingo. I like it.

RESPONDENT: Yeah.

INTERVIEWER: All right.

RESPONDENT: Things that will go out and really increase the likelihood for it to come in.

INTERVIEWER: And you're seeing that all related to this?

RESPONDENT: I think we had those lectures the same week.

INTERVIEWER: Yeah. Oh, about the procreative –

RESPONDENT: Yeah, the two, and the –

INTERVIEWER: That's awesome. You've told me that you think you're doing pretty well in class. And the evidence that you've told me is the exams and the lab reports?

RESPONDENT: Mm-hmm.

INTERVIEWER: Are they the big markers?

RESPONDENT: I think just how everyone thinks. The exams are like everything. In this class they don't, they're only 10%. So it's really not, but I mean, that's kind of how you, so even if they're not a big mark of the grade, they're really a mark of your understanding, I think, of how you can put everything together. [0:59:03]

INTERVIEWER: And who do you talk to about this course?

RESPONDENT: I mean, my roommate's in this course. My next-door neighbors. And my friend is in the course. Before the exam, I'll talk to the different people in the class.

INTERVIEWER: Are there any other things you think I should know about you, the course, that you want to share?

RESPONDENT: No. I know people are frustrated with the class. I think it's just a different way of learning.

INTERVIEWER: So what do you think would help?

RESPONDENT: I think, so, (inaudible at 0:59:36) has added the part where she talks about toolkit and what we have. And actually, that's something I put in my survey that we did. I was like, me and others, are used to a lecture where you come, and I think it would be useful if after class or on Fridays we came back and went over what we learned and how it connected to other things, so we can really, I think a lot of people feel that they haven't learned anything. Like, I did that activity, I don't know what was going on. I don't understand it. And I think if you come back and show this is what we got out of that, and here's how it connects to other things, it would increase people's confidence. Especially for the exam, where they're expected to do that. I think for some people the bridge isn't natural, that maybe an intermediate step is needed.

INTERVIEWER: I see. And so you mentioned toolkit. Can you explain what you mean by that? [1:00:26]

RESPONDENT: So, we did one today where she just went over what we've learned, the different representations we have and how it connects to everything else.

INTERVIEWER: Oh, I see. Okay.

RESPONDENT: So if you were to go to a problem and had no idea how to approach it, here's everything you know what fits with this problem.

INTERVIEWER: I see. And you think that's helping with the frustration?

RESPONDENT: I think for me, yeah. For others probably a little bit, hopefully. But.

INTERVIEWER: Is this a new way of learning for you?

RESPONDENT: Like I said, I think it's similar to high school, but at a much higher level, and it's three years later. So.

INTERVIEWER: Cool. Well (inaudible at 1:01:11), thank you again for such a lovely chat. I always liked chatting with you, (inaudible) the microbio down. I'm curious if you're ever going to make a model of that. I'd love to see a Python script that does that. That would be so cool, right? But awesome. That's all I have for you. Yeah. Do you mind if I kind of contact you again, maybe at the end of the course or maybe even after the semester?

RESPONDENT: Yeah.

INTERVIEWER: And we'll try it again?

RESPONDENT: Sounds good.

INTERVIEWER: Thanks.

RESPONDENT: No problem.

INTERVIEWER: Was it hard to find this –

RESPONDENT: No, I lived in homes for two years.

INTERVIEWER: So that was a piece of cake for you.

RESPONDENT: I'm like West Side, somewhere on the basement. I knew how to, it was (inaudible). So.

INTERVIEWER: All right, have a good day.

RESPONDENT: You too.

**END TRANSCRIPT**

# APPENDIX N

## TRANSCRIPT: MARIA INTERVIEW 3

# TRANSCRIPT OF AUDIO FILE:

# MARIA-INTERVIEW3-03-30-17

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*The text below represents a professional transcriptionist's understanding of the words spoken. No guarantee of complete accuracy is expressed or implied, particularly regarding spellings of names and other unfamiliar or hard-to-hear words and phrases. (ph) or (sp?) indicate phonetics or best guesses. To verify important quotes, we recommend listening to the corresponding audio. Timestamps throughout the transcript facilitate locating the desired quote, using software such as Windows Media player.*

**BEGIN TRANSCRIPT:**

RESPONDENT: – today than I did a couple days ago. So.

INTERVIEWER: It's getting there.

RESPONDENT: Should be fine.

INTERVIEWER: It will be fine. Yeah. Not too worried.

RESPONDENT: No. Yeah.

INTERVIEWER: Yeah. What other classes are you taking?

RESPONDENT: Let's see. This semester, I have virology, biochemistry, physics, and a fourth one. HPS.

INTERVIEWER: Okay. How much more time do you have at MSU?

RESPONDENT: One more year.

INTERVIEWER: One more year. Okay, so you're a junior.

RESPONDENT: Yeah.

INTERVIEWER: Okay. Cool. So, we haven't talked since, what? October?

RESPONDENT: Something like that.

INTERVIEWER: It's been a long time.

RESPONDENT: Yep.

INTERVIEWER: So, the purpose of this interview is to just touch base on that last bit of the first semester course –

RESPONDENT: Mm ‘kay.

INTERVIEWER: – now that you are done with it.

RESPONDENT: It’s been a while.

INTERVIEWER: Yeah. It’s been a while.

RESPONDENT: (Chuckling) Something about that.

INTERVIEWER: So my first question is, “If you were to describe the first semester physics course, LB273, to another student, what would you say?” [00:00:58]

RESPONDENT: I’d say it’s very integrated with other fields. I think a lot of times, physics is like pure physics, like, what a physicist wants to know. But I think the first semester was very much trying to make it relevant to other people. So it was a lot of group work and working together and relating it to other, like chemistry and biology.

INTERVIEWER: Mm-hmm. Some of the content that you guys covered in that last little bit – I have a list here just to jog your memory. Chemical energy, bound states, Lennard-Jones potential, thermodynamics, and Gibbs free energy. So I’m curious – what were some parts of LB272 that you enjoyed?

RESPONDENT: I definitely liked the relation to other topics, especially with the end stuff like that. Especially related. [00:02:00]

I liked the labs, mostly. Because they let you actually see what was going on, rather than being told what was going on. Yeah. And then –

INTERVIEWER: Why did you like that?

RESPONDENT: I mean, for me, physics isn’t necessarily intuitive. It’s not something a lot of people have actually had in high school and things. I don’t think it’s necessarily required as much as the other ones. So, being told something – like, the whole “equal and opposite forces” isn’t something most people would actually just believe if you told them. So actually showing it and being able to prove it to yourself is pretty useful.

INTERVIEWER: Were there any topics that you particularly enjoyed?

RESPONDENT: I liked kinematics, because it made sense.

INTERVIEWER: Kinematics. Yeah.

RESPONDENT: Then I thought the thermodynamics was useful, because that comes up a lot in my other classes.

INTERVIEWER: Okay.

RESPONDENT: Yeah. [00:03:00]

INTERVIEWER: How do they show up?

RESPONDENT: It was on my first biochemistry exam. It was like, you have to calculate delta G, and just knowing the background of that. The physics of it helps explain – it comes up almost every time we do a reaction. Like, "This is favorable, because you're releasing CO2, so you increase the entropy."

INTERVIEWER: Oh, wow.

RESPONDENT: So –

INTERVIEWER: Awesome.

RESPONDENT: Yeah.

INTERVIEWER: Were there any kinds of class activities that you particularly enjoyed?

RESPONDENT: I think I liked the worksheets –

INTERVIEWER: Okay.

RESPONDENT: – because they let you see if you could apply what you learned. You usually liked working in groups and stuff, so it wasn't like you were out on your own.

INTERVIEWER: Mm-hmm. What were some parts that you did not enjoy?

RESPONDENT: I felt it was like a very intensive course. It was three times a week, two hours a day, and you were always doing something. Because there were no lectures, so you were also doing a lab or doing a worksheet. It was a little more intense than I was prepared for. [00:04:00]

INTERVIEWER: Yeah.

RESPONDENT: But.

INTERVIEWER: The intensity – so was it just something that you just didn't want to have to be on?

RESPONDENT: Yeah. I guess it was more personal effort than other classes. Like the Briggs chemistry. Really, just sit there most of the time, and then occasionally, clicker question comes along. So, it's like you teaching yourself with guidance, more. So.

INTERVIEWER: Why did you enroll in the 273 course?

RESPONDENT: Yeah. So I actually had a friend who decided to take the other physics class because she didn't want to take the new Briggs one.

INTERVIEWER: The university one?

RESPONDENT: Yeah.

INTERVIEWER: Yeah.

RESPONDENT: She didn't do as well. I – basically, I was looking at them, and not knowing – I knew there was going to be like a "guinea pig" session. It was going to be new. But in Briggs, I know where my advisors are, I know where my professors are. I know everything's going to be in home's (ph) hall. So I knew if I needed resources, it'd be easier to get to them. [00:05:00]

INTERVIEWER: Did you end up using the resources?

RESPONDENT: I didn't think I ever came to Vashti's Office Hours or anything. But it was nice. I guess the other part of it was knowing that I would know most of the people in the class, and that helped. A lot of my friends ended up being in that class, so I could talk to other people pretty easily.

INTERVIEWER: Why that particular semester?

RESPONDENT: Because I had to. (Chuckling)

INTERVIEWER: (Chuckling)

RESPONDENT: Because I was taking organic chemistry last year, and I didn't want to take orgo and physics together.

INTERVIEWER: Oh, okay.

RESPONDENT: Because they're both year-long courses –

INTERVIEWER: Gotcha.

RESPONDENT: – and, yeah, a little more time consuming.

INTERVIEWER: Gotcha.

RESPONDENT: So I didn't have that this year. So.

INTERVIEWER: Okay. You said it was required. Why do you think it's required?

RESPONDENT: Physics?

INTERVIEWER: Yeah.

RESPONDENT: Oh, we talk about this in my HPS class all the time.

INTERVIEWER: Oh, really?

RESPONDENT: Yeah. Physics is based on math, but based – all – almost all sciences are based on physics.

INTERVIEWER: Mm. [00:06:00]

RESPONDENT: The root of chemistry goes back to physics, and then the root of biology goes back to chemistry. It just keeps like – if you were to fall down the hierarchy of it, it would always end in physics.

INTERVIEWER: Really? Okay.

RESPONDENT: I feel like.

INTERVIEWER: Which HPS class did you discuss this in?

RESPONDENT: History of science.

INTERVIEWER: Okay.

RESPONDENT: 333.

INTERVIEWER: 333. Okay. You guys talked about –

RESPONDENT: We talked about it a lot. We'll look up – because we talk disciplines and fields. If you look at almost any scientific requirements for a major, it always includes physics. Geology has to take physics, but they don't have to take any other – like, chemistry or bio.

INTERVIEWER: Gotcha.

RESPONDENT: So we talked about that stuff.

INTERVIEWER: And you think the reason is because if you distill it down at the end –

RESPONDENT: Mm-hmm.

INTERVIEWER: – at the bottom, it's always physics?

RESPONDENT: And it's been around for a long time. Because the other fields had to branch off of it. So.

INTERVIEWER: Mm. 'Kay. What do you think the role of physics is in your life right now?

RESPONDENT: My life right now, it's like an explanatory model for the other sciences that I'm more interested in that I actually want a career in. [00:07:01]

So it helps explain why things are happening the way they are.

INTERVIEWER: Why do you think physics can do that?

RESPONDENT: Because I think it – the goal of physics is to explain the phenomenon around, that make up the world. Like, explain the energy and the atoms. Everything goes from there.

INTERVIEWER: Hm. Is this different from what you believed now the role of physics is in your life? Is it different from when you were first starting 273?

RESPONDENT: Probably, yeah. It's easier to see. Now that you're done, you're like, "Okay. So that explains everything I've learned before."

INTERVIEWER: Hm.

RESPONDENT: Where, beforehand, I didn't know what I was going to learn. So.

INTERVIEWER: Yeah. Do you have a specific example of something that you've looked back and you're like, "Oh, yeah"?

RESPONDENT: I mean, a lot of the thermodynamics. I remember that was a unit in chemistry, and I just blew it off. Then I came back in physics, and I was like, "Oh, crap."

INTERVIEWER: Oh, yeah. [00:07:59]

RESPONDENT: And then it showed up in biochemistry and my other classes. It – it's an explanatory reason for the reactions that are happening.

INTERVIEWER: What do you see yourself doing in the future?

RESPONDENT: I want to go to grad school for epidemiology.

INTERVIEWER: Nice. I think we talked about your interest in epidemiology before. How do you see yourself using physics in that future path?

RESPONDENT: Well. As I'm looking at the classes for epidemiology, I'm seeing that I – some of the programs, I can't even apply to because they require linear algebra and Calc III.

INTERVIEWER: Oh, okay.

RESPONDENT: Becau – and I was talking to a physics major in my HPS class, and it's because those are used for the modeling of disease and epidemiology. So, I probably won't personally do that, because I didn't take those classes. But it's used, still, to model an epidemiology.

INTERVIEWER: I see.

RESPONDENT: So.

INTERVIEWER: I see. So you think that the – so you mentioned Calc and linear algebra. [00:08:59]

And so you're seeing the connection to physics as well?

RESPONDENT: Yeah. So, I know a guy in a class who is a physics major, working with an epidemiologist. He's doing all the math for the model for the guy who wants to release mosquitoes to help get rid of malaria.

INTERVIEWER: Whoa.

RESPONDENT: So, the physics guy doesn't really know anything about the actual topic of research. But he's able to use his skills to complete the job.

INTERVIEWER: Mm 'kay. When you were looking at epidemiology courses, were there graduate courses?

RESPONDENT: Mm-hmm.

INTERVIEWER: And do they require – so, they require –

RESPONDENT: Some programs require it.

INTERVIEWER: Okay. So you – so you're saying that you're not going to necessarily take those classes.

RESPONDENT: Yeah. But I know that in the future, it's going to come up. Then I may be working with people that have more of a physics background than –

INTERVIEWER: Gotcha.

RESPONDENT: – I do.

INTERVIEWER: Got you. So what do you think is important to get out of the course that's outside your discipline?

RESPONDENT: Skills. Like a tool set. [00:10:00]

Because I guess it's not going to give you necessarily the strict knowledge you're going to need, but it's going to be the things that make sense and help contribute to the pathway.

INTERVIEWER: Hm.

RESPONDENT: So, kind of like where you can just memorize facts and know what happens, or you can know why it happens. I guess that's how I see physics. Any course outside of your discipline should probably help give you a tool set to address other problems.

INTERVIEWER: Hm.

RESPONDENT: And kind of like –

INTERVIEWER: And so you – yeah. Can you give me an example of a tool set?

RESPONDENT: A lot of the – I think the thinking processes you go through in physics, especially with designing the labs. Because you have to design the labs. You don't – you kind of know the phenomenon you're trying to get at, but the whole point is that you don't know exactly what's going on. And just like, that process is very embedded in the scientific method. The – what I always like to do in physics is, "What do I know, and what is the problem asking, and how do I get from point A to point B?" [00:11:02]

So that's, I think, a good skill when you're trying to figure out a problem.

INTERVIEWER: Got you. So what was important for you to take away from the physics class, specifically?

RESPONDENT: I guess just the relationships to other fields. To biology, mostly.

INTERVIEWER: Okay. Do you find yourself using those connections?

RESPONDENT: Yeah.

INTERVIEWER: Yeah?

RESPONDENT: Yeah, in the – in some of my other classes, I'll be like, "Oh. That makes sense because the law of thermodynamics," or, I saw it somewhere. Like, the torque of the movement of bacteria and stuff. It all – you can just memorize it, or you can know why it happens. So I see those connections in my other courses.

INTERVIEWER: Do you feel like the physics has helped you make those connections a little more?

RESPONDENT: Yeah. [00:12:00]

I think a lot of people will just feel like, "I have to memorize this." I was like, "Well, I don't have to memorize it because it just make senses. I can go through the process and be like, 'Of course that happens, because physics.' "

INTERVIEWER: Because physics.

RESPONDENT: Because physics. So.

INTERVIEWER: How do you see physics being important to you in the real world?

RESPONDENT: I like to know what's going on around me and why. That's why I want to be a scientist. So I think help – physics helps explain that in certain circumstances where I wouldn't necessarily have known before why something was happening.

INTERVIEWER: When did you first start being curious about why things happen?

RESPONDENT: I've always wanted a science career. It's changed. When I was little, it was, "I want to be an astronomer, an astronaut," and different things. But I've always – I don't know. I've always just been curious. I wanted something that would let me keep learning. I just like to learn.

INTERVIEWER: Interesting. How do you see yourself using physics in the real world? [00:12:59]

Now, you've mentioned in the epidemiology career path that some people may be able to use physics. So how do you see yourself using physics in the world?

RESPONDENT: I don't know if I'll be like, "Oh. This is physics." But it's just things we've learned about momentum crashing. The collisions and – I think maybe it's more subconscious. I'm going to be like, "Oh, I can do this because of physics." So I can't really think of a certain scenario.

INTERVIEWER: Hm. You mentioned that it was important to take away this tool kit.

RESPONDENT: Yeah. So that, as well.

INTERVIEWER: Do you see yourself using that?

RESPONDENT: Yeah, I think. Especially in a career like science-related. Like, a scenario.

INTERVIEWER: Mm-hmm.

RESPONDENT: Being able to boil it down to what do I have, what's – what can I use to get to what I need. And like the labs that we designed. [00:14:03]

Like, trying to figure out how I'm trying to get from point A to B.

INTERVIEWER: Okay. You mentioned some connections already. Are you seeing some connections between physics and your other classes?

RESPONDENT: Yeah.

INTERVIEWER: Yep?

RESPONDENT: (Chuckling) When – what was it? This was more related to this semester, but I'm sure it happened last semester. We – my history of science class, we've talked about a certain field. Optics, I think. We talked about the history of optics. We walked through it. The professor explained the core experiments. Then, the very next day, I opened up my physics readings for the week, and it was just repeating everything my HPS professor had said the day before. It was really weird.

I know I've seen it in my microbiology classes. There'll be like, "torque" and different words like that. It'll just be like, "That's key word." Like, physics words. And, yeah. Like "thermodynamics" and "kinetic energy," and things like that. [00:15:00]

INTERVIEWER: So, what do you think the connection is between biology and physics?

RESPONDENT: I think when you boil it all down, biology is just like transferring energy into different things. Like, "Oh, I need energy for this. I'm going to make this molecule or degrade this molecule." The process behind what allows you to do that is going to be the explanation from physics. But then you see it kind of – I think a lot on the micro scale, as a microbiologist. But on the macro scale, you see it in the movement of things and why certain shapes of animals are favored over other ones.

INTERVIEWER: Mm-hmm.

RESPONDENT: Stuff like that.

INTERVIEWER: Do you think physics applies equally to the micro and macro scales?

RESPONDENT: Yeah. Definitely.

INTERVIEWER: Okay.

RESPONDENT: I just don't think as much on the macro level, so I don't – it's been a long time since I talked biology.

INTERVIEWER: Just regular, general –

RESPONDENT: Yeah. Like –

INTERVIEWER: – biology?

RESPONDENT: – thinking about evolution, and macro level.

INTERVIEWER: So what kind of processes are you interested in at micro? [00:16:00]

RESPONDENT: Micro? I really like the progression of disease. So I really want to do infectious – I really have liked my virology course. So, the progression of infection to actual clinical outset. And then epidemiology's more focused on the clinical outset to the population, of how to contain –

INTERVIEWER: Gotcha. So when you're talking about the micro and the virology, do you see physics showing up in there?

RESPONDENT: Not as much, because we tend to focus on one virus and then just a glimpse into that and then move on. We don't delve into the processes as much.

INTERVIEWER: Got you.

RESPONDENT: But I know it's there, like in the back of my head. I think they expect you to have known that from biochemistry.

INTERVIEWER: Got you.

RESPONDENT: But, yeah.

INTERVIEWER: How about the connection between chemistry and physics?

RESPONDENT: Yeah. That one's really easy. (Chuckling)

INTERVIEWER: That's easy?

RESPONDENT: Yeah. What was it we were doing yesterday in – I saw it a lot first semester, too. [00:17:00]

Especially – because thermodynamics was a unit in chemistry. I like the velocity, like gasses and pressure. But then, yesterday in physics, we did all the photoelectric effect. That was a unit in chemistry.

INTERVIEWER: Got ya.

RESPONDENT: The problems that we were solving could have been equally asked in LB171.

INTERVIEWER: I see. And that's the chemistry course.

RESPONDENT: Yeah. Sorry.

INTERVIEWER: Yeah. I've learned all the numbers –

RESPONDENT: (Chuckling)

INTERVIEWER: – a few times.

RESPONDENT: Unless you take them, there's really no point.

INTERVIEWER: Right. The HPS ones are the hardest, because each number can –

RESPONDENT: I don't know. I don't even remember what number I'm in. (Chuckling)

INTERVIEWER: So that's why I was asking what the topic is. That usually helps me understand what the course is about. Do you think the first semester course changed your interest in physics?

RESPONDENT: A little bit. It was more of like, "Oh, I can use this. It's useful more of, 'My program is making me take this, and I don't want to be here.' " (Chuckling) [00:17:59]

So that was the mindset at the beginning.

INTERVIEWER: Yeah.

RESPONDENT: Yeah.

INTERVIEWER: Did it change?

RESPONDENT: Yeah. Kind of like, "Why am I making –I'm never going to try and measure gravity. Why are they making me take this?" And, yeah, I think it's changed to more of like, it's an explanation to the other things like it does. It's an asset, too. Understanding.

INTERVIEWER: So if you were to meet somebody – and let's say me –

RESPONDENT: (Chuckling)

INTERVIEWER: – and I go, "Well, I want to be a microbiologist. I don't really need to measure gravity." Let's say I'm about to take – you're my mentor and I'm about to take physics. What would you tell me?

RESPONDENT: I guess I'd tell you unless you just want to spend your whole life memorizing facts on things and never actually understanding why something is happening, sure, don't take physics. But if you want to understand why your experiment failed when you did it this way versus why it worked when you did it that way, you should take physics. [00:18:57]

INTERVIEWER: Mm. Okay.

RESPONDENT: Understanding why your bacteria are doing a certain thing this way, this time, and not doing a certain thing that time. It's probably physics.

INTERVIEWER: It's probably physics.

RESPONDENT: Probably physics. Unless you didn't feed them or something.

(Chuckling)

INTERVIEWER: Unless you didn't feed them. Yeah. This question is going to sound familiar because we've asked it –

RESPONDENT: (Chuckling)

INTERVIEWER: – before. So when I mention diffusion, what comes to mind for you?

RESPONDENT: Oh, yeah. Oh, gosh. It's been so long.

INTERVIEWER: It's been so long.

RESPONDENT: I think immediately I always come up with that little diagram where they have a bunch of balls on one side and not a lot of balls on the other side. Then, over time, them moving and equaling out. So, the movement of concentration due to the random collisions.

INTERVIEWER: Due to the random collisions. Okay. Could you give me a definition –

RESPONDENT: Yeah.

INTERVIEWER: – of diffusion?

RESPONDENT: Let's see. Movement from a concentrated area to a less concentrated area. [00:20:01]

Over time. As a process of random collisions.

INTERVIEWER: Okay.

RESPONDENT: Yeah.

INTERVIEWER: Can you describe the process of diffusion?

RESPONDENT: At least I think of it right now is that you have – if you have a container, a set container, things are going to be moving, they have a certain kinetic energy, and they'll randomly hit either each other or the wall of the container.

Then, when they collide, there's going to be a transfer of kinetic energy, and they're going to switch directions in some form. As they do that, they're going to keep switching directions. Eventually, if you have an open container, they're going to start spreading out. They'll move until they hit something. So. They're going to go be – from, if they're moving in, they'll eventually head out because they'll switch their direction. It's like that. (Chuckling)

INTERVIEWER: That makes sense.

RESPONDENT: Okay. [00:21:00]

INTERVIEWER: Do you see connections between diffusion to the biological molecules or situations?

RESPONDENT: Yeah. Especially from diseases and things. You'd be a – what was it we were studying? Diabetes?

INTERVIEWER: Mm.

RESPONDENT: Diabetes, one of the things that can happen is you can get more ketone bodies in your blood, which makes the – well, that's not the right one. There's one disease where you can get more molecules in your blood. So then the water is more likely to stay in your blood, in the more concentrated area rather than being excreted. That's the process of balancing the osmolality, which is related to the diffusion.

INTERVIEWER: I see.

RESPONDENT: So, different things happening in your body. It's kind of easy to visualize through the diffusion of water in or out of your cells. [00:21:59]

INTERVIEWER: So what – how does the water know to go to the place where there's higher concentration?

RESPONDENT: I think we explained that with thermodynamics, but it's been a long time. (Chuckling)

INTERVIEWER: It's been a long time.

RESPONDENT: It may – I remember at one point, it made so much sense.

INTERVIEWER: Yeah.

RESPONDENT: Now I'm trying to think of – the – there's something that's going to trigger – I'll walk out of here –

INTERVIEWER: (Chuckling)

RESPONDENT: – and I'll go, "That's what it was." But at the moment, I got none.

INTERVIEWER: It's all right. In reflecting about what you thought about diffusion when you started the course last semester and what you know now, what do you think you learned about diffusion?

RESPONDENT: I think I see it more at a micro level than a macro level. Kind of like explaining why. I know – I knew the process of diffusion, but now I understand why, so I can see more of the interactions between the actual molecules and why they spread out. Versus just the, "Oh, that goes from this to this." [00:22:58]

It's kind of like, more snapshots in between –

INTERVIEWER: Got ya.

RESPONDENT: – to understand what's going on.

INTERVIEWER: And if you were to pick out what helped you learn that smaller, zoomed-in, what could you point to in class that you did?

RESPONDENT: Definitely the code –

INTERVIEWER: Oh, really?

RESPONDENT: – that we did on diffusion. Yeah.

INTERVIEWER: What was helpful about that?

RESPONDENT: I think it let you put together the math of the physics and also a visualization. I'm really a visual learner. So to see, like, "I've changed this, and this is what happened," was really useful.

INTERVIEWER: Mm. So what was useful about seeing it?

RESPONDENT: I think it just helps you connect it to the real world. Like, physics – when you just have the math equations, it's just on paper. You're like, "All right. Well, I solved for this, but what does it mean?" So when you solve for this in a code, you get to actually see what it means. [00:23:56]

Then you can connect, like, "Okay. You have an – " For me, I have another memory, and when I picture thing – when I think of things, I think of them more in pictures. So it helps me remember and connect it to other things. Oh, if I see something, I'm like, "That looks like what I, my code looked like."

INTERVIEWER: I see. You said that you can change things and see what happens.

RESPONDENT: Mm-hmm.

INTERVIEWER: Can you give me an example of something that changed in the code, and what you saw?

RESPONDENT: I think we changed the mass of things –

INTERVIEWER: Okay.

RESPONDENT: – to see how that affected the collision. Sometimes, they would – it would be an elastic collision. Sometimes it wouldn't. We changed the number of molecules to see how that affected the time it took. Then we put on like a trace so that we could find an individual thing and follow it throughout the process.

INTERVIEWER: Mm-hmm. Great. Are you currently in physics?

RESPONDENT: Yes. I'm in 274. Whatever the second half is. [00:24:59]

INTERVIEWER: You're in the Professor Quarter's (ph)?

RESPONDENT: Quartermeyer's (sp?).

INTERVIEWER: Okay. How was that?

RESPONDENT: It's good. It's different.

INTERVIEWER: Can you tell me a little bit about that?

RESPONDENT: It's more in line with, like, kind of what I expected. It's more in line with what the chemistry courses were. There is some lecture, and then – but there is – the coding, I think, is a little more intense. I don't know if it's this way and the other professors, too, if it's just a model of 274. But being able to do it on your own, and it always seems like it's going to be impossible. But, yeah. At the due date, you always have something.

The labs are a little, I feel like, trickier, sometimes. Like – I don't know. Thinking back, I don't think I know what I was doing until the end of the lab in first semester, either. But I feel like I never know what I'm doing until the very end. I'm like, "Okay. Now it makes sense." And I'm going to leave. It clicks, but through the whole process, it's a little confusing. [00:26:03]

INTERVIEWER: Mm.

RESPONDENT: But I think I like the topics, maybe, a little more. Some of them, they're easier to relate to, like the real world. Like sound and light – those are easier to see kind of in your every day. Then, like the previous topics, but they're a little harder to relate to biology in terms of explanations for those things.

INTERVIEWER: So the second semester topics are easier to relate to on an everyday, but harder to biology? Is that what you said?

RESPONDENT: Yeah.

INTERVIEWER: Okay.

RESPONDENT: I think so.

INTERVIEWER: Why do you think it's – you said you like that it connects to everyday life. Why? Why is that important?

RESPONDENT: I think it's just easier to learn. When you have something in a factory, just trying to memorize, you can mix it up in your head. Like, "Was it A or was it B? I don't remember which was which." [00:26:59]

But when you have something like light, you can be like, "Well, yesterday, when I was doing this, the light reflected off the mirror, and then – " So you can look back and be like, "I know it has to be this, because I've seen it every day."

INTERVIEWER: I see.

RESPONDENT: Kind of light. Like, I guess, like a rainbow. Like different things. You can see them and then you can be like, "I know it has to be like this."

INTERVIEWER: Mm. I'm curious. Since you're a microbiologist, a lot of the microbio stuff is hard to see in everyday life, right?

RESPONDENT: Mm-hmm.

INTERVIEWER: So is that a challenge?

RESPONDENT: Yeah, it is. It's kind of why I want to do epidemiology.

INTERVIEWER: Yeah.

RESPONDENT: I like the disease on the more macro level –

INTERVIEWER: Got ya.

RESPONDENT: – I've found. Yeah. I can – yeah. It can be really hard. A lot of times, I talk about the effects of the micros. A lot of people aren't as interested in what's actually happening in the microbes unless they're more biochemistry-related.

INTERVIEWER: Mm. Okay. [00:27:56]

So comparing across these two kind of experiences you've had the first semester and second semester, do you have ideas about which one you're able to learn better in? Do you have preferences?

RESPONDENT: Yeah. I think I would take a certain elements from each one and –

INTERVIEWER: Yeah.

RESPONDENT: – combine them. I like having, like, maybe one formal lecture, like we have in 274 to see like, "All right. These are the equations I need. This is how it relates to that." Seeing that, I like the labs better in the first semester, and the group work. The worksheets that were more connected to what we were doing. I don't know if the other classes used it, but we have tutorials in Dr. Quartermeyer's (sp?), and they are really hard to see how they connect.

INTERVIEWER: Yeah.

RESPONDENT: So. Combining the different elements from each.

INTERVIEWER: Gotcha. [00:28:58]

What – so you mentioned some resources that you had available in the first semester.

RESPONDENT: Mm-hmm.

INTERVIEWER: Are you seeking out resources for the second semester?

RESPONDENT: I mean, I'm definitely – I have even more people that I turn to in second semester for things. I made my roommate go to help room last night. (Chuckling) Help, to figure out something for both of us.

INTERVIEWER: Oh, I see. As an emissary? (Crosstalk)

RESPONDENT: Yeah. Like, "I don't have time to go. You go."

INTERVIEWER: Yeah.

RESPONDENT: So, she did that. But – and I have e-mailed Dr. Quartermeyer (sp?) a few times for help on the code, which I never did second semester, first semester.

INTERVIEWER: How do you like the coding? So you did it in both semesters, right?

RESPONDENT: Yeah. I like it even more in this semester. Although last night was really frustrating with my coding project, and I couldn't get it to work. But there's always, like, when you do get it to work by yourself, there's immense pride.

INTERVIEWER: Yeah.

RESPONDENT: You're like, "I coded that." So, I mean, that's fun. [00:29:58]

I like being able to see it and being like, "This is how the physics would work in – on actual objects."

INTERVIEWER: Before you took the first semester physics, had you ever coded before?

RESPONDENT: (Chuckling) Nope.

INTERVIEWER: So how does it feel then, now you're able to do projects and do it by yourself?

RESPONDENT: Yeah. I like it, especially –

INTERVIEWER: Yeah.

RESPONDENT: – because I know not so much physics coding, but understanding coding languages is a big part for some parts of epidemiology.

INTERVIEWER: Okay.

RESPONDENT: So I'm excited that I always have some experience in that.

INTERVIEWER: So you're seeing a direct connection to –

RESPONDENT: Mm-hmm.

INTERVIEWER: – the future?

RESPONDENT: Yep.

INTERVIEWER: Yep? Okay.

RESPONDENT: I have to take another programming class next year, so.

INTERVIEWER: Oh, yeah. What's the class you're going to take?

RESPONDENT: It's actually through the epi department. It's –

INTERVIEWER: Okay.

RESPONDENT: – for SAS –

INTERVIEWER: Oh, okay.

RESPONDENT: – program.

INTERVIEWER: Okay. I think I've heard of SAS.

RESPONDENT: It's statistical analysis –

INTERVIEWER: I see.

RESPONDENT: – for databases and stuff.

INTERVIEWER: Gotcha. Gotcha. How are you doing in the class?

RESPONDENT: Okay. Not as good as I was doing last semester.

INTERVIEWER: Why do you think that is?

RESPONDENT: I think the – for some reason, I think the exams are harder to study for –

INTERVIEWER: Okay.

RESPONDENT:– is what it is. [00:31:01]

I've done really well in all the other categories.

INTERVIEWER: Yeah.

RESPONDENT: But then, I got – my first exam grade was lower than any of my exam grades first semester. We just took one on Monday, and I'm not feeling so hot about it.

INTERVIEWER: Okay. Okay.

RESPONDENT: I always feel like I really know what's going on. I think part of it might be time crunch. We only have an hour. I think if there wasn't the pressure – if I was told at home, "Go do this in an hour," I think I could. But in the exam room, I feel like it's really hard to – I feel like I'm not getting everything I know on there.

INTERVIEWER: Okay.

RESPONDENT: Yeah. It's really just the exams. Everything else, afterwards, it clicks.

INTERVIEWER: Okay. Well, Maria (sp?), it's been wonderful chatting with you.

RESPONDENT: (Chuckling) Thanks.

INTERVIEWER: Do you mind if I follow up with you? So, next year is your last year?

RESPONDENT: Yes.

INTERVIEWER: Okay. So do you mind if I follow up with you future?

RESPONDENT: Yeah.

INTERVIEWER: Yeah.

RESPONDENT: Mm-hmm.

INTERVIEWER: When you're closer to graduation? Just like, "Congrats, you made it through." Right? "One more year."

RESPONDENT: Yes. I'm so excited. [00:32:00]

INTERVIEWER: How is the course load next year?

RESPONDENT: It's decent. I only have four credits I have to take in the spring. So I'm like –

INTERVIEWER: That's awesome.

RESPONDENT: – "What do I do? Do I take –

INTERVIEWER: Yeah.

RESPONDENT: – grad courses? Do I just go get work?"

INTERVIEWER: So would grad courses be a head start to –

RESPONDENT: Mm-hmm. Yeah.

INTERVIEWER: – achieving that? Okay.

RESPONDENT: So.

INTERVIEWER: Yeah.

RESPONDENT: That's the goal.

INTERVIEWER: Sweet.

RESPONDENT: Pay undergrad rates for classes I can apply to grad school.

INTERVIEWER: That's pretty great. That's awesome. Are you applying to grad schools now?

RESPONDENT: Yep. All right. I will –

INTERVIEWER: Or –

RESPONDENT: – be in the summer.

INTERVIEWER: In the summer. Okay.

RESPONDENT: Yeah. Grad school's –

INTERVIEWER: Yeah.

RESPONDENT: – a little more relaxed than med school, so I've got more time than they do.

INTERVIEWER: Oh, I see. Yeah, because I hear people stressing out about the MCAT. This Friday or something?

RESPONDENT: Yeah. There's a session coming up, and then there's a May section. A lot of people are taking one or the other.

INTERVIEWER: Gotcha.

RESPONDENT: So. It's in full swing.

INTERVIEWER: Yeah. Yeah, it's a lot of pressure.

RESPONDENT: My – a lot of my friends are taking it. I'm like, "All right. Not talking to you for like the next two weeks."

INTERVIEWER: Yeah. You don't need to absorb their stress.

RESPONDENT: Mm-hmm.

INTERVIEWER: Awesome. Cool.

RESPONDENT: Thanks.

INTERVIEWER: Thanks again for chatting with me.

RESPONDENT: No problem.

**END TRANSCRIPT**

## APPENDIX O

## TRANSCRIPT: MARIA INTERVIEW 4

# TRANSCRIPT OF AUDIO FILE:

# LB273-11.15.17-MARIA_LAINTERVIEW1

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*The text below represents a professional transcriptionist's understanding of the words spoken. No guarantee of complete accuracy is expressed or implied, particularly regarding spellings of names and other unfamiliar or hard-to-hear words and phrases. (ph) or (sp?) indicate phonetics or best guesses. To verify important quotes, we recommend listening to the corresponding audio. Timestamps throughout the transcript facilitate locating the desired quote.*

**BEGIN TRANSCRIPT:**

INTERVIEWER: Cambridge.

RESPONDENT: Yeah. I haven't really looked at costs or anything, so I was like, I don't want to…

INTERVIEWER: Well, they might have scholarships, right?

RESPONDENT: Yeah. And so, one of the scholarships I applied to is for Cambridge, and that's why I applied to Cambridge. I didn't just one day wake and, like, I guess I'll –

INTERVIEWER: I just thought one day you woke up and you're like, this is what Maria (ph at 0:00:27) does today.

RESPONDENT: Mm-hmm. So we'll see. That one is pretty competitive, so.

INTERVIEWER: I'll start this as a backup. On a scale of one to ten, how excited are you?

RESPONDENT: Like, solid ten.

INTERVIEWER: A solid ten?

RESPONDENT: It's kind of abstract right now. I think the reality of it will hit in a little bit.

INTERVIEWER: Yeah. What does your family think?

RESPONDENT: They're excited.

INTERVIEWER: Yeah?

RESPONDENT: Yeah.

INTERVIEWER: Did you tell all your friends?

RESPONDENT: I haven't yet. Because I woke up at like eight a.m. to go to work. I saw the e-mail, or the, they have an online application portal. [0:01:00]

INTERVIEWER: Gotcha. Were you checking every day?

RESPONDENT: Yeah.

INTERVIEWER: Multiple times a day?

RESPONDENT: Yes.

INTERVIEWER: I see. How much time passed from when you got the, like, I didn't get the interview, to this, was like a couple days?

RESPONDENT: From the other scholarship?

INTERVIEWER: Yeah.

RESPONDENT: That was like two weeks ago.

INTERVIEWER: Ugh. Okay, (inaudible at 0:01:20)

RESPONDENT: I had my Cambridge interview last Friday, and it went well. (laughter). I felt like it went well, so that was all right.

INTERVIEWER: So looking back on it, what do you think you did well, what made you feel like, all right?

RESPONDENT: They just seemed very, it was two men, two professors. And they just seemed very into it. Because most of my experience, that was in infectious disease, but their entire program was chronic diseases. So the entire time, I was like, I'm not going to get in. I'm not, I wasn't even going to apply for the scholarship.

INTERVIEWER: Wow.

RESPONDENT: The woman at the scholarship office was like, you have to apply. You have to apply. And so I did. And so then I applied to Cambridge, and they're just like, yeah. I was able to argue, like I think I would be a good fit, and I actually want to get experience in other things. And they're like yeah, that's great. And they were pretty into it. I didn't really stumble or anything, so. [0:02:12]

INTERVIEWER: Awesome.

RESPONDENT: Yeah.

INTERVIEWER: I'm proud of you. That's amazing. But yeah, Cambridge.

RESPONDENT: Yeah.

INTERVIEWER: Wow. Was it through Skype?

RESPONDENT: Yeah, it was a Skype interview.

INTERVIEWER: Okay, I figured.

RESPONDENT: And of course my desktop computer wasn't working, so I was using my little iPad.

INTERVIEWER: That's awesome. Well, that's good news. Well deserved, though. So, the point of this interview, before we start, same things as before. I think you've got the hang of it. You know, instructors don't know, well, you don't have any instructors.

RESPONDENT: No.

INTERVIEWER: So it doesn't really matter anymore. You're free. Cambridge, here you go. But we just want to touch base because we followed you through the LB273 experience. And then, now you're teaching it. And so we wanted to get your thoughts on it. So first, I mean, do you have some reflections on what this teaching experience has been like? [0:03:12]

RESPONDENT: I've enjoyed it. I've always kind of enjoyed teaching and tutoring, it's a fun dynamic. I enjoy teaching other people things. So, I really enjoyed that, interacting with the students. Yeah, it's kind of like a different perspective. Like when you're a student, it's your first time seeing something. And so you, now I know, this is why we're doing this, and they're going to make this connection to this other thing we did, and this is going to connect in the future. The other day, they were proposing experiments and this group wanted to do this configuration with springs, to see how each one contributed to the spring coefficient. And it reminded me of a lot of the stuff Gerd (ph at 0:04:02) did with his in (ph) series and parallel circuits. I was like, oh yeah, that's a thing you're going to have to get comfortable with.

INTERVIEWER: What's one thing that, like an activity from 273 that you think differently about now that you're on the teaching side?

RESPONDENT: Probably the codes.

INTERVIEWER: The codes?

RESPONDENT: Yeah. Because especially now with the microscope lab, I think they play a really important role. But as students, you get really frustrated. It's not working, and you're focused more on that than the actual, what the code is supposed to be doing. And when you get it to work, what does that tell you?

INTERVIEWER: What's the –

RESPONDENT: The meta, the meta point. Instead of just the, like this one line is wrong and I can't get it to work.

INTERVIEWER: Do you think you had that perspective when you were a student? [0:05:00]

RESPONDENT: At the beginning, definitely. Towards the end I was a little more comfortable with the codes.

INTERVIEWER: So in the beginning, you were focused on the frustration?

RESPONDENT: Yeah, like not understanding the codes.

INTERVIEWER: I see.

RESPONDENT: I feel like the students probably feel, but towards the end I was…

INTERVIEWER: So what do you think makes it different, now that you're teaching the coding stuff and helping people figure it out, that now you're able to see the, as you said, the meta?

RESPONDENT: I think realizing the point is not that you have to be an expert coder at the end. I still don't really know. You make things work. I understand if somebody else writes a code. But if you handed me a blank sheet, I couldn't probably make a code. And so, realizing that that's not the point, and that it will, it's just another model, it's another tool.

INTERVIEWER: So do you think, which do you think is more valuable to you? Being able to get a blank sheet and write it, or to be able to troubleshoot and change and modify? [0:06:11]

RESPONDENT: I think in terms of physics coding and stuff, just the modifying and things. I like to have that model. That instead of something stationary on paper, that's actually moving and you can play with. Personally, I'd like to be able to code things. I think that's cool, and a skill, but in terms of actually understanding physics or another subject that's not my specialty, I'm totally fine just being handed a code.

INTERVIEWER: Gotcha. Okay. Are there any other activities that you think differently about now?

RESPONDENT: So like the investigations. I think a lot of the students and even when I was in the class, I'd be kind of like, what's the point? But I think now, I view it more as another instructional tool. Especially not just for physics, but designing an experiment. Like general science education. It's a really good tool, and I think students miss that. Focusing on what makes a good experiment. We've talked about it a little bit in L.A. prep. I think students think about physics differently than their other science courses. They like to think of it as a lecture course without a lab component. It's like no, you need to come up with an independent and a dependent variable and a hypothesis just like you would in chemistry. [0:07:36]

INTERVIEWER: I remember you saying that in class.

RESPONDENT: Yeah. And I think yesterday a lot of students were struggling with that. They'll be like, we're just going to do this. And I was like, that's not an experiment. What's your question? What's your independent? What's your dependent? They're like, oh. I don't know.

INTERVIEWER: So I remember last year, I think wound healing and the paramecium activities struck out at you as being I think more interesting. What do you think about them now?

RESPONDENT: Yeah, I was sad we didn't get to the paramecium. It was cut. Yeah, I think that one, and I guess the trade-off was we did the ATP one yesterday. And I think in my mind, those kind of hold a similar place, where especially when you start getting into the chemical energy and stuff like that, a lot of students who are more like human bio or something start to feel lost. And I think being able to connect it back to something like microbiology or biochemistry helps them feel a little more confident. And so I think that's why I like the paramecium one, is I feel like I knew something going in, not just coming out. And so I think that, I see that value now a little bit more. Now that I'm able to see more students. [0:08:51]

INTERVIEWER: Gotcha. and this is the first semester that you had (ph) a microscope.

RESPONDENT: Yeah.

INTERVIEWER: What did you think about that?

RESPONDENT: That was interesting. Because I think a lot of students, it was helpful that they had the cameras for sure. Because that takes away the hardest layer of a microscope, which is (inaudible at 0:08:51). But I think that was another case where students were like well, science is happening and physics, and is physics science. Like, of course. But they weren't really thinking through it all. A lot of people just squirting things on microscopes. And so, I don't really know how you address that. But I think it was interesting. And I know students were a little frustrated. It was our first time running it. But that's just how life goes. And sometimes you're the guinea pigs. But I think, I found it interesting. You know, they had different variables they could play with and come up with an experiment that was a little more structured, and I think that helped them as well. [0:09:59]

INTERVIEWER: Now, you're at the end of your undergraduate career, and you're off to the next journey. Looking back, what do you think was valuable about LB273 when you were a student?

RESPONDENT: I think definitely that focus on physics is such a good core science, and so I feel like designing experiments in physics and things like, it helped with just science in general. It builds your skills as a scientist. Not even as a physicist, just a scientist. And so I think that was really helpful. I think there was a lot of critical thinking that you don't necessarily get in your chemistry and biology classes. A lot of well, what do you think? And you have to come up with it. Because, the studio physics style, and through investigations. And so it really forces you to be focused and thinking about what you're doing, not just passively absorbing information. And so I think that was really good. And just thinking about the world around me in a way that I hadn't before, like I hadn't had physics since way before, and it was all about pushing blocks up ramps. Where this was like well, what's going on under the microscope? Or what's going on in the real world? [0:11:14]

INTERVIEWER: You said critical thinking. What does that mean in the classroom? Can you give me an example of what it means to do critical thinking?

RESPONDENT: I think the investigations are a good spot, where you're just handed some things and you have to decide what's important, what do I think I should change, and just I guess critical thinking and also troubleshooting. What do these results mean? And really having to sit down and think through the physics and the actual data that you got and connecting them. And I think it's also just a challenging course. You have to really be present the entire time, and really thinking through what you're doing and what you're learning. I guess it's just mentally challenging. [0:12:05]

INTERVIEWER: You said that the physics class made you see the world around you differently. Do you have any examples?

RESPONDENT: Hm. I don't know. I'm sure I do, if I think hard on it. The other day we were learning about, something about enzymes and things, and cells, and I just look at Marilyn who was in the course too, and I say, "physics." And she was in physics, and she said, "Ah, yes." (laughter). Because a lot of people are just like oh yeah, that's what biology does. But the whole kinetics between, inside a cell, is actually physics. I think like, it lets you unpack the wand waving they do in biology classes. I think there's a lot of want waving.

INTERVIEWER: What does that mean? [0:12:58]

RESPONDENT: Like they'll say, and this is what the cell does. It just, sometimes it favors this and sometimes it favors that. And you're just like, okay, sure. But the why doesn't favor this versus why does it favor that. So kinetics, and physics that's even beyond me. So. But I think even just recognizing that there is an explanation for that is something that isn't even really touched on.

INTERVIEWER: I see. And that's in bio and chemistry?

RESPONDENT: Yeah. You see that with the ATP too. A lot of people think oh yeah, if I break bonds I get energy. And I think that's because it's a step that bio classes tend to skip. That there's an in-between where you break a bond then form a bond.

INTERVIEWER: I remember seeing that for the first time, it blew my mind.

RESPONDENT: That's what a student said the other day. She said, I was the one who figured this out in my AP high school class, and just, everybody's mind was blown. My mind was blown. (laughter). Yeah, it's pretty great. [0:14:02]

INTERVIEWER: So, is there an activity that you did not like when you were a student, but now as an L.A. you find yourself liking?

RESPONDENT: Probably the investigations.

INTERVIEWER: The investigations?

RESPONDENT: Yeah. (inaudible at 0:14:12). Like, I think the class, physics, as a sequence (ph) is almost exhausting. Because you, there were, there's no break. There's no time when you're just sitting there, writing down notes. You have to be present for six hours a week. And that's not true of a lot of classes. I don't think that's a bad thing, I just think it's something that I struggled with as a student. And I think I saw that a lot in the investigations. It's a lot of doing. You are doing things. And so that kind of took away from that as a student. But now seeing the actual purpose.

INTERVIEWER: So of the activities we've done this semester, which do you think are the most valuable for a student that's doing life sciences, like biology or biological sciences?

RESPONDENT: I think the codes. Because I didn't realize until recently how much of biology is moving towards computational modeling. You see a lot of epidemiologists actually working with physicists, because they need (inaudible at 0:15:25) calculus to model diseases and things. So some of the things Vashti has brought in where you're modeling proteins and things, like the life scientists can discover something. Like, do you think this protein interacts with this one? But how do you show that? How do you show that to other people? You're going to model it. So I think the coding is really valuable, as just an asset. Maybe just a skill to have.

In terms of understanding, I think the course does a pretty good job of connecting to other sciences. Very few things are just like the physics world, just a cart, you know? The cart usually is representing something. I think that was something students were struggling with yesterday when designing labs. They're like we're going to move this cart, it's going to do something. I was like, that's no fun. I was like, aren't you interested in something about the real world? Don't you want to know something? And so, the groups that were struggling, I tried to push them towards thinking of the course as a life sciences course. I think the ATP and the different exercises are helpful. [0:16:37]

INTERVIEWER: So of the activities we've done this semester, which do you think are the most important for a student to understand thoroughly?

RESPONDENT: I have to remember all of them we did this semester. (laughter) I think probably the lab reports like the things they did as formal labs. Because that's going to combine everything. You know, like the investigations, I always tell students it's okay to feel a little shaky after the investigation. Like that's your first time. So in terms of actually understanding thoroughly, I don't think it's as important on an investigation. And then you know, we usually do some practice worksheets, and those are important, but those are usually just plugging in numbers and thinking about how you're actually going to use the physics. Where I think the lab reports, I haven't actually seen a video lab report but that's combining using the models, connecting it to the real world, and actual physics concepts. And so I would think that would be a good benchmark for all the previous things. And understanding thoroughly, yeah. Any activity that's usually, I think the models are something the students struggle with, and I think they're the most important.

INTERVIEWER: Gotcha. You've mentioned the real world a lot, like connecting to the real world. Why do you think that's important?

RESPONDENT: One level I think it's important is just engagement. Keeping students interested and focused. But also these students, I think we have one physics major across Vashti's two sections, one or two. And so most of these kids are like why do I have to learn physics? And so I think connecting it back to the real world helps give physics some credibility in their minds, like yes this is a useful thing to know. Like there are many applications, it's not just an esoteric thing that you're going to hold in the back of your brain for no reason. It has a purpose. And so I think connecting it to the real world is the best argument for that purpose. [0:18:56]

INTERVIEWER: And, of the activities we did this semester, which do you think are the most relevant for future biologists?

RESPONDENT: Future biologists. We did one early in the semester, it's coming back to me. I think the one, yeah, the wound healing one. It's one of the first ones they do, which I think is cool. Because you have a lot of pre-med in the Lyman Briggs, and it's like this is physics, but it's also the end question is do you give antibiotics? That is a question you are going to come across many times as a doctor. Do you prescribe antibiotics or don't you? That's your call. And so I think that, is probably an important one. A lot of the stuff we've done recently is a little more chemistry based. The ATP one I think is a little interesting, because that's something students will learn a lot. It's not necessarily something they'll, every biologist is going to use in their future. But you know, in their other courses they're going to see it a lot. Trying to think. I remember the wound healing specifically. [0:20:06]

INTERVIEWER: Sticks out at you.

RESPONDENT: Yeah. That's the one that sticks out the most.

INTERVIEWER: So after taking two semesters of physics, and now teaching physics, do you feel more confident in your ability to do physics?

RESPONDENT: Yes. I feel like my ability to, my phone keeps going off –

INTERVIEWER: You can silence it. I thought it was my phone for a second.

RESPONDENT: No. It's mine.

INTERVIEWER: Cambridge. They're like…

RESPONDENT: It's my mom.

INTERVIEWER: We're sending you a plane.

RESPONDENT: It's all of the –

INTERVIEWER: Does she know?

RESPONDENT: Yeah, they both know.

INTERVIEWER: She's probably really excited.

RESPONDENT: Yeah. Yes. Doing physics. Confidence.

INTERVIEWER: Do you feel more confident in your ability to do physics?

RESPONDENT: I think at the nitty gritty level, oh is this graph exactly right? I actually go back to my notes at this point. I'm not as confident. But in terms of general concepts, like definitely. I can look at a situation and draw up a free body diagram. So I think in terms of modeling a situation, I can do that. But in terms of, is this the right number to go here? A lot of this stuff I look up sometimes. When I'm doing worksheets and stuff. Because, that's kind of, it felt like the focus of the class. To be able to recognize physics and know what's going on in terms of physics but not necessarily be able to actually go through the numbers and figure it all out. [0:21:38]

INTERVIEWER: And is that different from what you felt when you were a student?

RESPONDENT: I think as a student yeah, it was really fresh and I was able to do it all. And really work out a problem. But I think as an L.A., I focus more broadly on, are your representations correct? Are you understanding the actual physics of the situation? Your acceleration is slightly off. Just go through and check your calculations. Like whatever.

INTERVIEWER: Do you feel that you have an improved understanding of physics, now that you're on the teaching side?

RESPONDENT: I think so, yeah. I think understanding, yeah, because I, I don't know how to say this. Because I can think through and why that is correct. Because a lot of times I have to be able to help students get to that point, and I have to reassure myself that that point is the right place to go. And making sure I have a solid foundation and multiple ways to talk about it. Just so that I can help teach it. And so a lot of times I'll confer with Vashti and make sure this is why this is happening, right? [0:22:58]

INTERVIEWER: Gotcha. Is this the first major teaching experience you've had?

RESPONDENT: Yeah, in a classroom setting. I mean, I was a writing center tutor in high school, so I worked with groups. And I've tutored individuals in college. But in terms of actual classroom setting.

INTERVIEWER: And after being on the teaching side, do you feel that there are skills you've been able to develop?

RESPONDENT: I think so. I think talking about it in multiple ways is, a lot of times in the classroom I'm like, this way makes sense to me so this is how I'm going to think about it. But just because that's what makes sense to you, doesn't mean that's how it works for somebody else. So as a teacher you have to be able to wrap your head around different ways somebody might be thinking about this. Especially in the representations and models, there are multiple correct ways to do it. Just because you favor one way. So I think thinking about it different ways, being able to get at a deeper level, like I said, and this is why this is happening. Being able to explain it to somebody else. [0:24:06]

INTERVIEWER: Do you feel proud of anything from this semester?

RESPONDENT: Yeah, I feel pretty good after talking to students and they get something. I can't, there hasn't been a specific moment when I'm like oh yeah. I was pretty impressed with the group yesterday that was doing the different spring configurations and talking it through with them. That was like yeah, I think you guys have a really cool setup. And so stuff like that has happened a few times, where I feel proud of their physics knowledge. That they were able to come up with this stuff.

INTERVIEWER: And have you felt proud of your own stuff? [0:24:51]

RESPONDENT: Yeah. I think there have been a few situations that have been a little difficult and being able to, like the other day when I taught the gradient and I was like, this is what I remember guys. Go for it. But I think they got it. So, that was good.

INTERVIEWER: Are there any other moments that you felt proud?

RESPONDENT: I think during the split board meetings. Because I usually run them myself. They're usually during the beginning, so (inaudible at 0:25:18)'s not there. And being able to bring them all together. They don't always make it the easiest task in the world. They don't talk a lot. So being able to engage them, keep it moving, that's more of a leadership thing.

INTERVIEWER: Gotcha. And have you talked to your family about your teaching experience in physics class?

RESPONDENT: Yeah, I was home last weekend, and I was grading, so it's like so how are you liking the teaching? And like, because he was a teacher. He enjoys teaching. And so yeah, we talked a little bit about it.

INTERVIEWER: What would that conversation sound like? [0:25:51]

RESPONDENT: Mostly just like, how, whether I'm enjoying it or not. That I am, and it's something that I like to do.

INTERVIEWER: Is it something surprising for them?

RESPONDENT: I don't think so. Because, yeah, especially to my dad. He taught community college classes, on the side. That's not, he was never actually a formal teacher. And so it's something he enjoys to do as well.

INTERVIEWER: What do your friends think, that you're a physics L.A.?

RESPONDENT: My friends that were in physics think it's a little crazy.

INTERVIEWER: Yeah?

RESPONDENT: Yeah, like you're doing it again? (laughter) But I think some of them also teach other courses, and a lot of my friends are just like the teaching personality, I guess. They like to learn and they like to help others learn. So I don't think they're surprised that I'm teaching anything. I think they're a little surprised it's physics. You're a microbiology major, what are you doing in physics? [0:26:49]

INTERVIEWER: Yeah. Does it feel different to you, that you're a physics L.A. and not a bio L.A. or a chem L.A.?

RESPONDENT: It feels a little different. It's a little strange to say. But I think I would prefer it. I feel like there's less pressure, because I'm not an actual physicist, to know every single answer. I feel like if I was in a biology course, I'd feel a lot more pressure to know exactly what is happening all the time. I think in a physics course, because I'm not a physics major and most of them aren't a physics major, it's okay to say I don't know, but for the purposes of this class, I think this is, what you're doing is okay. That's happened a few times.

INTERVIEWER: And did anything seem hard or impossible at first in physics, but eventually you were able to understand?

RESPONDENT: The code. Always the code.

INTERVIEWER: Always the code? [0:27:47]

RESPONDENT: That first day with the code was rough. But in terms of actual physics concepts, I don't, like I feel like physics is very logical. That meshes well with my learning style. So there wasn't anything that ever seemed impossible. You know, there was a lot of new information. Especially once we had moved past chematics (ph at 0:28:15), that was kind of difficult to just incorporate and think about. I think the statistical physics is still, seemed pretty crazy. But yeah, I think I had the understanding that the course aimed for. I still feel like there's a lot of unknowns going on over there. But I don't think anything ever felt impossible.

INTERVIEWER: Gotcha. some people think that to be good at science or physics, it has to come easy to you. On a spectrum of agree–disagree, where would you put yourself?

RESPONDENT: Probably closer to disagree.

INTERVIEWER: Yeah.

RESPONDENT: I think if you're able to get it, you know, in the end. That's what's important. I mean, you can't spend your entire life figuring out one, somebody just dropped a (inaudible at 0:29:12). But like, I don't think to be good at physics, you have to be able to just do it all right away. It's all right to sit on it a few days and wait for that aha moment. Because that aha moment is probably coming. If you just sit there and mull over it for a while.

INTERVIEWER: Do you remember any aha moments for yourself?

RESPONDENT: I know there were some. I'm trying to…

INTERVIEWER: Or even as an L.A., now looking back on that old material, you know? [0:29:46]

RESPONDENT: I remember a lot of conversations with Anna, who was the L.A. last year. And at the end, just being like, yes. This makes sense now. And I can remember little ones. The other day, when we were doing the true false for the, what is that? The Lennard-Jones Potential. I think after that it was like, I got it. I know what this graph means now. I understand the whole dynamics that are going on there. And that one, I just remember that, because I looked at the sheet and it came back to me. So that was recently. I can't remember specifically.

INTERVIEWER: Did you feel like you understood it when you were a student, or now as an L.A.?

RESPONDENT: A student. As a student, yeah.

INTERVIEWER: As a student.

RESPONDENT: Yeah, I really liked going over that.

INTERVIEWER: Gotcha. Do you think physics is important to you?

RESPONDENT: Personally?

INTERVIEWER: Yeah.

RESPONDENT: I think yeah, like I like to know as much as possible about everything around me. I just like to learn. It's what I like to do. I'm weird like that. And so I think having one more way to think about the world, that's important to me. And so I guess, in that respect, physics is important. Just knowing something, having another way to think about things.

INTERVIEWER: Okay. Do you think it's valuable that you took the physics class? [0:31:22]

RESPONDENT: Yeah. Yeah, I think, for all the reasons that we talked about. Just having lots of ways to think about the world. Like lots of different models. The class is really focused on all the different representations. There's skills that come out of it. The coding and the scientific design. And I think on multiple levels, (inaudible at 0:31:47).

INTERVIEWER: What was different about how you thought about physics before the class sorry, was this different, this whole experience now, looking back on this two semesters of physics and then teaching it. Was that different from what you expected, before you even started LB273?

RESPONDENT: Yeah, if you had told me I was going to be teaching physics, I would probably have told you you were crazy.

INTERVIEWER: Yeah.

RESPONDENT: Because I didn't think about physics before the course. Other than that I had to take it, and I was dreading it. I had physics, I think as a sophomore in high school. I don't even remember it. There was vaguely some carts and some ramps, and something about work. And you did less work if you went up a ramp. That's all I remember. That's all I have. And so I, it's not something I really thought about. But now, yeah, I can look at a situation and recognize that there's maybe not specifically what is happening at the physics level, but understanding what concepts you would apply. What is applicable. [0:32:58]

INTERVIEWER: Gotcha. what would you tell, so you said that if somebody told you you were going to be teaching physics that you would probably not have believed them. What do you think the difference maker was? What made you think hey, let me give this a shot?

RESPONDENT: I think it was being in the classroom, and then seeing the other L.A.'s and being like yeah, I can do that. By the end of the course, I was like, I could do that and enjoy that. Your job is to go up and ask questions. And that's what I like to do. So I think I can do that. So yeah, it's just a process of being in the class and gaining confidence in my physics skills, but also seeing the actual L.A.'s and seeing myself doing that. [0:33:52]

INTERVIEWER: So reconcile something for me. You describe yourself as a person who loves to learn. And you had this physics class in high school. And then now you have this physics class. But this one seems to have made an impact on you. But then the high school physics class, you can barely remember it. But you were a learner, and loved to learn, in both situations. Right?

RESPONDENT: So I think it just had to do with the interest level. I like to learn, but it has to be interesting to me. Like, I can go learn something else, you know? And so I think that's, in high school just what I always focus on. I think I was taking that at the same time as my U.S. History class, and that was way more interesting. I remember everything about that. I think that was just, part of it was the style. And like I said, it was all in the physics world. That's how I talk about it with my students is, let's get out of the physics world and go to the real world. Things are not just a ramp, things are not just a cart. You know? It's an SUV and a small car or something. And there was none of that, it was all, this is a ramp. This is, you know. [0:35:07]

INTERVIEWER: So say more words around that. Tell me what's in that box of physics world, and what's in the real world.

RESPONDENT: Like, I guess the physics world to me is just something that, you're just doing it for physics' sake. Like, a mass and a pulley and a cart. Okay, but what does that tell you? This, you get some equation, but how are you going to use that equation? I guess the how and the why starts getting me out of just the physics world.

INTERVIEWER: Gotcha. Okay.

RESPONDENT: Anything that's like the objects and the tools and everything is the physics world to me.

INTERVIEWER: And did being a physics L.A. affect your feelings on the role of physics in your life? [0:35:55]

RESPONDENT: I don't think so. Much. Just because it's kind of like the same activities and the same process, just from a slightly different perspective. And I'd already developed that understanding of how to connect it to what I like to do as a student. And so I think mostly it's just building on that. It's not really changing it.

INTERVIEWER: So it's adding to what's already there.

RESPONDENT: Yeah, and just another, I'm going through it all over again. So it's just remembering.

INTERVIEWER: Gotcha. And did being a physics L.A. come into play when you were thinking about applying to scholarships and grad school?

RESPONDENT: Oh yeah.

INTERVIEWER: Yeah?

RESPONDENT: Yeah, I felt that was something that I should highlight and that was important to me. I asked Vashti for a letter of rec, partly as a professor, but also as a supervisor. Being a teacher, being able to recommend my teaching skills and comment on them. So I think, yeah. And it's something I want to do in the future, so I think being able to show that I have that experience is really important.

INTERVIEWER: Awesome. And when you were told you'd be an L.A. for this course, what did you think initially?

RESPONDENT: I was excited. Like I kind of knew what I was getting into, I guess. And I mean, I had enjoyed my class with Vashti. I didn't really talk to Katie very much, but she always seemed very nice. And seeing the physics team, they all had little sweatshirts last year. I was like yeah, that's a group I could be a part of. I don't think I was, and I wasn't even that nervous. Because I think that expectations are laid out that you don't have to know all the answers. I was like yeah, I can ask people questions. [0:37:44]

INTERVIEWER: Is there reason why you applied to be an L.A.?

RESPONDENT: I think it was just the knowing that I enjoy teaching, and that this was a pretty incredible opportunity for an undergrad. There's not a lot of teaching in a formal classroom.

INTERVIEWER: And so, how if at all has this L.A. position affected how you see physics in the real world? Or in your life?

RESPONDENT: I think it's just remembering the realizations I had last year. Because I'm going through it all over again. The same activities. And we'd be like, last year, we thought about this. And just kind of going through that all again, it helps, a second memory is helping cement it a little bit more. And last year, I was really able to make connections to the other classes I was in, just because I would start to see physics in something we were doing in one of my other classes. And so I think having physics again this semester, I can see it in the classes I also have this semester. So it's making even more connections to other things. [0:39:05]

INTERVIEWER: I remember when you were taking physics, the 273 course, you were also taking prokaryotic physiology.

RESPONDENT: Oh yeah.

INTERVIEWER: And there were connections between the two. Did that continue to happen with other courses, or in prokaryotic physiology more, after we talked about that?

RESPONDENT: Yeah, I had biochemistry the next semester. And then I have microbial genetics this semester. And so I think there is a lot of, the kinetics I was talking about, yes, and it favors this one and when the concentration is high enough. And you're like yeah, that's a physics problem. You could probably design something in 273 to talk about this a little more in depth. And they're just being like, and it happens. So I can see where 273 could open more doors. They weren't always doors I could open myself. But I was like, I bet you that's a thing they could do. [0:40:02]

INTERVIEWER: When I mentioned prokaryotic physiology, you had a smile.

RESPONDENT: I forgot about it. It seems like so long ago, I can't believe that was last year.

INTERVIEWER: Okay, I asked you that already. So, has being a physics L.A. affected your view of your ability to do physics problems?

RESPONDENT: I think so, both positively and negatively. Because sometimes, I am usually able to draw the correct free body diagram, and all the models that go through it. And make sure that I understand the concepts of it. But sometimes, when I'm grading, and they don't provide the actual correct value, that is the correct value, I usually ask the other L.A. who's grading, that's what you got, right? Before I grade all these students? I'm doing this right, right? And so I think in terms of actually making sure I'm doing the math and incorporating everything, that part's a little more shaky than when I was student. But thinking about new things, I can, yeah. I can do. Like a lot of the students, like yesterday we were coming up with things that obviously we had never done, so I had to think about them as a new concept, or some of the new labs we've done through. [0:41:32]

INTERVIEWER: Gotcha. So you were able to adapt to their new things even though you hadn't seen that situation before?

RESPONDENT: Yeah.

INTERVIEWER: Okay. And can you describe the L.A. team this semester, and your role in it?

RESPONDENT: Sure. So I don't really see anybody other than Rahul (ph at 0:41:47). Except at the hour prep meeting and the half hour overlap. So I feel like there's a little bit of disconnect. I haven't really had a conversation with Jordan, except when we we'd gone slack, when we were both grading. So I feel like, that is something that, Rahul (ph) wanted to have a holiday party. So, maybe something like that. Just having a social event at the beginning of the semester. Because I feel like it's a little disconnected. But I feel like it's pretty strong. There's a lot of different physics backgrounds and approaches. Like, I think Polo (ph at 0:42:29) should be the poster child for a physics student, because he would tell you every day in physics class that this is just so beyond me and I can't believe, did I do this right? And now he's teaching it. He obviously was doing it right, he just did not have any confidence coming in. But now he's teaching it. That is a success story. He should be on a poster. So I think, and then you have Jordan who's an actual physics major. So I think that diversity is helpful. [0:43:00]

INTERVIEWER: And you and Polo (ph) knew each other before being L.A.'s, right?

RESPONDENT: Yeah.

INTERVIEWER: Did you convince him to be an L.A.?

RESPONDENT: I think we convinced each other. Like, we were both considering applying. He's like, should we do it? I was like, we should do it. And so, he was like, I don't think he thought he would get it. I was like, Vashti loves you. You're, you know, you'll be fine. And so I think we kind of convinced each other.

INTERVIEWER: Okay. And now that you're approaching the end of the semester, do you have a sense for what parts of being an L.A. that you have improved on?

RESPONDENT: I think knowing what answers to ask, or what questions to ask. Not answers, obviously. Whoo. Like, trying to think about it from a student perspective. Because coming in, you don't really know how other people are going to think. You just know how you think about it. But I think now, towards the end, I have a better idea of figuring out what students are doing wrong, how to broach that subject, and trying to, the reasons maybe why they're doing it that way. I think I've also, there are a few kind of difficult personalities maybe. And being able to handle those. Social skill. [0:44:31]

INTERVIEWER: Yeah. Can you describe some of those interactions?

RESPONDENT: I think there's a lot of people, Vashti calls it, they don't want to play the game. They think they know everything and they just want to brush you off. There's a lot of haughty eyebrows going on, and I know this is the answer, so. And I think just asking them more questions and being like, so why is it that? Almost kind of like adopting a similar attitude, like well, show off then. Tell me all about it. And then they start to see that maybe that isn't what's going on, in that situation, and just trying to not shatter their confidence, but try and convince them that they need to look a little more deeper into what they're doing.

INTERVIEWER: Gotcha. Was there anything you did for the first time as an L.A.? [0:45:23]

RESPONDENT: I mean, I had never led a group discussion, that was really interesting, I think. Because I've done a lot of split board meetings. And just trying to engage not as a fellow student but as an actual teacher, getting them to what they need to know, leading them, that was a different interaction for me.

INTERVIEWER: And I remember, there was one day where Vashti couldn't teach, and you stepped up and you led the class.

RESPONDENT: Yeah, that was crazy.

INTERVIEWER: Tell me about that.

RESPONDENT: That was kind of crazy. Because I felt like as it was going on, I felt like, this is crazy. I felt like this isn't working. But at the end everyone was like, yeah, that was good. I think we all got it. I was like are you sure? I don't know. I just, as an L.A. I'm fine just kind of staying at one table if I need to for a longer period of time, because I know Rahul (ph) or Vashti, somebody will get to the other tables. But when you're the lead instructor, you have to make sure that every table is getting to it and being able to extract yourself from conversations, and make sure that everyone is getting what they need to know. [0:46:33]

INTERVIEWER: Gotcha.

RESPONDENT: So that was a whole 'nother thought process, I guess.

INTERVIEWER: Did you get any feedback from students?

RESPONDENT: I don't think so. I'm not sure I wanted feedback. I think that was the first or second coding and a lot of students were frustrated. They left visibly frustrated. I tried, anyone that I thought it would help to talk to, I tried to stop them and, like, did you get it? But anyone that seemed like maybe they should just go home, or, you know, just go sit down for a while. So. [0:47:10]

INTERVIEWER: Is there anything you would suggest for future physics L.A.'s?

RESPONDENT: I guess focusing not so much on the right answer, but the actual thought process. And what comes before the answer, like all their models and things. When I was grading, I graded the past three weeks, and a lot of people could get the numbers and things to work. But their free body diagrams would have the box accelerating into the sky or something. So there was a disconnect between understanding how to model the situation and how to actually get the answers they wanted.

INTERVIEWER: And if you could go back in time and talk to your former self, as they're getting ready to start LB273, what would you tell them?

RESPONDENT: Just calm down. It'll be fine. You know, I think there was a lot of apprehension, if you don't know things going into the course you're not going to do well. Like if you don't understand biochemistry before going into biochemistry, good luck. But I think with physics, it's designed as an introductory course, and they really take that into account, that you haven't had physics before. And I think just having confidence, it's really just your ability to learn that is, that's the only thing you need. Is you need to be able to learn. You don't need to know physics. And so just having that confidence. [0:48:35]

INTERVIEWER: So I've reached the end of all my questions. What's been the highlight of these three semesters?

RESPONDENT: I just really have enjoyed being a teacher in the classroom. I find that enjoyable. And talking with students, and when they get it, that feels good for the day. So.

INTERVIEWER: Do you think before teaching you were still going to plan on teaching in the future, or now it's a little more solidified? Has it affected…

RESPONDENT: I think I want to teach in the future. It's just a matter of if I would have the opportunities. Am I ready? I think this has helped cement, yeah, I think I'm qualified now for future positions, and I have something to draw on and show people, you should give me that position. Because I, you know, I can do it.

INTERVIEWER: Awesome. Awesome. Well, Maria, it's been great. Anything else you want to share with me about the course, teaching, the students, fellow L.A.'s, anything? [0:49:42]

RESPONDENT: I don't think so.

INTERVIEWER: Okay. Well, you're free to go. What are you doing for the rest of the day?

RESPONDENT: I'm going to class.

INTERVIEWER: Are you buying a Cambridge shirt? That's the first thing. Sweatshirt, right?

RESPONDENT: Always. So, but the part, it's like a conditional offer, is what they do. That's their acceptance. So you have to provide your transcripts when you complete your degree. You have to be able to afford it. You have to sign something saying you'll pay for it. So, I have to look at all that. And I have to get my portal thing figured out, so I can see what the conditions are. So yeah. But.

INTERVIEWER: It sounds scarier than it is, but I think it's just boilerplate stuff.

RESPONDENT: Yeah, I think so too.

INTERVIEWER: But they make it sound really scary.

RESPONDENT: From what I can tell, in the U.S. this would be considered and acceptance. Because all the grad schools here do that too. Like, they just call you accepted.

INTERVIEWER: Yeah, they just have the little box at the end.

RESPONDENT: Like, you have to do all this.

INTERVIEWER: Exactly.

RESPONDENT: Before you can actually show up at our school.

INTERVIEWER: Before the end of the first semester, you have to have your transcript in or something like that. But yeah.

RESPONDENT: So yeah. Then I have to go home and start looking into Cambridge.

INTERVIEWER: Yeah. Is your family excited that you're leaving?

RESPONDENT: So, my family is an interesting one. So my mom actually lived in DC for a year, my freshman year of college. So for a year it was just my dad and my brother at home. And four years before that, we had moved to Ann Arbor. So my dad was up north a lot, so it was just my mom, my brother and I. So we're pretty used to people coming and going.

INTERVIEWER: Cool. That's going to be great.

RESPONDENT: My mom thinks she can work remotely from the U.K. That's what she's decided.

INTERVIEWER: I don't know if you want it. It's all right, mom!

RESPONDENT: She's not as clingy as other moms.

INTERVIEWER: Is she more like a friend?

RESPONDENT: Yeah.

INTERVIEWER: Are there any celebrities in Cambridge right now?

RESPONDENT: Oh, I'm sure. I'll have to check. There probably are some pretty amazing professors.

INTERVIEWER: Keep in touch. When you're hobnobbing with the (inaudible at 0:51:39) folks.

RESPONDENT: Yeah, we'll see.

INTERVIEWER: Have a great one.

RESPONDENT: Yeah, you too.

**END TRANSCRIPT**

## APPENDIX P

## TRANSCRIPT: MILES INTERVIEW 1

1 "So, orgo lab huh?"

2 "Orgo lab, not a fan. Biochemists, I'm just afraid of orgo, organic chemistry I do not. I'm perfectly content in my research lab."

3 So what research lab do you do now?

4 I'm in a biochem lab.

5 "Biochem lab, ok."

6 "I don't know if you've ever heard of David Arnasti but, I work for him, and he's the greatest human being I've met in my entire life."

7 The greatest human being you've ever met?

8 "Well, one of the greatest human beings."

9 Ok.

10 He's a very good guy, I really like working with him. So that's cool.

11 What do you do?

12 My mentor is the assistant professor, she's really busy, she teaches at LCC, so she's been really busy so, the whole lab just focuses on RBF, which is a repressor protein in, it was one of the conserved repressors in fruit fly and in human genomics and things like that. We focus on that repressor. There's a whole class of genes that are conserved in both too, it has to do with, especially in cell cycle and things like that. They think these genes have to do with cells going haywire forming tumors and cancers. We're looking at these classes of genes and trying to mutate them. It has to do with polarity genes. My specific project is a gene called Veng, I have to mutate it and transfect it into cells and see what happens.

13 That sounds so cool!

14 It's very cool, when I came into it I was like, I'm going to be washing dishes and stuff. I actually am doing real stuff.

15 That's fantastic.

16 First, a general one, can you tell me a little about yourself?

17 Um..I'm a junior here at Michigan State, I'm in the college of lyman briggs, My major is biochemistry, I'm gonna pursue a minor in Italian and bioethics, I like biology a lot, it's probably my favorite science. Is that, what else?

18 That's great! Bioethics and biochemistry seem like they go together, Italian?

19 "Yes, I come from a very big italian family. Family is very important to me, my family still lives in Italy, Growing up I heard grandparents, aunts, and uncles speaking it to one another. We picked up on little things, mostly swear words. I was really interested in master it. I'm not going to master it because I'm too old. I'm pretty proficient, I spent two summers ago in Italy, and that was really cool, I studied there for 6 weeks, my family still lives there, so I stayed with them for another 3 weeks. I was there for 2 months. It was the greatest time of my life. I'm trying to go back there this summer with some kind of internship or something. We'll see.

20 Fantastic, um… so… you're in bio, you're a bio major, so what courses are you taking other than orgo lab?

21 "I'm a biochem major

22 Oh Biochem, sorry.

23 I have physics right now, biochem —advanced biochem, the one biochem and engineers have to take. um… HPS and the target of that class is environmental or nat., environmental? It's, i can't remember the exact name of it but it's basically just how we look at environment, wilderness, and things like that. And then I'm also taking Orgo 2 lab."

24 Okay, cool. A lot of courses.

25 Yeah, I'm most nervous about physics to be completely honest, I've never taken physics before, never so, and It's just a very different way of thinking about things, and I don't. It's interesting to see, you hear horror stories about physics and how, especially here because there are lyman briggs kids who will not take lyman briggs physics because they heard it's so bad. And so they take the regular, general university physics, and so I was really worried about that. I don't know but then my advisor, Kent, he talked me into taking this physics because it was changing the, you guys were changing the curriculum, not you guys but whoever was changing the curriculum. And more interactive and things like that. So I said ok, I'll give it a try. but I'm still nervous because I have no, my foundation is like intuition on things moving, you know what i mean, I've never really looked at all these different graphs on one thing. So that's been a little different for me.

26 So what classes did you have exposure to in high school, like what science classes.

27 Yeah I know, everyone is always like, you didn't take physics in high school? I'm like no. We only had like. Freshman, in my first year I did

chemistry, or maybe it was biology, and then my Second year i think i did honors chem, 3rd year, i did comparative anatomy and physiology, and then my 4th year, oh I took AP bio."

28 Okay

29 Yeah that's what it was, okay.

30 Great, so this will be your first physics class.

31 This is my very very very first physics class.

32 Exciting

33 Nervewracking, all these other kids have this foundation, like they understand certain things, and I've never even seen these, half of these equations, and i'm like okay.

34 So you've heard the horror stories, you decide to take lyman briggs because of the advisor's recommendation that it was going to be more interactive.

35 I really thought it was interesting that we don't have like an actual lab, and how she kind of explained the first day of class, how we wanna, i want you guys to do physics, and i was like ok that's cool. it's been pretty cool i think. I like it.

36 Do you like that kind of learning style?

37 I do, and I thought it was really cool, especially the other day, I kind of had an "a-ha""moment, when we were looking at the position graph, the what was the middle graph, the velocity graph, and the acceleration graph. It was so much more, it was so much more simple to see how they're all derivatives of each other. You can go any way, the derivative or integral. you know things like that so at least for me I thought that was very useful, because you know you hear that it's calc-based or things like that and you don't really understand what that really means but seeing it on a graph, something you can visualize, I'm a visual learner, i could see it. There was another kid in my group, he's really good at math, so he was explaining to me, oh yeah, look, so the area under the curve is like this and i was like ""Oh my god!"" so I thought that was really cool!"

38 That is really cool. so it seems like you have some background in calculus that the derivatives and integrals were coming from.

39 Yeah I took, my first two years here i took, or no, just my first year i took, uh…calc 2. so that's all. yeah, cause i had calc in high school and then i tested into calc 2 and then i just took that and that was it.

40 Great, so um… I'm curious what the class looks from your point of view. Can you describe for me what you did in class yesterday?

41 So yesterday we did, um…, we got in our groups, and we had to whiteboard, oh yesterday, ok yesterday I was a little like, that's the day, ok yesterday, I'm going to be honest, yesterday I was a little {sharp intake of breath}, because that's when we started getting into the equations and things like that. I think I'm not giving myself enough credit. I think I know it, I just have to practice it. I think that's what I'm most worried about right now, but anyways what we did was we basically like she said, formalized everything we were working on last week, with all these different graphs, what each means, and how they're all derived from each other. i liked how we did it in numbers first, they gave us a graph and told us to find anything we could from the graph, so then, obviously we cant get everything, but it was cool how you can just get all this information from one graph. so first we did it with the numbers from the graph, no it was the other way around. First we did it in concepts, then we did it in numbers. We put variables in. So we got the actual equations, the real equations. The ""physics equations"" [hand quotes] that everyone's afraid of. Those ones, that was the last thing we did in class.

42 So I know you guys um… work in groups in the beginning, um… so is it mostly group work in the class?

43 Yeah, I think it's all group work i mean, i dont remember anytime doing anything by myself besides the pre like surveys and stuff like that but other than that it's been pretty much just been group based, which has been cool.

44 OK, so um…were you working on like worksheet for most of the day?

45 Yeah, it was um… what we were doing a lot with the sensors and walking away from the sensor, and kind of understanding the positive direction with positive acceleration, you know things like that. so that was, that was that, and then we had worksheets to fill out with that and all these trends to see how they relate.

46 So you said at the end of this, um..the class came to um… the physics equations, so how did that happen?

47 It was just i think, she asked us to look at this graph and we just kind of did it together as a class. Which was cool, it was cool because some kids really knew what they were talking about, the kids who have obviously had physics before. It was cool to hear and see how it all related I guess.

but yeah it was the real equations and stuff like that. i mean i I was so tired on monday i was like oh my god {groans}, so i was dragging and i was getting intimidated because I've never seen this stuff before. but i mean like i said, I think with practice maybe it will come a little easier with for me.

48 So um… How did you handle kind of being kind of uneasy with the…

49 I just sat uncomfortably to be honest with you, for a little while. I just kind of talked to my friends after class. cause the group i was in i knew a few people in the group and so we were just talking about how we're nervous, or how I was nervous and they were giving me positive reinforcement. saying it'll be fine, so…

50 Are there opportunities in the class to kind of check your understanding?

51 Yeah, the, OK one of our TA's, her name is Anna, she is so, like she's so thoughtful, and i'll just raise my hand, she'll be right over and it's just I like how she explains things, i might be biased i don't know, but she's so nice, and everytime i've been confused about something and i've raised my hand and she's come over, cause when we get confused it's mostly like a group consensus confused because obviously if no one in the group knows it it's not going to be a productive discussion of how to figure it out, so that's why we call TA's over and stuff like that. so we called her over um… a few times and she just like will walk us through things and concepts and things like that, and ask us questions and why things are the way they are, so, and so she has honestly helped the most of my understanding of the general concepts and things like that.

52 And so there are times where like the group is not able to reach a consensus [oh for sure yeah], can you describe one of those moments?

53 Um…ok so, we were trying to figure out, we couldn't under… we weren't wrapping our heads around acceleration at first how when you're slowing down, the velocity and acceleration are in opposite directions, we were really not understanding that and i dont know if jumping right into the graphs, because to me it seemed like we were expected to just jump right into these graphs and do what we did with the motion sensors, but it was just with position and velocity, so that was pretty easy, but when we added acceleration in there, that's when it kind of got a little and when we were doing the graphs first for this particular accelration concept, for me, i felt completely lost, and so, that's i think a foundation, starting this whole concept of acceleration, feeling lost and like oh my god what is going on right now, and how it's saying slow down and speed up, like ok, what is going, just like, and then we had a discussion and at least in my opinion, i dont think it was very proactive, she was asking us like ok what are some laws and rules you can make, to me i didn't think it was proactive because i wasnt seeing anything, and even though she was trying to like trying to like put people's boards and stuff, just me personally, i could not see it. so maybe it was good, but for me, i was not seeing it at all.

54 And then we had another worksheet to work on in groups on the same concept of acceleration with velocity, position, and things like that, and like i said, our group, we had no idea why accelration, one of the graphs had negative acceleration, we had no idea. so anna, she came over and she was talking, like ok you're driving a car, and you hit the brakes and like that force against you and it, then she didnt obviously give us the answer, but she wanted us to walk through it and she did and then at the end she formalized like ok so when you slow down, it's the velocity against the acceleration, it's like opposite forces and so. for me that helped my understanding more than the discussion before that. but yeah, our group was very, we had no idea and we were all, and

55 for me so far, what i feel in physics i feel like it's ok to overthink a situation but like you can take it to a whole different extreme. because i know specifically, I overthink everything. and so when i'm trying to, when I think about physics problems, sometimes I will overthink. and i felt like We were all just overthinking in completely different ways, because we each had like a good point, but, i mean and they all seemed true to me because I'm just taking this class, i dont know like, I've never practiced this stuff in my life. and i mean i don't know if the other people in my group have, but they seemed like they were lost too. THat's why it was like ""OK anna, please come over and help us""" So that was the situation describing.

56 And so, this working on a worksheet, and coming up with rules, is that pretty typical for a day.

57 Yeah it seemed like we did that with the position and the velocity too, and with that i thought that was pretty, i liked that when it was just those two things unless maybe i just understood that those concepts better, i'm not really sure but with the whole acceleration worksheet, i was just like what, what are we doing, why are we doing this. yeah, cause i was, i was just not, and then she was asking us to see these rules and trends, and then she was, she was asking so many quest…like ok, ok so when we raise our hands, and someone says something, that's on their board, it's almost like she questions it, she wants us to answer if it's true or not.

58 If no one's going to get it like, but then if no one gets it, she writes it down on the side and it's almost like she puts it aside and I dunno, in my opinion i wish it was addressed right then and there. I don't like these standing questions all class. There's an extra sheet of paper that literally says questions, and when you look at it at the end of the discussion, there's like 4 unanswered questions on there, that not even the whole class could come up with. For me that's intimidating, that's very overwhelming, and so I just don't like that. I get that she wants us to work through this ourselves, but for me, sometimes I need that lecture, I need that lecture like this is just how it goes. I prefer for someone to go that way. So with acceleration, that was the case. But motion, i mean uh… position and velocity that really wasn't the case.

59 So these um… open questions that are still kind of lingering, they're uncomfortable?

60 I hate them, very uncomfortable.

61 So do you think they'll be resolved or do you think they'll be left to the wayside.

62 I don't know, I think the way the class is going now, they're going to, she's going to keep doing it like that. How she just leaves them aside.

63 Do you think you're ever going to revisit them and have a satisfying…

64 I mean maybe we have revisied them, but to me, I just never get that ""this is the answer to that question"". This is the pull the string moment that she wanted us to get at that we couldn't get at. For me I still haven't seen it for acceleration, and I don't even know what the questions were. So it's hard for me, I guess I should have written them down, but also during class, she puts up whiteboards on the TV's instead of what she's writing down, and I know it's hard to flip back and forth but sometimes that kind of frustrates me too because i dont know what she's writing down. I mean everyone's saying it, but at the same time, I don't know I prefer to see it instead of what this whiteboard says that may or may not be even right. It's the whole concept of like I don't know what's right, and if there's a question, what's the answer, if we can't reach it then it just hangs there for me, so I'm like ok."

65 Is this similar to other classes you've taken?
66 Never, [laughs] never. like it's

67 I guess it's kind of better because, like if you're wrong, if you say something wrong, youre wrong in certain classes, and if you're right you're right. It's kinda like that grey area in every class that you just, it's very not concrete, i don't know it's very different. but um… yeah I've never really had a class where if a question is asked, she just writes the questions, it's always like this is the facts [writing motion] it's like this is a rule in physics, not like ""let's just answer that later"" So that's been a little different, no it has been very different.

68 If you had to guess, why do you think they've structured it this way?

69 I think they've structured it that way because they want us to reach the answer ourselves, I mean because, the way that it works is that, we work in groups, and we kinda see how it works first without really knowing exactly how they all kinda relate and stuff like that. Um..yeah, and so in like discussions. We'll work on something and we'll have class discussion right after basically with whiteboards, seeing everyone's ideas. Since we all did the same thing and saw how it worked, I guess they want us to kind of figure out these rules ourselves. To have that connection to something we'll remember. I guess that's the best way I can explain it, other than they want us to do it ourselves and work through it knowing the very, this is what it is, this is the concept you have to know. I think that's probably why they have us do it.

70 So the rules of acceleration seemed kind of uncomfortable, but you said you felt better with the position and velocity, so did it feel more like you came up with the answer?

71 Oh yeah for sure for sure, with position and velocity, i felt like it was cuz, it was that whole idea of like disp, the whole idea of displacement over time, i for some reason i just understood that because it makes sense, you know, but with acceleration sometimes looking at the graph and seeing like just a straight line it's not, i've never, i've never even thought of if it's a constant acceleration,it's just a straight line, you're going fast you know? you should be "Aaah!", you know? it's not what it is, it's like okay, you have negative to worry about, it's like oh my god. but i mean other than that, it's been pretty good i guess.

72 Where do you think learning is happening, there are a lot of things you're doing, where do you think learning is happening?

73 It's happening right there and then. That one day I was describing earlier, that one day we were comparing all the graphs, and we were looking at how they, like you can get the derivative of this from this, and you can go backwards with the integrla, i had just like a {breaking sound} like a very surreal like a-ha moment for me, and i think i'll remember, i know for sure i've learned exactly like the concept so now i just need for me personally i just need to see like how it works in a problem like that's going to be on an exam. you know what i mean? and so i need to like do it now. that's what i need to do. and i wish we did more of that in class. i wish we did more problems where like okay this is the concept we just learned in a question that is a physics problem that everyone's afraid of. like you don't have to be afraid of it since like you know this derivative/integral, like it was so cool to see.

74 and another cool thing to see is yesterday, even though it was very overwhelming, we looked at how you could do it both in terms of calculus and algebra. and i thought that was very cool, and i cant remember exactly the concept, i'd have to go and look back, but it was uh…, it was oh it was change in position…was it change in position…? i think it was displacement, it was just the equation for displacement and it was just really cool to see how you can do it both ways, you know it doesnt have to be calculus and it doesnt have to be algebra, so i thought that was really cool, that was a learning thing for me too.

75 Um…can you take me to that epiphany where you were looking across these three different kind of representations.

76 Yeah I was um..like everyone was kind of, in my group like i said so, like the 2 girls sitting next to me they seemed like way smarter than me which is fine like whatever, and then my friend was on this side, and then across the table was another guy, he was really, he's a guy that's really good at math, and there was another guy over there and he was just good at physics. and um…like i said when we were doing those graphs and it showed the 3, they were all conversing, i was just, i prefer sometimes in group work to just kind of, especially when i'm not confident on it, cuz i'm not confident with physics right now. and so i was just trying to listen to what they were saying, and um… the girl next to me and then the

kid who is really good at calculus, he's really good at calculus, they were like talking oh integral derivative, and i was like oh god, what is. so i was like can you like explain this to me?

77 and so he literally took like from 0 to 2, and he said ok, on the acceleration graph, and he said ok so the area under this is the integral, now if we go over here, that's what, that's the velocity now. and then we went, and it was just i just, the way i saw it was just so interesting and i've never thought of it that way. and i didn't think, i wasnt understanding how when they were just talking about it, but seeing it on exactly how he was moving it with his fingers it was very very surreal, like it was one of those ah-ha moments. also with the acceleration when anna came to talk to me, it made so much more sense like i was, i couldnt even believe it.

78 This is the speeding up and slowing down?

79 Yeah and like how something can have negative acceleration, i really wasn't understanding that, and it's still not really like but i understood it and especially in that moment i knew i understood it in the way that way i wrote it down in my notes, i can go back and revisit that moment when i understood very clearly so.

80 That's awesome.

81 So those were the two most surreal moments i've had in this class so far and it's only like the second week of school. so i guess that's cool, because i was talking to someone else and they were like oh no {hard to make out}

82 So have you seen any biology in this course?

83 Not yet, no. It's all just been kinetics, or kinematics, I don't know. It's all been movement and stuff like that. and i know i did the reading yesterday was about um… it was kind of like, it was showing us how to program this software to see like a model or python, vpython or something like that. um..but i know i saw on the agenda that we're gonna be getting into that, something with biology so i dont know what exactly it is but it said it on the, i think we're doing it on friday or maybe it's tomorrow, tomorrow or friday i dont know. so i mean hopefully tomorrow.

84 Do you see like physics popping up in your other classes?

85 The only class that, it's interesting because the only class i've seen it so far is biochem. And i thought that was very interesting because, um…it was kind of how, i mean we didn't pull out equations and start to figure certain things out but it was just the physics, we were just talking about um… our first chapter was all about water and how like life today formed err, evolved around just like a molecule, that was crazy for me first off.

86 and second off, um… we were talking about hydrogen bonds and how in solution, water wants to maximize the hydrogen bonds with each other, and so, water can form 3.4 hydrogen bonds with other water in case you want to know, exam next week. so we were talking about how when proteins, um…, like when enzyme finds a substrate, its usually nonpolar segments of the substrate and the enzyme, so that's kind of like how it stays together. and i mean there's other things that go into it, but anyways, the whole point was when you break the hydrogen bonds of water molecules, it's unfavorable, because it's a decrease in entropy, and that's not like a favorable reaction, and so,

87 um… we were looking at or, he was just kind of talking to us about the concept of how it's physics how the water, that it's unfavorable how water is being pushed out as the enzyme and substrate come together, and i just thought that was so interesting and it was almost like i saw it in my head for the first time and i never really thought about that quite that way, and i'm sure that's going to help me in seeing physics in other classes too. cuz biochem, it's all the sciences in basically one class. so i mean i'm sure we'll look at other things like that.

88 this physics she said we were going to talk about chemistry and biology too, so i mean i'm sure i'll see it there too. but biochem is the only class so far ive seen it.

89 And they located that in the entropy kind of favorable thing?

90 Yeah how it's just an unfavorable reaction and you have to compensate with other things, and why that's favorable in some, like making up the loss of entropy of breaking hydrogen bonds is made up by um…bonding with other intramolecular forces and things like that, so, yeah i thought that was interesting because i never really thought about it. and the way i, it was like in that moment i saw exactly what he meant, and at least what i thought what he meant, so i thought that was cool.

91 So zooming out a little bit, um… biology chemistry and physics, do you see them as related?

92 I never really did, now I mean, they have to be. I mean because, I never, like I said, I never took a physics class so I never, I guess I never really because I'm very visual so when I learn something I have to be able to see it in my head. So I never really visualized like I said, water molecules moving away from something, there's obviously driving forces behind it like I said I never really took physics so I didn't know. And I mean, it has to be physics. Like all of that has to be, every kind of movement or, we've only done movement so far, I'm sure they're like other. I mean I think there's like light, I'm like I don't know, shit. And so um.. It has to be, I think physics is a driving force behind everything, it has to be. At least I think so, I don't know.

93 Are there similarities you see between them, or differences? Do some of them share certain qualities? I don't know if that's too vague of a question.

94 No no, I think Chemistry, i can only speak for chemistry and biology because those are the only courses i've taken so far, i've seen similarities there, biology really doesnt focus on chemistry though, the extent of the chemistry is just like knowing the structure of pyruvate, just little stuff like that, why certain things, why electrons are moving, you dont really, you dont know that. and that's why i was really attracted to biochemistry because i was inter…i wanted to, because i love biology, love biology, and so i wanted to know why all of this was happening. chemistry kind of gave a little more insight into that and so i'm hoping physics lends even more insight into that just because of the forces and like all these laws and stuff i've never even known existed. so i guess in terms of similarities i guess its all, i dont know, i guess i really didnt answer the question, i kind of went off on a little tangent. i just dont know if i see similarities and differences between them, i mena they're very different just cuz in chemistry you have to memorize structures and stuff. and you have to know like electrons and yeah i guess there's a lot of differences between biology and chemistry, i think there's way more differences than similarities.

95 OK

96 Like at the very, most general statement, way more differences than similarities. and with physics i really cant speak for physics right now.

97 Because it's your first time.

98 Yeah.

99 I know you said you've covered motion so far or kinematics, um… what physics concepts have you covered so far?

100 Position versus time, velocity versus time, acceleration vs. time, motion maps, and then i feel like that's too general. i mean just kind of like how they all relate. and how this one situation is looked at in like 4 different, very different ways. but it's simplified, you know? and how we have to understand these simplified ways to put it all together in a question or something.

101 Great. Do you see these concepts having connections to like other classes?

102 Um..kinematics, I don't think I can see it now.

103 OK

104 I don't think i can see it right now, maybe with magnets and stuff, when we do magnets, i dont know what that's called, maybe i'll be able to see that a little better because i mean we'll obviously have to be talking about electrons and positive and negative, so maybe then? but right now i havent seen it no.

105 Do you think, um… do you think you'll ever see these concepts like the velocity, positon, and acceleration in your other classes maybe later on or may revisit them?

106 I mean in chemistry we had to work with equations a lot, and like um, the speed of light we had to use in some equation, i dont remember. I remember, especially in the 2nd semester of chemistry, especially when we were dealing with thermodynamics, we were dealing a lot with i dont know if its physics though, but it was we had to like manipulate equations and he really wanted us to, my professor really wanted us to focus on what the right unit was, so like if it was meters per second or if it was like meters squared over seconds, you know what i'm saying? so i mean, i'm sure that's physics, i just dont know exactly how yet i guess. um… i guess that's the only.

107 So you've seen glimpses

108 Yeah i've seen glimpses, and i just, it has to be physics, like it has to be physics, in my mind it has to be physics but i just dont know like how exactly yet.

109 Gotcha, so do you ever think of physics outside of the classroom?

110 No, literally never. We filled that question on the survey and I was like "no", like what the? I mean magnets but I don't know.

111 Do you ever find yourself talking to family or friends about physics?

112 Not once.

113 Or even like about the concepts you learned in class recently?

114 No, {laughs} no.

115 Fair enough.

116 I mean like moved, like no, no i haven't. I 100% have not. I'm a first generation college student so my family doesn't understand sometimes.

117 So right now you're working in a biochemistry lab, you're a biochemistry major, what do you see yourself doing in the future?

118 I want to go to med school. I'd love to go to med school, it makes me very nervous but I mean, I hope I get there. I have a pretty good work ethic I think, so I think I have good chances. I want to make sure I have all of my bases covered before I apply cause i want to do it right the first time.

119 Okay

120 Yeah, I want to go to med school

121 Can I ask why do you want to go to med school?

122 That's the question i've been, I mean I wanted to be a doctor.

<<He tells a story about watching a movie about someone getting hit by a car in NY and a doctor and nurse help in the streets. loves kids, working with kids, doesnt see himself working in biochem lab forever, hospice volunteering, how death can be viewed>>

123 <<Talks about commitment needed to go to med school. wants to concentrate on cardiology>>

124 Do you see yourself using physics in this med school and doctor career?

125 I mean I'm sure I'm going to, I just don't know how exactly. I mean it's one of those sciences that med schools look for, lyman briggs is bacially focused on their students or whatever being proficient in all the sciences, so obviously it's something important. I just don't know how exacty it's going to be used I guess.

126 Do you still have to take the MCAT? This physics part of that?

127 Oh yeah, I actually taught an MCAT review program at the beginning of last summer.
And they were really looking for physics people to like explain, and that was, that was during the class that went through all the classes, i taught a few chapters of biology, and one chapter of chemistry, and then just like in the MCAT they added a new critical thinking section, stuff like that. so i had to teach a few little, they were just like doing problems and stuff like that. but um… physics was like the big one that they had to reschedule certain days around because the people taking the class didnt feel they had enough time to go over the physics part, and that was kind of like the first time i saw physics like right up close, cause i didnt know, and these tutors were pulling their hair out, these kids just looked terrible after the physics parts and they missed lunch a few days, just to do physics, and it was kind of weird but i mean you gotta do it, it's on the MCAT, and that's going to be a huge factor for med school, so i dont know how those kids did but hopefully they did fine i dont know, i didnt have to tutor physics {laughs}

128 So I'm going to ask you this question, um…it may or may not bring something to mind, so no pressure, um… so when I say diffusion, what comes to mind?

129 I think of molecules increasing entropy, so they're spreading out in order to increase entropy. Like that's just the, it's a favorable thing, entropy. Like everything, the natural law, everything wants to spread out, so that's what I think of.

130 So molecules spreading [yes] and increasing entropy. [yes] and you said that was favorable [yes] OK. What's entropy?

131 Entropy is a unit, like they, it's all relative when it comes to that stuff but it's um... it's like, it's one of the laws, is it thermodynamics, the 2nd law of thermodynamics, or the first law. One of the laws of thermodynamics is um... increasing, it was almost described as like chaos when I first learned it in chemistry. How everything has a tendency to inc..., disorder, like you know disorder of the universe, the universe tends to go towards disorder. So that's, at least that's how I learned it in chemistry. I guess I'm just not really good at verbalizing it but I mean I can see it.

132 So where did you learn about diffusion before?

133 Chemistry. Yeah chemistry was the first time.

134 And um... do you remember like kind of like the context in which you learned about, like what topics.

135 Thermodynamics it was like uh... yeah it was, it was...Oh wait maybe I'm thinking of entropy. Can I use that?

136 Sure

137 But wait it was diffusion [yeah] Honestly

138 I think entropy was thing you talked about {hard to make out}

139 Yeah I think actually the first time I learned about diffusion might have been biology, how like going, it was a lab when I was a senior in high school in AP Bio, how water could pass through selectively permeable or selective permeable membrane, and not certain other um... bigger molecules, i think that was the first time I learned about diffusion. And then entropy was chemistry, i didnt know anything about entropy till freshman year here in chemistry so i was in college.

140 OK, Are there things about diffusion that you may still not understand?

141 I'm sure there are, I mean i'm sure i've only scratched the surface of all this stuff I mean...god!

142 I can rephrase, are there things that are confusing

143 Hm...I mean i guess like why it happens, i mean i know why, i can say because of entropy because you discetely...it's favorable to increase disorder but i guess i dont know why exactly that's a thing. and i feel like that's why physics comes into play because that's the driving force behind all this movement, i think? i'm sure it is, it has to be, it has to be, because even when you look, you type, in organic chemistry like the moving of electrons, that has to, it has to something with like charges or like i mean it does have to do with charges but like why you know, like why did that even happen, like why did the world evolve for...yeah. so it has to, it has to be physics, it has to be, i just don't know how.

144 So I've got to ask, you mentioned it has to be physics, so where did you get the idea that, or hm... how can i ask this question. um...why do you think so, you said it has to be physics, it has to be physics somewhere, um...can you describe what you're thinking when you say that?

145 Yeah i mean i guess, i'm very, i feel, at least I personally like to pride myself in saying that i'm very analytical, and I like to know exactly why things work. and I guess there's so many things. i think that's people, that's why a lot of people are afraid of the sciences because there's, it's so hard to say exactly why without knowing so many different concepts at once. And so i mean The more I've learned it's easier to visualize all this stuff in my head cause I've said I'm a visual learner and so um... but there's still so many different things that i can't really see why like even the moving of electrons, like why that, why exactly that's happening, it has to do with different charges and things like that but there's just, there's a piece there that i feel like is still kind of, i don't know, it's just,

146 OK, in biochemistry, we learned about, it's called proton jumping or um... er... uh... is it proton jumping? i cant remember the exact name of it, but basically it has to do with the uh... electrons jumping from different er...yeah electrons jumping from different hydrogen atoms, i think. and so that was like, that's one of those things where it's like, why? you know like {shrugs}, cause i don't know, cause everything is just made up of these little thing, i don't know, i'm, i don't know {laughs} but i think it has to be physics because cause i feel like there's so much that, there's a piece of it that i'm not seeing yet.

147 but there's something making it do it, and you're thinking that physics {crosstalk}

148 Yeah, i guess all my responses are very biased towards like chemistries and the biologies and things like that but i mean physics has to do with like your car moving and things like that {collides hands} hm... forces that's stuff i really don't understand yet but yeah i'm sure, maybe that's why i don't think about it, i don't understand it, i don't know, maybe if i understood it better i'd think about physics outside a little bit more but i don't understand it right now so, i've just never been exposed. you know so i'm ignorant, i'm ignorant, i don't know, i don't know {laughs}

149 I don't know if i'd go that far um...how would you say um... the class is going so far, are you enjoying it?

150 Yes, i am enjoying it, like i said i don't like the standing questions, i think that needs to change, like i cannot wait for evaluations cause that's the first thing i'm writing down, that has to change. That gives me so much anxiety i just cant even i hate that. i really hate, i think i want a question addressed right there and then, i don't like these standing questions.

151 how would you say you're doing in the course.

152 <<talks about issues with LON-CAPA>>

# APPENDIX Q

## TRANSCRIPT: MILES INTERVIEW 2

# TRANSCRIPT OF AUDIO FILE:

# MILES-INTERVIEW2-11.15.16

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*The text below represents a professional transcriptionist's understanding of the words spoken. No guarantee of complete accuracy is expressed or implied, particularly regarding spellings of names and other unfamiliar or hard-to-hear words and phrases. (ph) or (sp?) indicate phonetics or best guesses. To verify important quotes, we recommend listening to the corresponding audio. Timestamps throughout the transcript facilitate locating the desired quote.*

**BEGIN TRANSCRIPT:**

RESPONDENT: Yeah, all right.

INTERVIEWER: We haven't really chatted since the first interview.

RESPONDENT: No. Just been surviving this semester.

INTERVIEWER: Surviving, huh?

RESPONDENT: Yeah.

INTERVIEWER: Just surviving?

RESPONDENT: Yeah. It's been a rough one.

INTERVIEWER: It's been a rough one?

RESPONDENT: It's been a rough one.

INTERVIEWER: What's been going on?

RESPONDENT: Just my classes are really hard. Even this class. (Chuckling) So. But other than that, I mean, all is well.

INTERVIEWER: Yeah.

RESPONDENT: What are you going to do? Long-term investments.

INTERVIEWER: Sure. How does this week look for you, and the next week? Or the half the week?

RESPONDENT: Honestly, I was just thinking about how busy I was this week. Because yesterday, I had – I have class all morning and then I work at 6:30 at night. But then in between –

INTERVIEWER: Oh, wow.

RESPONDENT: – yesterday, I had to do part of the experiment that I'm working on today. So I was at – so I was gone all day.

INTERVIEWER: Yeah.

RESPONDENT: And then today, I had a meeting with my lab boss. And then I went right to Orgo lab. And then I had to go back to the lab and do another experiment. Now I'm here, and I have class tonight at five. And then tomorrow, I have – I'm sure you don't even care, but I just –

INTERVIEWER: I do.

RESPONDENT: – I'm just –

INTERVIEWER: (Crosstalk)

RESPONDENT: – going to run through this for you. [00:01:06]

INTERVIEWER: No. I (inaudible at 00:01:06) (chuckling)

RESPONDENT: (Chuckling) I have to plan every second of this week out. And it's my – I've got class all morning, and then I have to go – I have to be in Howell (sp?) to visit my hospice patients, and then I have an interview for my other job. Like, at – the front desk job. And then I have to go to work at 6:30. I'm probably going to be late to work. I'm probably going to get fired. No, I'm just kidding. I won't get fired, but – and then Thursday is another busy day, which is classes and then being in the lab. Then, on Friday, same thing. I've got to go home, get a haircut, and then I've got the exam on Monday. I'm supposed to go to the Lion's game on Sunday with my friend's family. I'm just like, "I have no timeframe."

INTERVIEWER: Yeah. That's, that was an impossibly busy schedule.

RESPONDENT: Yeah. And on top of it, I'm very sick, so –

INTERVIEWER: (Chuckling)

RESPONDENT: I'm living.

INTERVIEWER: (Chuckling)

RESPONDENT: I'm really living.

INTERVIEWER: Yay. You'll get through it. And I said this interview – it's maybe a little different from what we did before. [00:02:02]

So I'm going to ask you about things that you've been asked to do in class. So, a stack of activities that you've done, and I'm going to run through what your thoughts are on it. You'll hear me repeat the same sort of questions for each one. Hopefully, it doesn't get too tedious for you.

RESPONDENT: Okay.

INTERVIEWER: And so first, I'd like to start with this one. I think it's the Investigating Collisions.

RESPONDENT: Okay.

INTERVIEWER: And first, if you have any thoughts –

RESPONDENT: Was this the lab that we had to do?

INTERVIEWER: I think so. It's a lab investigation. Yeah.

(Pause from 00:02:32 to 00:02:37)

RESPONDENT: Okay. This was like, the first lab that we did, right? I'm almost positive. Because we did two with, like, the front claim that the SUV was safer. Yeah. First instruction model situation.

INTERVIEWER: Yeah. I think it says your friend –

RESPONDENT: Yeah.

INTERVIEWER: Yeah.

RESPONDENT: I think this was the first one. [00:02:59]

You know what? I think I struggled on this one.

INTERVIEWER: Okay.

RESPONDENT: Just because it was the first lab. And to be quite honest with you, I didn't even know that we needed, like, a specific research question. I mean, luckily, the group I was working in, we kind of formed one innately. We just said, "Okay. At what point – " Actually, because then she started to talk in class about how the report – the first set of reports she saw was – they were terrible, basically. And I was like, "Shit. That's my report. Like, for sure." Then she was going through, like, the things she did and then didn't like during class specifically. And she pointed out our specific research questions. So I'm like, "Okay. So maybe I didn't do as bad." And I – after –

INTERVIEWER: As an exemplar –

RESPONDENT: Yeah. As like a, "Do this." So, I was glad that we did that. The only thing that I'm still struggling with, even on the second write-up, was the starting model. Starting models, I guess, just – I'm struggling with that. [00:04:00]

So I'm going to have to work on that for the research (ph).

INTERVIEWER: Like, as a conflict? Like, as a – work?

RESPONDENT: Yeah. I guess I just – because I thought for this one, especially, I described it well. But I still got points off of describing –

INTERVIEWER: Oh, I see.

RESPONDENT: – the starting model. So, I don't know. I'm going to have to talk to her a little bit more about that. But I mean, this lab, I think, was okay. Like I said, the question I didn't know that we needed a specific question – and then I felt like we were just – yeah. I don't know. It was the first one. So we just kind of threw ourselves into it and said, "Okay, I guess we'll – " and then the L.A. – or the T.A.s or whatever – were picking stuff out and helping us along the way. So. And then I think –

INTERVIEWER: Great.

RESPONDENT: – all went well for this one. For the most part.

INTERVIEWER: Hm. Why do you think of the instructors have you do activities like this?

RESPONDENT: Well, I mean, ultimately, I think it's just to form the laws that form laws. Or, not "form," but I guess "expose" the things that would be in, like, a lecture. [00:05:04]

So, like, instead of just given an equation and going through practice problems during class or something, we're given something that will help us find out the answer. The, find out that equation. You know what I mean? Like, it's a, stepping stones to get to somewhere that – or, like a, one of the toolkit – or, tools that we need in our toolbox, or something like that. So I think that's what these are about. Because, I mean, the, one was about collisions, and then the next one was energy conser – was it energy conservation? It was something with energy.

INTERVIEWER: Uh-huh.

RESPONDENT: So. Yeah. With force. So, I mean, it's like seeing these different things, I guess, that we would normally just be told about.

INTERVIEWER: Okay. And what's different here? You said "exposing."

RESPONDENT: Yeah.

INTERVIEWER: Can you unpack that for me a little bit more?

RESPONDENT: This class is all about unpacking, huh? [00:06:02]

(Chuckling)

INTERVIEWER: (Chuckling) Have you heard that term before? Is that –

RESPONDENT: I've heard it, like, 20 million –

INTERVIEWER: Okay.

RESPONDENT: – times.

INTERVIEWER: (Chuckling)

RESPONDENT: Like, because the only way we'd know if one was safer than the other, we'd have to create a starting model for that and then run trials that vary different things. So we'd have to figure out, "Well, first, how do we determine safety?" Well, first we have to figure out the – well, no. Actually, the, "How do you determine safety?" and then figure out your trials that would show dependence on whatever your independent variable is.

INTERVIEWER: Uh-huh.

RESPONDENT: You know what I mean? So I guess exposing these laws or these big, like, gen – overarching themes in the class of physics I guess would be like that. I don't know if that makes sense.

INTERVIEWER: I think so.

RESPONDENT: But just kind of like looking at our results and seeing, "Okay. So, velocities were pretty much – " I don't know. [00:07:04]

Just because when we were doing this one, it was all about momentum. So we had to see how, like, how first momentum was – how both had momentum, and then how, what it looked like after they collided, and things like that. So, we came to the law, "Oh, momentum is conserved." So.

INTERVIEWER: I see.

RESPONDENT: I think it's things like that.

INTERVIEWER: Mm ‘kay. Do you find activities as this valuable?

RESPONDENT: The first one – I guess the first – like, the beginning of class. I can’t – like, I feel like at the beginning of class, I was still a little lost with what was going on. I was still trying to get used to the class. I still don’t even think I’m completely used to the class, to be quite honest with you. But I mean, I feel like they do help. It helps me when I can personally, like, and slowly think through something at my own time. [00:07:59]

INTERVIEWER: Okay.

RESPONDENT: Because these – I mean, these experiments are supposed to be – we’re supposed to think through them and then form trials based on that. Sometimes – I mean, af – I think this lab, especially, I was in a group with two really smart people. And they were just flying through it. They both had physics before. I was like – so, I was still missing the entire point of this lab. I remember that very specifically. Then, when I want, needed to write the report, I was like, “What am I doing?”

INTERVIEWER: Yeah.

RESPONDENT: But then for the second lab write-up, I was at a different group and I was the one who, like, came up with the ideas and stuff. I was hap – so happy with my experiment. And, I mean, it turned out really well, so.

INTERVIEWER: Great.

RESPONDENT: I guess they work for me when I can go at my own pace with it.

INTERVIEWER: Okay.

RESPONDENT: But sometimes I feel like that’s lost when you’re in a group that, with really smart people. Because really smart people who’ve had physics before, they’re going to look at this and be like, “Okay, yeah. Of course. Why?” You know what I mean? [00:08:58]

INTERVIEWER: A. Yeah.

RESPONDENT: So, I think there’s just ver – there are a lot of different – everyone is at very different levels in the class, and it’s hard to keep up sometimes with different people. So.

INTERVIEWER: Okay.

RESPONDENT: With the – and if you’re asking about this one specifically, I was completely lost on this lab, to be quite honest with you.

INTERVIEWER: But in the labs that you’re able to take the lead on.

RESPONDENT: Yes. Like, the second one.

INTERVIEWER: That was not –

RESPONDENT: I was – I felt very comfortable –

INTERVIEWER: Okay.

RESPONDENT: – with the second one. And I was ver – I, like, flew through the lab report. So. I did well on it.

INTERVIEWER: That's great.

RESPONDENT: Minus the starting model. I'll never get the starting model.

INTERVIEWER: (Chuckling) It was going to honor (ph) you.

RESPONDENT: That ohm.

INTERVIEWER: How do you think mathematics plays a role in these investigations?

RESPONDENT: Like, applied math, or just looking at data? Like, we have to use it –

INTERVIEWER: Who cares what your, what you call math? Like, what do you think?

RESPONDENT: (Crosstalk)

INTERVIEWER: Yeah. What you see as mathematics.

RESPONDENT: This one in particular?

INTERVIEWER: Sure. Or, if you want to expand to investigations in general, that's okay as well. [00:10:02]

RESPONDENT: Sometimes –

INTERVIEWER: Some of the graphics didn't load up.

RESPONDENT: Yeah. That's okay. Sometimes I don't really know – mm, for this one in particular, I don't think I really thought of math at all.

INTERVIEWER: Okay.

RESPONDENT: Yeah. No, I didn't, because I was more interested in the graphs and seeing what happened after the collision and then right before and stuff. I guess when I really was looking at math, I was looking at math on the second one when we had to see – I – God, I have to recall. We have – we sent a car down a ramp –

INTERVIEWER: Mm-hmm.

RESPONDENT: Oh, and then we were trying to see – so, first we were trying to see if the, if there was a point at which we could raise the ramp in a sm – in, like, a lighter, smaller car could go down it and then hit a big SUV or whatever. [00:11:02]

Which was just double the mass of the regular one. And so we were trying to find if there was that point where there would be more force applied. Obviously, we didn't find that, because force will be even, upon the collision. Just because this one's coming down, it won't exert more force. So, we were testing that. We didn't know that. Which was useful for me, because I didn't know that, and I still was like, "Oh, yeah. This one will have more force. It'll be traveling down –

INTERVIEWER: Yeah.

RESPONDENT: "No problem." Then we look at our graph and, same number. And then we were trying to find at how that – we were trying to figure out how the acceleration – like, if we increase the acceleration. Or if we increased the m – yeah. If we increased the acceleration, by how much would that affect the force. And we kind of looked at that throughout all of our trials. Just because we kept the masses the same so we would only be altering the acceleration based on the height of the ramp. [00:12:00]

And then the force that either exert, exerted each other upon the collision. So, I guess in terms of math, we were, kind of looked at that. Vashi (sp?) kind of helped us, like, unpack that. That we could look at it as, "Okay, so you double the mass. And so from this acceleration, this will happen. From this one, this will happen." And then I guess looking at it that way. And that was the only time I remember looking at math at an investigation.

INTERVIEWER: So what are you pointing to when you say that you're using math? Is the kind of –

RESPONDENT: Like, the "Force equals M times A." So, the force equation. And so we looked at, "Okay, so the force was this. What was the acceleration?"

INTERVIEWER: I see.

RESPONDENT: So, like, da – so, if we increa – so, if the ramp was at, like, 5 centimeters off the ground, it would be this acceleration, which would give this force.

INTERVIEWER: I see.

RESPONDENT: And then we predict the second force based on the acceleration going down from, like, 10 –

INTERVIEWER: Got you.

RESPONDENT: – centimeters, which would double the acceleration. [00:12:59]

INTERVIEWER: Okay.

RESPONDENT: So the force would be double, basically. So everything would be proportional based on the acceleration. I guess that's what I was getting at.

INTERVIEWER: Okay. And do you think biology or chemistry play a role in these lab investigations?

RESPONDENT: I'm still trying to figure it out. Because I – I was getting excited whenever we talk about how it's going to be like chemistry. Because I'm very comfortable with chemistry and I'm like, "Yeah, this will work." But I, especially for the one where we were trying to simulate chemical reactions and we had to keep – what we did, we did three simulations. We did two balls. Then we had to figure out the P transfer equation.

INTERVIEWER: Uh-huh.

RESPONDENT: So that really wasn't a chemical reaction, because that – like, in reality, that one happened. I don't – I mean, unless it does with – we were thinking HCL and water. Like, I don't know. Never mind. I don't know what I'm saying. And then another one was that we had to keep them in a box. [00:14:01]

INTERVIEWER: Mm-hmm.

RESPONDENT: Then, another one, we had to – I forgot what we had to do for that one. But I'm still trying to fi –

INTERVIEWER: I actually have those –

RESPONDENT: Oh, really?

INTERVIEWER: – here. Yeah.

RESPONDENT: Oh.

INTERVIEWER: So –

RESPONDENT: Okay.

INTERVIEWER: – we'll get to them.

RESPONDENT: Okay. I'll try to think of –

INTERVIEWER: Yeah. Absolutely. Yeah.

RESPONDENT: – other things, then.

INTERVIEWER: Well, no. I mean, like, investigations, though. Like –

RESPONDENT: Oh, in this? Oh in –

INTERVIEWER: Yeah.

RESPONDENT: Okay. These ones.

INTERVIEWER: Like these lab investigations that you do. And I think we're going to talk about the coding in a little bit. I'm curious if you see biology or chemistry playing a role.

RESPONDENT: In this one? No. And then in the other one, no. Anything with collisions, no bias – bio or chemistry. No. None of that. (Chuckling)

INTERVIEWER: Fair enough.

RESPONDENT: (Chuckling)

INTERVIEWER: Do you think doing investigations like this represents what it means to do physics?

RESPONDENT: Yes. Yes, because I think – because I mean, especially the ones with the f – I think for me, this lab is blurry still in my head. I don't think I really wrapped my head around what we did and why we did it, to be quite honest with you. [00:15:02]

So it's hard to speak about this lab in particular. But I know about the second one. The one that I personally thought about a lot. I think that one, it's really clear to me that you'd have to do something like that to see – like, because how would we know about the, that the force will be – like, the force that this one will exert on the parked car. How would we know that the force this one would exert on that one would be the same?

INTERVIEWER: Mm-hmm.

RESPONDENT: You know what I mean? So I guess with our tools and stuff, like the IO labs and whatever, and the whiteboards and weights and things like that. I mean, you kind of have to do that to see these things. And I mean, some people, I'm sure they could innately just imagine it. I'm just not sure I could quite do that. So I think they are pretty beneficial for me.

INTERVIEWER: Mm 'kay. [00:15:57]

RESPONDENT: Yeah. But I mean, I wouldn't – if someone – if we didn't do this second lab, and we were just told, "Okay, force equals mass times acceleration, and the force this one will exert – " Like, they're opposite forces. You know what I mean? Like, equal but opposite forces if it's not accelerating or whatever? I wouldn't – there was no way I would have graphed (ph) – like, there's literally not. No way I would've understood that.

INTERVIEWER: Okay.

RESPONDENT: To be quite honest with you. And like, the one investigation with the coffee filter and the paper plate? There is no way I would have understood. Like, in the freefall, the terminal velocity that the gravity – because it's not accelerating. So, like, the gravity arrow is the same as the normal force. So, I would've – there's no way I would've just been able to think of that without do – I think seeing it. So. I guess, yeah, the investigations helped. This one, I don't know. I don't know. For someone who's not read physics –

INTERVIEWER: Sure. [00:16:59]

RESPONDENT: – and jumping into the class, and then jumping right into momentum and things that – well, we didn't jump right into it, but eventually getting into it, and this being our first lab. I don't know. I think there are still missing pieces that I wish I would have had and I still don't even have that I could clearly see this lab and, like, about it, I guess. I don't know. But yeah. I think overall, they're pretty helpful.

INTERVIEWER: So, you've told me how the investigation kind of cement these ideas for you that otherwise would have been unclear.

RESPONDENT: Yeah. For the most parts.

INTERVIEWER: I'm curious if you think the investigations represent what it means to do physics.

RESPONDENT: Do physics.

INTERVIEWER: Yeah. Like, in your head, if you have a conception of what it means to do physics. And if these lab investigations represent that.

RESPONDENT: I mean, I guess. But just because we've been doing them in class. And like, it's a physics class, so. I mean, so like, why would they be giving us something to do if it's not physics? [00:18:00]

So, I mean, we have to do it, right? I don't know. I don't know if I'm understanding the question, but – I mean, I guess. Because I don't know. I don't know what. Coming into the class, I just didn't know what physics – well, I mean, I knew what physics was, but I didn't really know what it meant. And all these vectors and stuff like that, I had no idea about that.

INTERVIEWER: Yeah.

RESPONDENT: I mean, you – yeah. I mean, that's doing physics, these experiments. So. Student physics.

INTERVIEWER: Okay. I think that's a perfectly reasonable –

RESPONDENT: (Chuckling) Yeah.

INTERVIEWER: – answer. Yeah.

RESPONDENT: Yeah. I'm just going to say that.

INTERVIEWER: Are, do –

RESPONDENT: I don't even know where we're going.

INTERVIEWER: Absolutely. (Chuckling) No. I wanted to get at if you had in your head what it meant to do physics.

RESPONDENT: Not really –

INTERVIEWER: Right.

RESPONDENT: – now.

INTERVIEWER: So, I think –

RESPONDENT: Yeah.

INTERVIEWER: – what you told me was perfectly acceptable, which is like, "Oh, yeah. This is what we do in class.

RESPONDENT: Yeah. This class is just kind of –

INTERVIEWER: (Crosstalk) are funny. Yeah.

RESPONDENT: – giving me the definition.

INTERVIEWER: Right (ph). Okay. Do you think these lab investigations specific equipped you to answer questions outside of class?

(Pause from 00:18:51 to 00:19:02)

RESPONDENT: Hm. [00:19:02]

Yeah. I guess. I mean, because we do – like, sometimes, I'm still unsure of what's an investigation and what's just like a worksheet.

INTERVIEWER: Mm.

RESPONDENT: You know what I mean? I guess –

INTERVIEWER: I (crosstalk).

RESPONDENT: Because, like, maybe – it's probably just me. So.

INTERVIEWER: Yeah.

RESPONDENT: I mean, because like I said, for this one, I still was not understanding –

INTERVIEWER: Sure.

RESPONDENT: – momentum is conserved. So, after – because we did this, like, right before the first exam. And, like, this stuff was barely even on the fi – second exam. Or, was barely even on – or, no. There was like, one question on the first exam about it, but it was super easy. And I remembered the night before the exam, that's kind of when it clicked –

INTERVIEWER: Mm.

RESPONDENT: – that momentum is conserved. I already turned this in. Like, everything was already said and done.

INTERVIEWER: Right.

RESPONDENT: So, no.

INTERVIEWER: Okay.

RESPONDENT: For this one, no. [00:20:00]

The force one. Like, the second experiment, yeah.

INTERVIEWER: What kind of questions do you think had helped you?

RESPONDENT: Just like the, if the – well, first, it just clicked that there's going to be opposite force. Like, that was one of the biggest "Aha!" moments I've had in the class, to be quite honest with you. I never really realized that they would have opposite forces even on a collision, even if one is not moving. That never – like, that was – I was like, "What? Whoa!"

INTERVIEWER: Yeah.

RESPONDENT: So, I guess – and, for that one in particular, yes. That one helped me. Because then we were going – then we needed that when we looked at the weights, and we had to figure out how – like, so, it wasn't moving, so things were going to cancel and things like that. I don't know. I feel like we've just been building on this theme. Because then, even on the second exam, the first question. Oh my gosh. The one with the ramp with the car?

INTERVIEWER: Uh-huh. [00:21:00]

RESPONDENT: So when we re-did it – by the way, the second exam – oh, no. I was – wow. But then when we re-did it in class, it made sense that, like – so, this X – so, all the forces in the Y direction. So, like, force, net – for Y direction or whatever – is no movement whatsoever. So that's all going to cancel. I guess – so that second lab helped me with understanding that. Then, we needed it for kinetic – for the friction. Like, kinetic friction and static friction. Sometimes – if it's on a ramp, we needed to break it apart and then solve for the co-efficient of friction or whatever. So, in that sense, yes. The investigations help me.

INTERVIEWER: Okay.

RESPONDENT: But if I understand the investigation, I know where to go. They'll help me, I guess, thus far. But this one in particular? No.

INTERVIEWER: But how about outside of class?

RESPONDENT: Outside of class? I mean, yeah. So, yeah. So, if I had to tackle a physics problem, I would think of all of this stuff. [00:22:01]

At least, I think so. Because this is all the stuff in my toolkit, and all the things that I've been working with all semester and wrapping my brain around. So, I think I would feel comfortable answering a question that isn't our class. From our class.

INTERVIEWER: And do you think you'll run into that?

RESPONDENT: Oh, for sure. Yeah. Because I tutor – or, I do like an MCAT program over the summer, and they have biochemistry, biochem, physics; all that stuff. We're just basically like, L.A.'s or whatever.

INTERVIEWER: Yeah.

RESPONDENT: So, people come with different questions all the time. Like, this past summer, physics was the only course that I couldn't help anybody with. So I feel like I would be able to help someone moreso with that. I mean, I think I would feel pretty comfortable with doing it. I mean, I'm not afraid to be wrong. So if I didn't know something, I would just say I don't know, or anything. But I would never be afraid to, "Oh, I'm not going to know what I'm not even going to try." [00:23:00]

So I would go right at it. Yeah.

INTERVIEWER: Great. The next thing I have for you, I think these are whiteboard consensus board, do you think?

RESPONDENT: Okay.

INTERVIEWER: First, any thoughts that you would have?

RESPONDENT: Sometimes, whiteboard confuses me more sometimes.

INTERVIEWER: Can you explain?

RESPONDENT: Well, especially in the first – like, during the unit wa (ph) – well, not unit one. All the material in the first exam, I just was not understanding whiteboard meetings, why we had them. I just felt like it was so – like, almost disorganized. And I felt like it was going back to the lecture. I didn't know if I should take out my notebook and write this down, or what I should do. And so I was thinking about all this. So I don't think I was really comprehending what she was talking about, or what everyone else was saying. So I wasn't seeing the connections that we were making on these whiteboards. [00:23:59]

But I think with time, I – as I've been getting used to the class, I can see where we're going with things. Especially the, with the second experiment. We had a whiteboard meeting about how everyone – like, what everyone did in their experiments to increase their confidence. I saw that. And then the terminal velocity activity that we did when we did the whiteboard after that. I guess that one helped. But these ones in particular, I have to look at these ones.

(Pause from 00:24:29 to 00:24:36)

RESPONDENT: Okay, so this was like, kind of the second experiment that we did, I think. Because it's "a force is proportional" math, mass and – yeah. Because then the, we came to this equation based on everyone's results. Or the select people she called on.

INTERVIEWER: What's the process to get to something like this? [00:25:02]

RESPONDENT: Like, the equation? Or just –

INTERVIEWER: Or just the – like, to get to form this three-page – or –

RESPONDENT: Well, yeah. Because it looks like – and from what I can remember is we looked at how force was proportional to all these things based on different groups' experiments.

INTERVIEWER: Okay.

RESPONDENT: So this was their setup. These were their results. One of these is mine somewhere, I think.

INTERVIEWER: (Chuckling) Really?

RESPONDENT: To be quite on (ph) – yeah.

INTERVIEWER: That’s awesome.

RESPONDENT: Yeah. I feel like one of the –

INTERVIEWER: Like, a select buddy (ph).

RESPONDENT: Oh. This was ours.

INTERVIEWER: Awesome.

RESPONDENT: Yeah. Because we kept the same force. We changed the mass. And then we were trying to figure out this relationship. Me and the girl I was working with. Yeah. Because you double the mass on the car, and acceleration halved or whatever. Yeah. We did this. And then this one –

(Pause from 00:25:52 to 00:26:00)

RESPONDENT: I can’t remember really how we got to this one. [00:26:03]

Oh, and then this group was, like, overachievers.

INTERVIEWER: (Chuckling) Why do you say that?

RESPONDENT: They, like, killed it, because they did a ramp (ph).

INTERVIEWER: Oh.

RESPONDENT: And she said that she’s never seen this before. Or whatever. Yeah.

INTERVIEWER: Interesting.

RESPONDENT: So, this group, I remember, was really good. This one, I don’t really remember. I think I was still trying to process this. So this one is kind of a little blurry. I remember her writing this. Sometimes her writing’s a little messy, so I have to decipher what’s going on. So I think I was trying to figure out what would, what was going on here. But, yeah. I mean, looking back at this now, I’m like, “Oh, yeah. Force, net. Like, all the forces added up.”

INTERVIEWER: Makes sense now, looking at it?

RESPONDENT: Yeah. Makes sense now. So yeah, it was just piecing together what everyone else was doing to get to these big ideas.

INTERVIEWER: So why do you think the instructors do this kind of a thing?

RESPONDENT: Well, because then we won't be able to move on to the next – or get more difficult without knowing these fundamental things. [00:27:03]

Especially like this force. Like, the sum of all the forces. Force, net, or whatever. Because then – basically, the next step with all this stuff was that we split up forces in the X and the Y direction. You know what I mean? So we wen (ph) – we had to figure out what was going to cancel and – or, what the net force was still going to be, based on all the remaining forces. I mean, that's at least how I've been taking it.

INTERVIEWER: Okay.

RESPONDENT: Whenever she writes this. Like, this – if you're talking about math, whenever she writes this, this scares me, because it's derivative or whatever.

INTERVIEWER: Oh, the DVDT (ph)?

RESPONDENT: The DB (ph), DT (ph). Just like, a side note. I don't like to think about it this way. I prefer to think about it in other ways. Like this or whatever.

INTERVIEWER: I see.

RESPONDENT: Yeah. Just random side note.

INTERVIEWER: No. So, the calculus isn't helping you.

RESPONDENT: I mean, it helps me when I can look at a graph. Because we have to do the derivative of – what was it? [00:28:03]

Derivative of potential energy is force.

INTERVIEWER: Mm.

RESPONDENT: Or is it – I don't know if it's the other way around.

INTERVIEWER: I think that's right.

RESPONDENT: Okay.

INTERVIEWER: Derivative (crosstalk). Yeah.

RESPONDENT: Yeah. It's, the derivative of one of them will give you the graph of the other. The inverse graph of the other –

INTERVIEWER: Sure.

RESPONDENT: – one or whatever. When I was able to look at the graph, and then look at, “Okay, so the slope is decreasing at this point, and then concave up.” That helped me, because that’s taking the derivative of a line. That’s –

INTERVIEWER: Okay.

RESPONDENT: Visually, that’s, makes more sense to me than looking at this.

INTERVIEWER: I see.

RESPONDENT: And then, all the kinematics that was looking at the graph. Understanding, like, “Okay, the integral of position will be the velocity.” Or, “The integral of velocity will be the accelerating – “ the – so, looking at the graphs, it’s easier for me to switch over to the next one. But –

INTERVIEWER: Okay.

RESPONDENT: – thinking about it this way sometimes doesn’t help me. Because we’ve been – I feel like I barely see any, seen any equations throughout the entire semester. [00:28:58]

INTERVIEWER: I see.

RESPONDENT: And, like, I feel just comfortable with taking the inter (ph) – the derivative of an equation.

INTERVIEWER: I see.

RESPONDENT: And then I just – integrals scare me. So, derivatives, I –

INTERVIEWER: Got you.

RESPONDENT: – stick with more than anything.

INTERVIEWER: Fair enough.

RESPONDENT: But thinking about it this way, I can’t do that. I can’t just see that and say, “Oh.” Like, I panic first and then –

INTERVIEWER: (Chuckling)

RESPONDENT: – “Okay.”

INTERVIEWER: Yeah.

RESPONDENT: (Chuckling)

INTERVIEWER: That seems fair.

RESPONDENT: Yeah.

INTERVIEWER: Do you find activities like this valuable?

RESPONDENT: Whiteboard, or –

INTERVIEWER: I'm going to include both in that question. So, whiteboarding – like, things that lead up to it as well as including this sheet.

RESPONDENT: I mean, I've – I used to hate whiteboards. But I think it's they're growing on me.

INTERVIEWER: Yeah?

RESPONDENT: Because I can – yeah. I can see where they're, where she wants us to get to, based on what she's telling us to think about while doing an experiment. You know what I mean? So, they're starting to grow on me. So I feel like those are pretty beneficial. I still don't know if I should take notes or if I should not take notes. I guess it's all just a personal thing. Like, if you can go back and look at this and be okay with it. [00:30:02]

It just seems there's now – there's no structure that I'm used to. It's not a lecture. So that's a little scary sometimes, for me. But I mean, I guess I like whiteboards now that I understand them. Then, this stuff – like, equations and stuff. Sometimes the equations, deriving it to an equation trips me up just because I never really thought about – I never practiced that skill. So this is the first time I'm using – I'm, I have to look at units to get to an equay (ph) – I don't know. Like, unit analysis or whatever to get to an equation. So I guess that's a little different for me. Just because I never used those skills before. I mean, I – you can piece them together while she, while you're watching her do it. But I've never personally done it myself. So.

INTERVIEWER: Got you.

RESPONDENT: Sometimes, they're a little scary. [00:30:58]

INTERVIEWER: Okay. So, mm. So, you said they were valuable, but then sometimes they can get scary.

RESPONDENT: Yeah.

INTERVIEWER: So, can you point to specifics of –

RESPONDENT: The valuable parts?

INTERVIEWER: – Yale (ph), and then the [skate park] (ph)?

RESPONDENT: Valley (ph) – this is all valuable.

INTERVIEWER: Okay.

RESPONDENT: These little pieces here. This –

INTERVIEWER: The, “F is proportional to M – “

RESPONDENT: Yeah.

INTERVIEWER: “ – A”?

RESPONDENT: All these proportionalities, and then finally getting to it. A concrete thing that I know.

INTERVIEWER: Mm ‘kay.

RESPONDENT: Or that we’re going to use and apply. At the time, I think this all made sense to me, but looking at it now, I just see words that I’m like –

INTERVIEWER: Yeah. I mean, it’s been a little while since I –

RESPONDENT: Right. Yeah. It’s been a while. So I – I mean, I’m sure it was helpful.

INTERVIEWER: Sure.

RESPONDENT: This is helpful.

INTERVIEWER: Okay.

RESPONDENT: This. I wasn’t exactly sure how to use – I don’t think I was exactly sure how to use it. But looking back at this, this is very useful. And I’ve actually – I’ve referenced this.

INTERVIEWER: Okay.

RESPONDENT: Like, after – like, I – after all was said and done. I went back to, I think, this document in particular to look at how we got to this weird conclusion. [00:32:05]

INTERVIEWER: Yeah.

RESPONDENT: This, I still don’t know what’s happening here.

INTERVIEWER: Okay. The derivative of DVDT (ph), then?

RESPONDENT: Yeah. Just all that – I think I just honestly block it out –

INTERVIEWER: (Chuckling)

RESPONDENT: – to be quite honest with you.

INTERVIEWER: Sure.

RESPONDENT: Which, it probably is not good. I should really – I – then, this was getting toward the end of class. I think I was starting to zone out.

INTERVIEWER: Okay.

RESPONDENT: I don't know. Sometimes it gets all messy. It gets messy. There were a few whiteboards that were really messy. This one isn't too messy. I understood this one, because I – this is our experiment. So – like, I was very engaged in this.

INTERVIEWER: Now, do you see mathematics playing a role? I know you highlighted some of the derivatives.

RESPONDENT: Here. (Chuckling)

INTERVIEWER: Yeah, I know.

RESPONDENT: A little bit here. I mean, no, this is math. Proportions and things like that.

INTERVIEWER: Okay.

RESPONDENT: Yes.

INTERVIEWER: Any whiteboards in general? Do you see mathematics coming into play?

RESPONDENT: Yeah. Sometimes. [00:33:01]

I mean, more often than not, we don't really write our results on boards anymore, but moreso results and conclusions that we come to. I mean, you have to explain some of them with math. So I guess there's still math.

INTERVIEWER: Okay.

RESPONDENT: I just can't recall it off the top of my head right now. I mean, I have seen it.

INTERVIEWER: Mm 'kay. Do you see biology or chemistry playing a role in these whiteboarding processes?

RESPONDENT: No. I mean, not this one in particular. We had to track the speeds, or the velocities, of a wound healing, e. coli, and white blood cells. So I mean, that one. That one was actually pretty cool. So I guess that one was biology. And then – oh, and then there was one with – oh, it was with those, these stupid forces that are going to be on this exam with, like –

INTERVIEWER: Stupid forces. [00:34:00]

RESPONDENT: These ones are –

INTERVIEWER: (Chuckling)

RESPONDENT: – starting to scare me. Like, visco –

INTERVIEWER: Are you talking about the resistance?

RESPONDENT: Yes.

INTERVIEWER: Okay, good.

RESPONDENT: Like, viscosity, friction. Viscosity is the one with the paramecium with the applied force.

INTERVIEWER: Yep.

RESPONDENT: For some reason –

INTERVIEWER: I have it in here. Yeah. It's nice.

RESPONDENT: I see – yeah. That's – I can see it in there. But sometimes I –

INTERVIEWER: Still (ph)?

RESPONDENT: – like, miss what – I miss "big picture" because I've, I have anxiety about, like, not knowing, "Oh my gosh. What are – " Like, I can't see what's going on in my head.

INTERVIEWER: I see.

RESPONDENT: So, yeah. In this one in particular, no. There was nothing but physics in this one.

INTERVIEWER: Fair enough.

RESPONDENT: But, yeah. I mean, other ones that are –

INTERVIEWER: Sure. Do you think this whiteboarding process and this consensus board represents what it means to do physics? Like, what you think of when you think of doing physics?

RESPONDENT: Again, I never really had a pre-conceived idea of what physics was.

INTERVIEWER: Yeah.

RESPONDENT: But I mean, building on the definition that this class keeps providing me with –

INTERVIEWER: Uh-huh.

RESPONDENT: Yeah. [00:34:56]

Because, I mean, you have to look at all these relationships between all these different variables. You want to isolate one – or manipulate. Or you want one, only basically one variable, to change as a result of other thing – you know what I mean?

INTERVIEWER: Yeah.

RESPONDENT: So, I think that's what physic – I think that's doing physics.

INTERVIEWER: And do you think this whiteboarding and consensus board, they have equipped you to answer questions outside of class?

RESPONDENT: Yeah. The only one that I wish we would have done – like I said, I'll – I keep going back to this one. Like, when we had to break up the forces in X. Because this is like, I think I'm getting more and more comfortable with forces. And I'm – like, I feel almost most comfortable with forces right now. Just because I think I had a nice solid foundation when it came to this stuff. So I would feel comfortable answering force problems. Resistive forces still get in there. I got until Monday to really master that. But like, this stuff. [00:35:59]

And then when we had to break it up and X and – the X, [force is] (ph) in the X direction, [force is] (ph) in the Y direction, yes. I think this helped me. It helped me learn that stuff which would help me learn outside of class. I mean, I wish – if, in regards to whiteboarding, I wish we would have done a whiteboard on the, find the unknown mass.

INTERVIEWER: Mm.

RESPONDENT: I feel like that was something so important that we just skipped over, because we're using all that stuff, like, now, still. And I feel like we really should have focused more on, like, breaking up in the X and Y. At least, in my opinion.

INTERVIEWER: Okay.

RESPONDENT: And that's just me. But yes, I would feel comfortable – I think this helps me feel comfortable in solidifying everything to do physics outside of our class. Yes.

INTERVIEWER: I see. And then when you said find the unknown mass, you're done with the balanced forces one?

RESPONDENT: Yeah. So, like –

INTERVIEWER: The circle and the –

RESPONDENT: Yeah. Because you had to, like – I mean, based on how you were looking at it. Like, if you made a free body diagram. [00:36:59]

You would have to make one along an axis. Then, the other two, you'd have to break up into their components and find the direct (ph) – you know what I mean?

INTERVIEWER: Yeah.

RESPONDENT: Like, direction. And then, since it wasn't moving, they'd all cancel, and you can get to the mass. But. Yeah. I wish we would have done a whiteboard of that. Especially right – since it was right before an exam. That was on the exam. For me, it would have been helpful. Maybe we did, and I wasn't paying attention that day. But no, we didn't do it about that particular problem. But, like, maybe breaking up X and Y forces; that would have been very helpful. I don't know why we didn't focus on that, to be quite honest with you.

INTERVIEWER: Mm 'kay. Great. The next set of things. These are some in-class problems you've done.

RESPONDENT: Resistive forces.

INTERVIEWER: (Chuckling) That's one. (Chuckling)

RESPONDENT: Well, this one is. This one is – I don't remember doing this one.

INTERVIEWER: I think they wanted you to draw the – they gave you one plot. [00:38:01]

It would have been –

RESPONDENT: Oh, yeah.

INTERVIEWER: Okay.

RESPONDENT: This was before the second exam. Oh, yeah. This one was nice. I like this. I felt so comfortable doing this.

INTERVIEWER: Yeah.

RESPONDENT: I felt really comfortable doing this one. This one, no.

INTERVIEWER: (Chuckling)

RESPONDENT: I could not – I was –

INTERVIEWER: You didn't feel comfortable with it?

RESPONDENT: No. I was like –

INTERVIEWER: (Chuckling)

RESPONDENT: And I did the ree (ph) – because we did this on a Wednesday, so the reading –

INTERVIEWER: Sure.

RESPONDENT: – was the night before, on Tuesday, all about this stuff.

INTERVIEWER: Yeah.

RESPONDENT: Applied for (ph) – like, I still just – I couldn't – I have to get a fri (ph) – I realized – I'm realizing that I have to draw free body diagram before I do anything –

INTERVIEWER: Mm.

RESPONDENT: – with forces. Like, a free body diagram is the first thing I have to do. Because that solidifies that I – like, I can see what's going on, and I can understand what forces are at play. I still am struggling, honestly, with these forces. And I –

INTERVIEWER: Okay.

RESPONDENT: I have to honestly get help about, like, where this one comes in, and then why this one's different from viscosity. And, I don't know. But [you see that] (ph).

INTERVIEWER: So you're finding the force – free body diagrams to be helpful.

RESPONDENT: Oh, free body diagrams changed my life. [00:39:01]

INTERVIEWER: (Chuckling)

RESPONDENT: Like, truly changed my life. Yes. Those are very helpful for me.

INTERVIEWER: Well, that's great.

RESPONDENT: I can visualize it. But, yeah. This one was piece of cake. This one, not so much. Not so much.

INTERVIEWER: So, why do you think the instructors have you do these type of in-class problems?

RESPONDENT: Well, I think this one is – because this is on the kinematics and stuff. Then, this was – like bridging the gap in between forces and kinematics. So I think that's why they had us do this. "If you can do this, then you should be happy, because you're comfortable with – " like, how you can see the relationship between velocity and acceleration and force. And you can, like, draw them out. Do you know what I mean?

INTERVIEWER: Got you.

RESPONDENT: Because I can see that, "Okay, so we're slowing down. So it's going to be in the opposite direction. And then you're speeding back up, so it's in the same direction. It's slowing back – " You know what I mean?

INTERVIEWER: Mm-hmm.

RESPONDENT: So I can, like – I can see all that in my head now. And I – the force, obvi (ph) – is the same as the acceleration. So, like, it's – I don't know. I can – I think that that's why they give us this stuff. [00:40:02]

So, if you can do it, you're good.

INTERVIEWER: Great.

RESPONDENT: You can feel comfortable with it. But then this stuff, I think is just kind of to go a little step further.

INTERVIEWER: Uh-huh.

RESPONDENT: You know what I mean? So you can explore that frontier. So you – we established something in class together about these resistive forces. And that lung (ph) kappa (ph) and stuff like that is pretty straightforward, where you solve for one thing and whatever. But then, in this stuff, you have to dig a little deeper and explore some stuff that we weren't just told. And if you can do it, great. You're above the game. But then if you're struggling with it, "Okay, go back and refine – figure something out. You're not making connections somewhere." So I think it's kind of to see where we are. Almost like a self- (ph) – little reflective piece or something like that.

INTERVIEWER: So you mentioned on that one the dia (ph) – the graph one that you found it valuable because it helps you visualize? [00:41:02]

RESPONDENT: Yeah.

INTERVIEWER: What other things are valuable about these kinds of activities?

RESPONDENT: Well, because this one sa (ph) – like, it tells you to imagine the cart being pushed or pulled along the track. So, I could think of myself pulling or pushing it back based on this velocity graph.

INTERVIEWER: Oh, great.

RESPONDENT: I'm a visual learner. So, I think that's why it helps me. That's why I took from this activity that I can see what's going on here.

INTERVIEWER: How about this one? Is there anything valuable about that one?

RESPONDENT: There is. Still trying to figure it out.

INTERVIEWER: Sure.

RESPONDENT: No, I'm just kidding.

INTERVIEWER: (Chuckling)

RESPONDENT: It's – no, it's valuable because you should see the – I have – like, the whole entire back of my worksheet is filled, and then I had to do an additional sheet. Which is like, things that we talked about. I haven't reviewed it yet, just because I'm still scared to. "Two resistive forces." But I th – no. I think it's valuable just because – I mean, here's the equation that we're going to have to use. [00:42:01]

We had to draw a free body diagram. We had to look at all those different things. Yeah. So I mean, I – why they gave it to us, I think. Or what I took from it, it's a, "I need to make some more connections with –

INTERVIEWER: Cool.

RESPONDENT: "I need to build my fundamentals a little more. Or solidify them." Something.

INTERVIEWER: Do you see mathematics playing a role in these types of activities?

RESPONDENT: Yeah. I mean, this one. I mean, it's the relationships between – so the integral, this one, of velocities. The acceleration graph. And then, these ones will be proportional because F equals MA. So I mean, it'll be based on that. And the mass stays the same. So, yeah. I mean, I can see it in this one.

INTERVIEWER: Mm 'kay.

RESPONDENT: And I think I saw it in this one, too, because we had to use different values of – we had to plug stuff in here. And we had to use the density of wa (ph) – [00:42:59]

Like, down here is when we get to math. D and E. And if I remember correctly, she only wanted us to do A, B, and C. It was a Friday that we did this. No. Yeah. I don't – I – I think it was a Friday that we did this. And she only wanted us to do A, B, and C. And, like – then she came – because then she left the room for a little while and then came back, and we already – like, we were already working on D and E, so she just let us go for it. So I mean, it – and that's where the math was, I think. I don't know if it was in here. But for sure in D and E. Yeah. So, math. Yeah.

INTERVIEWER: Do you see biology and chemistry playing a role in these?

RESPONDENT: Yeah. This one.

INTERVIEWER: Mm 'kay.

RESPONDENT: I mean, this is a paramecia. So. Or paramecium, with the cilia and you have to think about its movement in the water. Or wherever it was swimming in this case. So, yeah. I – in this one – not in this one; no.

INTERVIEWER: Is the connection there? Do you feel that it's authentic? [00:44:01]

RESPONDENT: Meaning it's like a thing that happens?

INTERVIEWER: Sometimes – students have told me that it's, "Oh, at the end of the day, it's just a ball," or, "It's just a box." Or, "It's just a dot."

RESPONDENT: No, I for sure think it's authentic.

INTERVIEWER: Okay.

RESPONDENT: I mean, I don't think we'd be given it if it wasn't authentic. I mean, I think it's authentic. That's what happens. I think that's what happens when a paramecium is swimming through water, and there's cilias going – I mean, obviously we're just zooming in on one cilia or whatever, in this case. But yeah, I think of course that happens. It has to – everything has force and stuff. So, yeah. Of course, I think.

INTERVIEWER: Okay.

RESPONDENT: It has to be. I mean, sh**.

INTERVIEWER: (Laughing)

RESPONDENT: What are we learning? Why are we doing this?

INTERVIEWER: Right. [00:44:58]

So, do you think doing activities like this represents what it means to do physics?

RESPONDENT: For sure. Yeah.

INTERVIEWER: Yeah?

RESPONDENT: Yeah. For sure. These two, yeah. For sure. Just because you have to – I mean, you have to first identify these relationships.

INTERVIEWER: Uh-huh.

RESPONDENT: I mean, yeah. I mean, yeah, because you have to know. You have to know the relationships to do this. You know what I mean? At the beginning of the year, or the semester when we did, we weren't – I mean, at least me. I didn't know too much about, like, chem (ph) – I was even struggling with kinematics.

INTERVIEWER: Mm-hmm.

RESPONDENT: I wouldn't have been able to do this and feel comfortable doing it. But now I – like, I think doing physics would be like, doing it. Knowing it. And this one, I mean, yeah, of core (ph) – I think it has to be. You're working with viscosity and all these different things. You have – it has to be physics. So, yeah, I guess.

INTERVIEWER: Okay.

RESPONDENT: Yeah. [00:46:00]

INTERVIEWER: Do you think activities like this have equipped you to answer questions outside of the classroom?

RESPONDENT: Yeah. I think this one has. This one, just because I'm not comfortable with it, I think, "Not yet." But I'm sure it will. I'm sure I'm going to take something out of this worksheet. I have to go back and study for this exam –

INTERVIEWER: Sure.

RESPONDENT: – but I'm sure in the future it will. Yeah.

INTERVIEWER: Yeah.

RESPONDENT: Something will help me feel comfortable teaching outside of class.

INTERVIEWER: Okay. The next thing I have is, I think, the first of three of the coding things you've done.

RESPONDENT: Oh. Coding –

INTERVIEWER: (Chuckling)

RESPONDENT: Coding was something.

INTERVIEWER: It was something?

RESPONDENT: Yeah. But I mean, it's scary, kind of. Just be – it was scary. It was scary because you're just looking at all these things. Or, these letters and symbols and stuff. You're tryi – because ultimately, you're just telling a computer to do something.

INTERVIEWER: Yeah.

RESPONDENT: You know what I mean? [00:47:00]

So, I mean, I've never taken any type of coding or CSC – nothing. I – no. I hate technology. Like, I –

INTERVIEWER: Sure.

RESPONDENT: I barely know how to use my phone. So working how – like, making technology do something for me was a little like, "What am I doing?" I don't know. It's a – I don't even know what you asked. I think I just started to talk.

INTERVIEWER: (Chuckling) Don't worry.

RESPONDENT: So, I'm sorry. (Chuckling)

INTERVIEWER: No. We set up a pattern, right?

RESPONDENT: (Chuckling) I'm so sorry.

INTERVIEWER: For – no. First, you're telling me your thoughts on it –

RESPONDENT: Yeah.

INTERVIEWER: – and you are, and you're doing perfectly well. But if you're curious what my question was going to be –

RESPONDENT: Yeah. I mean, yeah.

INTERVIEWER: My question for this set is, starting with that first one: "Why do you think the instructors have you do something like this?"

RESPONDENT: Like, this first part – or, I mean, this –

INTERVIEWER: This whole activity. Yes.

RESPONDENT: Oh, the entire activity?

INTERVIEWER: Yeah.

RESPONDENT: Well, I –

INTERVIEWER: The activities like this one. Like, the trivia (ph).

RESPONDENT: Yeah. Well, this one was to basically look at conserving momentum and ultimately conserving energy. [00:48:00]

INTERVIEWER: Okay.

RESPONDENT: Because we came to these equation – we derived – so, there was an activity before this that we actually derived these equations from another equay (ph) – I forgot what we were doing.

INTERVIEWER: Sure.

RESPONDENT: But ultimately, that's what it was. And so this, in terms of, like, coding, would be the P transfer. So, in terms of knowing that, we did this activity to understand why. Why this equation is, and how it can make a computer and the balls bounce back off of each other.

INTERVIEWER: Mm.

RESPONDENT: And then have – and then at the very end, have a specific kinetic energy after, and how it had the same kinetic energy as before to show that energy was – kinetic energy was conserved from before the collision and then after the collision. So I think that's why. Yeah. I think that's why.

INTERVIEWER: Do you find activities like this valuable?

RESPONDENT: Coding in general, or?

INTERVIEWER: The coding that you're doing in this class, including this one.

RESPONDENT: I don't think so. [00:49:02]

I don't want to be ignorant in saying, "I don't think so," because we're paying, like, a million dollars to go to school here. You know what I mean?

INTERVIEWER: I don't think it's ignorant.

RESPONDENT: No; right. So I want to try to get some –

INTERVIEWER: Sure.

RESPONDENT: Actively try to get something out of everything. So I don't want to just be like, "No." Because a lot of people that, like, I'd been working with in groups, they, kind of bitter about all this stuff. I'm like, "Okay, well, just chill out for a minute. Like, these people are – they have a job for a reason. They're trying to teach us something."

INTERVIEWER: Yeah.

RESPONDENT: So I mean, I'm sure – like, it's valuable for other people. But for me, no, I don't think so.

INTERVIEWER: Okay.

RESPONDENT: No; I really don't think so. I don't think I'll ever code anything ever again.

INTERVIEWER: Anything ever again?

RESPONDENT: Like, after college.

INTERVIEWER: Okay.

RESPONDENT: So like, when I'm – I mean, maybe when I'm a doctor, I'll have to code something, but I'm sure someone will, while they're training me, sit down and tell me, like, "Blah, blah, blah." Like, I never –

INTERVIEWER: I see.

RESPONDENT: – will have to know how to co (ph) – I mean, if I would have had to, I would have had to take a bunch of CSC and stuff like that. So. [00:50:02]

INTERVIEWER: Got you.

RESPONDENT: Not particularly for this –

INTERVIEWER: So, you're saying –

RESPONDENT: – activity.

INTERVIEWER: – since these can be our science classes, they're not part of your major requirements?

RESPONDENT: Yeah.

INTERVIEWER: That you don't think it's going to be –

RESPONDENT: Yeah.

INTERVIEWER: Okay.

RESPONDENT: I think so. I think that's what I'm getting at.

INTERVIEWER: Okay. Do you think mathematics plays a role in these types of experiments?

RESPONDENT: Oh, yeah.

INTERVIEWER: Yeah?

RESPONDENT: Like, we had to derive these. These two equations from this big, fricking (ph) long equation.

INTERVIEWER: (Chuckling)

RESPONDENT: So, yeah.

INTERVIEWER: Okay.

RESPONDENT: And I remember I actually getting a little frustrated with trying to figure – like, get everything canceled and stuff like that.

INTERVIEWER: Sure.

RESPONDENT: So, yeah. To get these two equations, yeah, we had to use math, for sure. We had to use algebra. The other stuff with coding?

INTERVIEWER: Uh-huh.

RESPONDENT: No. I don't think so. On the exam, she gave us – a second exam. She gave us two pieces of – er, was it one or two pieces of code? I can't remember how many – it was like a – at least one on the first page, and then it was number two. [00:51:02]

So, there was part A, B, and C, I think. Part A was talking about P transfer. B was talking about, I think, conservation of momentum. And then C was, wanted us to solve for – so, we had to use math. What I'm getting at is we had to use math. I forgot what we had to use it for. Maybe to find the mass of – or, we had to find velocities or something? So, yeah. We had to use math in relationship to this. So, yeah. Math was involved. And then, to get these equations, yes, math was involved.

INTERVIEWER: Cool. Do you see biology and chemistry playing a role in the activities of this? Of these coding things?

RESPONDENT: No. Because ultimately, there's going to be proton-hopping and things like that. There are going to be other forces. Or, not for – I don't know. I'm ignorant and I nev (ph) – I don't want to ever use "forces" again because I never know, like, what a force is. Like, when we're going to these, like, different relationship – [00:52:01]

INTERVIEWER: Sure.

RESPONDENT: But, like, when it – when we're talking about chemicals and stuff, there are so many other things than just momentum to, that have to be taken into consideration.

INTERVIEWER: Mm-hmm.

RESPONDENT: You know what I mean? There are different electro-negativities of atoms that will de-localize electron clouds that therefore will perform chemistry. And that's not what this is. Like, this is just showing us –

INTERVIEWER: I see.

RESPONDENT: – how I took it. Conservation of momentum as it relates to conservation of energy.

INTERVIEWER: I see.

RESPONDENT: So I, when I think of chemical – when I think of this, I think of all those molecules floating around or whatever. I don't think of them as just traveling fast and then bouncing off of each other.

INTERVIEWER: I see.

RESPONDENT: That's not how I see it in my head. I see proton-hopping and electro-negative chlorine. I see different pieces to the puzzle.

INTERVIEWER: So you see a more complicated picture with this?

RESPONDENT: Yeah.

INTERVIEWER: Okay.

RESPONDENT: I see a much more complicated picture.

INTERVIEWER: Okay.

RESPONDENT: To this, in particular. Because I'm very comfortable with chemistry and stuff like that. [00:53:02]

So, I – yeah. I don't really see it. Or, realistic. Or like, maybe like the authentic chemistry or something, as it relates. But, yeah. I ka (ph) – I understand, like, yes. Especially with gases colliding into each other and things like that. Yeah. I mean, yeah. That have to collide. They'll have to do something after that. So. But for this one in particular, no.

INTERVIEWER: Okay.

RESPONDENT: No.

INTERVIEWER: Fair enough. Do you think this type of coding – now, I know that you said that your conception of what it means to do physics is kind of limited to what we're doing in class.

RESPONDENT: Yeah.

INTERVIEWER: So do you think this is a part of it?

RESPONDENT: Oh, for sure. Yeah. Because this – I think this is – at least from my understanding, I think this is like what a starting model is.

INTERVIEWER: Mmm.

RESPONDENT: Like, this is what – like, this is the starting model that – I mean, not for this particular situation. [00:53:59]

But this is a good resource to curate a starting model that would be beneficial for understanding something. You know what I mean? So maybe not this particular example, with, like – but I mean there's – like, maybe like an actual collision. Like, other things. I don't know.

INTERVIEWER: Yeah.

RESPONDENT: So, yeah. But I think this is – yeah. I think this – like, for me, this is what a starting model is. Like, a starting model will be like this.

INTERVIEWER: Okay. Awesome. Now, you mentioned that you probably will never code again. I'm curious –

RESPONDENT: I'm in.

INTERVIEWER: – if these coding activities have equipped you to answer questions outside of the class.

RESPONDENT: I'm sure they have, in a way. Or if I'd maybe invested myself a little more to, like, really grip – but I really have – to be honest with you, I think I have honestly tried very hard. But something just isn't clicking for me yet with coding. [00:55:01]

And so if I saw it outside of class, I think I would be afraid of it, to be quite – like, to be completely honest with you. I think I would be afraid of it. And, I mean, I would maybe look at the code. If someone came up to me and said, "Could you help me with this code?"

INTERVIEWER: Sure.

RESPONDENT: I would maybe look at the code. Then, if I saw – especially if it was things with momentum or something. I'd look for, like, P transfer. Any type of, like, indication of mass – any type of momentum. I would look for those pieces. But I'm not sure if I could piece them all together in a way that would satisfy whoever's asking me this question. I'm not sure if I could – but I would lend insight. "Oh, this is momentum.

INTERVIEWER: I see.

RESPONDENT: "You need to do this." I mean, I'm not even sure if I would – I mean, maybe. But I would be scared of it, and I don't think I would get the right answer. Or I would get to where someone asked me – I don't think I would get to where they wanted me to get to.

INTERVIEWER: Okay. [00:56:00]

RESPONDENT: I don't think. And like, the exam. Exam two, when she said there was going to be coding. I was like, "Oh, no." Like, "There's no way." Because it's just scare – like, I don't know. It's –

INTERVIEWER: Did it end up being okay, or?

RESPONDENT: I did way better than I thought I was going to do. They had a – she had a specific question. Part A was specifically about P transfer. I knew – it's almost like I knew – I knew the answer, but I didn't write the words –

INTERVIEWER: Ah. Yeah.

RESPONDENT: – that she wanted.

INTERVIEWER: Right.

RESPONDENT: Because then I got part B. I got all the points. Part C, I got all the points. It was just that part A. How she wanted us to know – I think because she wrote on the bottom of my exam, "Energy conservation or energy conserved?" And I think that's what she wanted me to say.

INTERVIEWER: I see.

RESPONDENT: Because I mean, we looked at how the kinetic energy was affected before and after the collision. So I think I should have –

INTERVIEWER: I see.

RESPONDENT: – included something like that. So, yeah. No. It wasn't as bad as I thought I was going to be, and I specifically wrote one of these equations down on my notecard. [00:57:05]

So I was – but it didn't really even help me.

INTERVIEWER: (Chuckling)

RESPONDENT: Like, I don't know how to – if I don't know what – if I don't – if you don't know it, you're not going to get it right. You know what I mean?

INTERVIEWER: Sure.

RESPONDENT: You can't just write an equay (ph) – this is college. Like – so, I mean, it wasn't as bad as I thought. No. Not at all. No.

INTERVIEWER: Great. The last little artifact I have from class is this. Is the third one in that sequence of three coding activities.

RESPONDENT: Oh, yeah.

INTERVIEWER: And then there's a back side, too.

RESPONDENT: Oh. Yeah. Okay.

INTERVIEWER: And so, I'm curious. I've asked this question before in the first interview. When I mention diffusion, what comes to mind?

RESPONDENT: Now – this is kind of really bringing it back to me. Because this – so, bef (ph) – did you ask "before the class," or, like –

INTERVIEWER: Oh, no. Like –

RESPONDENT: – thinking now?

INTERVIEWER: Right now.

RESPONDENT: Right now?

INTERVIEWER: I've asked you this question before.

RESPONDENT: Honestly?

INTERVIEWER: Whenever you can (crosstalk) it in there.

RESPONDENT: This activity really helped me formalize a visual representation of what diffusion – pieces of diffusion that make diffusion diffusion. [00:58:04]

Because all of these – because I think – I can't remember how, exactly, this video went. But I remember – like, it was – because all these molecules in a tight, packed space – like, bouncing off of each other – created or allowed them to disperse throughout the entire thing. So eventually, it went from this ball – this concentrated ball of whatever. And all the little interactions within caused it to diffuse out into the whole thing. So, that. I remember that. Actually, I remember that in class. That was like a, something that really helped me think about diffusion in a different way.

INTERVIEWER: Okay.

RESPONDENT: Because, I mean, it – that makes sense. Like, I never thought of diffusion that way. I was just told that it was that you disperse. You disperse throughout a liquid or something.

INTERVIEWER: Right.

RESPONDENT: You know what I mean? But there – has to with things that are interacting and bouncing off of each other, too. [00:59:04]

So. Yeah.

INTERVIEWER: Cool. Can you give me a definition of diffusion?

RESPONDENT: Diffusion?

(Pause from 00:59:09 to 00:59:15)

RESPONDENT: I don't even –

INTERVIEWER: It's okay if the answer's "No."

RESPONDENT: I feel like I – I can see it in my head. Typically, when I can see things in my head, it's easy (ph) – it's easier to formalize it in words.

INTERVIEWER: Sure.

RESPONDENT: Actually, I – maybe I just don't want to sound stupid. So, I guess I don't know. Because I can't really – and I blather too much, as you can see.

INTERVIEWER: No.

RESPONDENT: So, I (chuckling) –

INTERVIEWER: No, you're fine.

RESPONDENT: I'm just going to say no –

INTERVIEWER: That's fine.

RESPONDENT: – on the definition –

INTERVIEWER: Yeah.

RESPONDENT: – for right now. But I can see it. (Chuckling)

INTERVIEWER: Do you think the idea of diffusion connects to biological molecules?

RESPONDENT: Oh, yeah.

INTERVIEWER: For situations?

RESPONDENT: For sure. Yeah. [00:59:58]

Especially with all these things bouncing off of each other, which allows – or, which causes things to expand outward in the solution, or wherever it's expanding out to. So, yeah. I think – I mean, I think that's relevant. Any type of physiology or biochemistry. Things like that. Because, yeah. Things float around in solution for a reason, and things are kept at different concentrations for a reason. So, yeah. I mean –

INTERVIEWER: Cool.

RESPONDENT: – I think it makes sense to me that it all relates to biology and chemistry.

INTERVIEWER: All right. I think I've reached the end of my questions. Is there anything else that I should know about you or the course? Anything you want to bring up?

RESPONDENT: No. Nervous for the second ex – or, the third exam.

INTERVIEWER: Okay.

RESPONDENT: But I mean, other than that, I think all is well.

INTERVIEWER: Awesome.

RESPONDENT: Hopefully, the class will go just as well the rest of the semester for me.

INTERVIEWER: Is it okay if I reach out to you again for a third interview? [01:01:02]

RESPONDENT: Yeah.

INTERVIEWER: Okay.

RESPONDENT: For sure.

INTERVIEWER: Fantastic.

RESPONDENT: For sure.

INTERVIEWER: Home, as always?

RESPONDENT: Yeah.

INTERVIEWER: It’s always –

RESPONDENT: Maybe ask me, like, right – yeah. Maybe ask me right before the semester ends.

INTERVIEWER: (Chuckling)

RESPONDENT: Like, right before the final.

INTERVIEWER: True.

RESPONDENT: I got –

INTERVIEWER: (Chuckling)

RESPONDENT: I’ve still got to say, like this next unit and all these different – there are so many moving pieces that –

INTERVIEWER: Yes.

RESPONDENT: – sometimes it’s hard to see what’s going on.

INTERVIEWER: And it seems like you don’t have the easiest of schedules to begin with.

RESPONDENT: (Chuckling)

INTERVIEWER: So.

RESPONDENT: I wish.

INTERVIEWER: Yeah.

RESPONDENT: All right. Well, thank you.

INTERVIEWER: Hey.

RESPONDENT: I appreciate it.

INTERVIEWER: Cool. Awesome.

**END TRANSCRIPT**

# APPENDIX R

## TRANSCRIPT: MILES INTERVIEW 3

# TRANSCRIPT OF AUDIO FILE:

# MILES-INTERVIEW3-03.30.17

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*The text below represents a professional transcriptionist's understanding of the words spoken. No guarantee of complete accuracy is expressed or implied, particularly regarding spellings of names and other unfamiliar or hard-to-hear words and phrases. (ph) or (sp?) indicate phonetics or best guesses. To verify important quotes, we recommend listening to the corresponding audio. Timestamps throughout the transcript facilitate locating the desired quote, using software such as Windows Media player.*

**BEGIN TRANSCRIPT:**

RESPONDENT: Is at work. It’s – I work at the front desk. I’m a supervisor there, so.

INTERVIEWER: Supervisor.

RESPONDENT: Today, my office hours.

INTERVIEWER: Putting you in charge, huh?

RESPONDENT: Yeah. (Chuckling) I am. I love it. (Chuckling)

INTERVIEWER: So how are things going?

RESPONDENT: Good.

INTERVIEWER: Yeah?

RESPONDENT: Good. Classes are good. Difficult, but it’s – second semester’s always easier for me, because I’m used to my grind, and – so. I think it’s easier. What-not. Used to sleep deprivation by now, so, all is well. (Chuckling) How are you?

INTERVIEWER: You make it sound so good. I’m doing all right. I’m doing all right. It’s been a busy semester.

RESPONDENT: Oh, really?

INTERVIEWER: Yeah, I’m just doing a lot of stuff. But – yeah. So the reason why we wanted to touch base with you is because we haven’t even talked to you since, what, October?

RESPONDENT: Yeah. It’s been a while.

INTERVIEWER: So, there's that whole last bit of the first semester course that we haven't really reflected on.

RESPONDENT: Mm-hmm. Yeah.

INTERVIEWER: So, I want to basically follow up on that.

RESPONDENT: Okay.

INTERVIEWER: So my first question to you is, "If you were to describe the LB273 course to another student –

RESPONDENT: Okay. [00:01:01]

INTERVIEWER: " – what would you say?"

RESPONDENT: 273 is the first –

INTERVIEWER: The first semester.

RESPONDENT: – semester. Okay.

INTERVIEWER: Yep.

RESPONDENT: Very hands-on. Very hands-on, and thinking, I guess, outside the box. Yeah. I guess.

INTERVIEWER: What does "outside the box" mean?

RESPONDENT: Because it's not just like you're just given something and you say, "Okay. This is what it is. Now let's apply it." It's like, "Let's apply all of these skills to get to this thing." You know what I mean? So sometimes that requires someone to think outside the box and think about things a little differently than they might have thought about it if they were just given it in the first place. You know what I mean?

INTERVIEWER: Do you have an example of that in class?

RESPONDENT: Yes.

INTERVIEWER: Yeah. You do?

RESPONDENT: It's the – net force.

INTERVIEWER: Okay.

RESPONDENT: The concept of net force. That is something that I personally feel – because it was on our second exam. Er, did we have three exams and a final last semester? I'm –

INTERVIEWER: I think so.

RESPONDENT: Okay. So it was on, I think, one of the last exams. [00:01:59]

The concept just went right over my head. Like, until after I got my exam back and realized I got – every question that involved net force, I just completely got wrong. So then I was trying to think back to some of the labs that we did where we were supposed to pull that out of the lab. I wasn't thinking about it, I guess, in terms – outside the box.

INTERVIEWER: Oh, I see.

RESPONDENT: So then, I – like I said, it went completely over me. It wasn't until I came into Vashti's office and went over my exam with her when I actually understood the concept. So.

INTERVIEWER: Gotcha.

RESPONDENT: So.

INTERVIEWER: So when you're saying thinking outside the box is when you have – you mentioned a lab activity. You're supposed to be thinking about all that.

RESPONDENT: Right.

INTERVIEWER: Outside of what you're –

RESPONDENT: Yeah. So you're supposed to be thinking about what you're doing, and then what, in real – like, in physics language, what that's supposed to look like.

INTERVIEWER: Mm. I see.

RESPONDENT: In terms of the curriculum.

INTERVIEWER: I see.

RESPONDENT: But we have to make that connection, which required me to think outside the box.

INTERVIEWER: I see. I see.

RESPONDENT: Yeah.

INTERVIEWER: Okay. [00:03:00]

RESPONDENT: And it is challenging. I would say it is challenging.

INTERVIEWER: Yeah.

RESPONDENT: I would use "challenging" to describe it as well. Because I had to work my butt off in that class. Literally, I four-pointed by the skin of my teeth, I believe.

INTERVIEWER: So, tell me about the challenge.

RESPONDENT: It's just that – I felt as if during class, if I didn't – if I wasn't mentally there in class, or if I just thought about something just a little off, it – the day just went past me. I missed the bus for the day. You know what I mean? So that was one of the most challenging things for me. Especially because I found it very, much more difficult to teach myself what we were supposed to learn in class or what I may have missed in class. So that was challenging for me. So that required me to really come and utilize Office Hours. Utilize any physics resource I possibly could, whether that be Google, Office Hours, the LA's, things like that. [00:04:00]

So, I really had to utilize a lot of my resources more oft – way more often than not. Way more often than in any other class I've ever taken.

INTERVIEWER: Was that the difference? In case you'd missed those moments in class and you were lost, those resources were what made the difference for you?

RESPONDENT: Yes. Yes. And, I – like, after the second exam, me and a few of the other people in the class, we formed this really good study group. And study groups have never worked for me, ever. I hate study groups. They – I believe for me, they don't work. But with physics, they really did help, especially because they were – they're really smart. So they understood things and we answered each other's questions. They answered way more of my questions than I could help them with. So. That was cool. So, that was another resource I used. So. Yeah.

INTERVIEWER: So why – what did –

RESPONDENT: It was just quite a different class.

INTERVIEWER: Why did the group work, work for physics? When it doesn't work otherwise?

RESPONDENT: Right. That's what – I don't know. I mean, I think maybe that's just the nature of physics. [00:05:00]

I don't –

INTERVIEWER: Hm.

RESPONDENT: I don't really know. But, for – like I said, the study group for physics really helped me a lot. Yeah.

INTERVIEWER: Okay. Oh –

RESPONDENT: Last semester. Last.

INTERVIEWER: Right. What were some of the parts of the 273 course that you enjoyed?

RESPONDENT: I did like the labs. I did like the labs. Those were cool.

INTERVIEWER: Mm-hmm.

RESPONDENT: Sometimes a little, I guess, in reality. In theory, they seemed nicer or more enjoyable than just sitting there in a lecture. In theory, it seemed – it seems nice.

INTERVIEWER: What do you mean by, "in theory"? So was that not how you felt?

RESPONDENT: Well, because I'd never taken LB273 the last semester in the lecture format. So I don't know what it would be like.

INTERVIEWER: I see.

RESPONDENT: But it sounds like the way we learned things is more – it could be more appealing than just the lecture. [00:06:00]

INTERVIEWER: I see.

RESPONDENT: You know what I mean? Because I don't know if I really would have understood some of the momentum principles and what-not if it was just in lecture format. If we weren't doing those experiments and demonstrations with the IO labs and seeing the collisions and stuff like that. So I'm not sure – I mean, I wish I could give a more concrete answer like, "Yes. This way of teaching and learning is much better than the lecture format." But I think – I think I enjoyed it better.

INTERVIEWER: Gotcha.

RESPONDENT: So I like that part of it, and I liked the LA's. I had – Anna was one of my LA's. Genius. Like, she may – she eased me, my mind, almost every day. Just because I always felt like I was so not at the same caliber of understanding everything as everybody else. She would always sit down and be like, "No, you actually do understand it. You just – we just have to pull things apart a little bit." So that was really enjoyable part for me. I think that's maybe all I can think of right now. [00:07:02]

INTERVIEWER: Okay.

RESPONDENT: And I liked how – we did go slow, I feel like, through some stuff. I guess –and again, that's, I think we went slower. I don't know what another curriculum would be like.

INTERVIEWER: Right.

RESPONDENT: So I think we took our time with some stuff. So, yeah. I think I like those parts of it, if that answers your question.

INTERVIEWER: It does. To jog your memory of the, some of the content you covered, I have a list here. So, chemical energy, bound states, Lennard-Jones potential, thermodynamics, and Gibbs free energy. Any of those topics that you particularly enjoyed?

RESPONDENT: To be honest with you, if we're just reflecting on that last bit, I feel like we didn't take our time. So, I feel as if – I mean, maybe it was just me, but maybe I wasn't able to wrap my head around the potentials. Like, the potential energy curve and Coulomb's Law and stuff like that. Maybe I couldn't wrap my head around it as quickly as everyone else could, and stuff. [00:08:07]

Because I found myself for the final – because that was on the final. I don't think it was on exam three. I think it was – er, no. I might have been. I can't remember. But I remember that specifically, like the potentials and stuff like that. I – it took me slower to comprehend, and I still don't even really – I can't make the connection in my head, you know what I mean? So it's harder for me to – that foundation is a little shaky for me.

INTERVIEWER: Okay.

RESPONDENT: But the entropy stuff, I thought that was a really – I thought that was cool. I understood that. It would help me because – I mean, we've learned entropy every year since I was a junior in high school. So it was cool to build off of the idea and just get a little deeper every year leading up to the physics behind it, which is like the actual physics of it. So that was cool. So I liked that part of it.

INTERVIEWER: That's awesome.

RESPONDENT: Yeah. [00:09:00]

INTERVIEWER: What were some parts that you didn't enjoy?

RESPONDENT: Like I said, the potentials. Like, the potential energy curve, that was a little difficult for me. Like I said, just the feeling of feeling like I was behind and like I'd missed something during the labs. Because sometimes I said – like I said, the – some of the people I worked with in that class or I was closer to – because I'm more of the type – I do like small group settings, which I like. I liked how – oh. At the beginning of the year, it seemed like we were switching groups every day. Hated that. Absolutely hated that. But then in the mid – Vashti gave us a survey to do. What – how can she improve her teaching.

INTERVIEWER: Yeah.

RESPONDENT: It wasn't just me, but a lot of people, it seemed, to put, "We need concrete groups. We need to take a group and just stick with a group." I liked that way better. So – but there was like, cons to that, because people I worked with were really – they were really smart. [00:10:04]

I mean, they're intelligent people, and they're able to really logically think through things and see things in their head. Which sometimes, I can't (ph), too, do. Or it takes me a little bit more time to be able to get to that point. So, sometimes when we were doing labs, it just seemed like they knew exactly what was going on, and then they talked to Vashti or one of the LA's, and they'd be speaking almost like a different language in front of me.

I was like, "Well, what are you talking about?" I always almost felt bad to ask, "Okay. Can we slow down or something?" Just because – I don't know. I never want to decrease someone else's learning experience, even though it is somewhat at the expense of mind. But I'm willing to put more work into my personal issues later. That's what I had to do. That was my issue with the process of, I guess, group work and stuff like that. [00:11:00]

So that was something I didn't like. That feeling was very frustrating sometimes. I was – to be honest with you, I was a little s – intimidated by Vashti at the beginning of the course. So I never wanted to ask for – I was very worried about coming into Office Hours and things like that. That was just a "me" thing. So that was a little difficult, but then I totally got over that. So, yeah. Those parts, I'm not –

INTERVIEWER: Yeah.

RESPONDENT: – so sure about.

INTERVIEWER: Then you said earlier that you four-pointed the class.

RESPONDENT: I did four-point the class.

INTERVIEWER: So –

RESPONDENT: Yeah. I mean, I – I think I calculated – after exam three, I think I needed a 94. A 94 percent to get a 91.99 percent in the class.

INTERVIEWER: Ohhh.

RESPONDENT: So I – so I was like, "Okay." I – after I took the final, I asked Vashti. I'm like, "Listen, do you lower the four-point range or anything a little bit?" She's like, "No, it is what it is." [00:12:01]

I said, "Okay. When do we find out our grades?" And she's like, "Well, this should be uploaded in the next few days." I saw – I was for sure that – because the last question on the exam was about entropy, and it was about that log equa – the natural log equation. I forgot it. It was like the natural log of the different states, and then you had to add stuff or sub – I totally forgot. I'm forgetting that equation –

INTERVIEWER: Uh-huh.

RESPONDENT: – or whatever. But I forgot to subtract or add the energy states or whatever. So I got some – I got points off that one. That just made me so – I was like, "Okay. I three-fived. I three-fived the class." Like, "There's nothing you can do. It's fine." Then I logged in to my student phone. I saw that I four-pointed. I nearly jumped out a window. I couldn't even bel – I could not believe I four-pointed physics.

INTERVIEWER: Yeah.

RESPONDENT: That was very – it was a very fulfilling feeling, just because I really worked my butt off. Especially towards the end. Like, leading up to exam three and then after exam three. [00:13:02]

That's when I really was like, "Okay. You need to fig – " And that's when – it takes me a while to learn how to do – learn how to study, or learn how to grasp concepts and stuff like that. So that's just, I think a, by nature, that's what I am. So it took me exam one, exam two, to feel like crap every single day. Then to get it together for exam three and then the final. So I guess that was a really, I guess, fulfilling feeling that I was able to do. Then, on top of it, pull off the four-point. That was like the icing on the cake. I was so happy (chuckling) about that.

INTERVIEWER: Congratulations.

RESPONDENT: Thank you.

INTERVIEWER: That's awesome.

RESPONDENT: Yeah. I was very happy about that.

INTERVIEWER: So, take me back to – why did you enroll in LB273?

RESPONDENT: Well, I mean, it's a requirement for my major.

INTERVIEWER: It's a requirement. Okay.

RESPONDENT: Yeah. I'm – it's not – I really don't want to say I'm one of those people who just is going to take a class because it's required by my major. [00:14:00]

I really pride myself in thinking that I really am very passionate about learning. I would consider myself as a life learner. I will learn the rest of my life. I want to learn as much as I possibly can. I really believe knowledge is power. So I think that had something to do – I think that had some – it really didn't have the direct correlation to why I enrolled in the class. Because why I enrolled in the class was because it was required for my major.

INTERVIEWER: Sure.

RESPONDENT: But, I think that has to do with why I worked as hard as I did. You know what I mean? Because I really did want to understand what we were doing. I wanted to understand all of these concepts that we were learning and things like that. And wha – because physics is why things work. You know what I mean? That's what I've learned through – in Physics II now, and then last semester. That's why these laws and stuff are why the world around us works the way it does. [00:15:00]

So I thought that was such a valuable piece of knowledge that anybody should have. I really believe that once you have that knowledge, that that knowledge empowers you and you look at the world very differently. So that's why I really worked hard to understand everything I try to understand.

INTERVIEWER: That's great.

RESPONDENT: Yeah. So that's why – and that's why I actu – Vashti recommended me to be at LA, which still is somewhat beyond me. (Chuckling) I still don't know why exactly she did that. But I actual – I – because I was very conflicted about filling out the application. It was like – because I was worried that I didn't want to be – I didn't want to be, ever want to be a disservice to anybody else's learning.

INTERVIEWER: Oh.

RESPONDENT: So as an LA, I really wanted to make sure I had enough confidence to be able to – confidence and skill to answer questions and work through things with people and what-not. [00:15:58]

So I was a little self-conscious about that, but I thought about it and I was like, "Okay. I might as well just apply." I applied because I think it's really important. Especially if I – if I do – I mean, I'm not saying I will be an LA or anything like that. But if I was an LA, then I would be going through everything a second time. I feel like that would be even more valuable to my – I would get more out of it than anything. You know what I mean?

INTERVIEWER: Yeah.

RESPONDENT: Because that's – I'm going through everything again, reinforcing the foundation, reinforcing the concepts. Then, that leads to building off of it later in life, and other things I'm going to learn, too. So. Yeah.

INTERVIEWER: That's a really interesting perspective. Yeah.

RESPONDENT: Yeah.

INTERVIEWER: So, why did you take the online grade version?

RESPONDENT: Because I heard it was harder. I like the challenge.

INTERVIEWER: I see.

RESPONDENT: I'm very – I'm a very – for some reason, I'm just always been attracted to, I guess, challenges and stuff like that. So, I pride my – it's – I like the fulfilling feeling after. [00:16:58]

So I saw that 4.0 and I said, "That's good. This is good." So I get almost a high from that, and that's why I took it. I knew I wouldn't have learned as much as I – I wouldn't have understood what I understan – I don't think I would have understood what I understand now if I took the university physics or if I took it at a different university.

INTERVIEWER: Gotcha.

RESPONDENT: Just because a lot of people say, "Oh, yeah. The exams are just basically homework problems with different numbers." That's not something I'm interested in. I pay $27,000 a year for this institution, and you'd better believe I'm going to get – work my butt off to get a good education. So that's why I took Lyman-Briggs. And I think the Lyman-Briggs community is amazing. So there are so many resources, and everyone is so friendly, and stuff like that. So it's almost like a comfort zone that I wanted to stay in. Even though it was harder, I wanted to stay in it.

INTERVIEWER: Gotcha.

RESPONDENT: So. Yeah.

INTERVIEWER: Why do you think it's required for your major?

RESPONDENT: Well, it's going to be on the MCAT. So.

INTERVIEWER: It's going to be on the MCAT. [00:18:00]

RESPONDENT: Yeah. So I think that's why – and then – I mean, physics is why everything works. I mean –

INTERVIEWER: Why everything works.

RESPONDENT: – why chemicals, molecules bind together has to do something with the energy states at which each is at and what those bond energies are. I don't know. It's – physics is literally how everything works. It's almost the most mind-boggling thing to think about. How all these white men from years and years and years ago looked at the world so differently that they were able to figure all this stuff out and then write it. It's absolutely fascinating, because physics is literally how everything works. It's even beyond the scope of my knowledge, so. I can even hardly comprehend half of what – a quarter of what they could see, and what I'm sure anybody who's good at physics can really see. So I think that's really interesting, because it's a whole different way of thinking. It's completely different from bio, chem. So different. So different. So. I think that's –

INTERVIEWER: Awesome. [00:18:59]

RESPONDENT: I think having – being required to learn that way of thinking or at least practice that way of thinking is going to be a valuable skill for us. So, I mean –

INTERVIEWER: What do you think is different about the way of thinking in physics as opposed to bio, do you think?

RESPONDENT: I don't know. I really don't know. I can pinpoint who has the physics brain, but I can't figure out why they have it or how they see things differently than I am seeing it. That – that was a little frustrating for me while taking the class, too. Because it almost seems like anybody who's very comfortable with technology, for instance. Like, computers and stuff – and this is like a crazy over-generalization.

INTERVIEWER: Sure.

RESPONDENT: But this is just what I've seen. I don't mean to – what do you call it? Profile or anything like that. But just from what I've seen, anybody who's good with computers and coding and stuff like that is good at physics. They are just automatically good at physics. I don't know if it has to do with thinking through things very logically, or what. [00:19:59]

Or anything anybody who's good at, really good at math, and understands equations and stuff like that, they're good at physics. But. I don't know why I just – it just doesn't come easily to me. I really don't know why. I think we all just – our life experiences have sh – molded our minds in certain ways, that if someone's good at memorizing something, you're good at memorizing something. If someone's good at visualizing something, someone's good at visualizing.

I think I'm more of a visual learner. If I can't visualize it in my head, then I don't understand it. I really don't understand it. So if I can't just close my eyes and see, like, the force diagram in my head, no. I – it takes me way longer to do. I don't know if someone else is, who's good at physics can visualize it, or if they can just logically think through it in terms of an equation. I don't know. But I think that's why I can't su – I think that's why I sometimes struggle with the physics way of thinking, is because I can't visualize it sometimes. [00:20:57]

INTERVIEWER: Gotcha. So why is it you're not good at physics?

RESPONDENT: I mean, I'm sure I'm fine at physics, but I get – I'm very not confident with it, sometimes. It's, like I said, such a new way of thinking for me, that if I don't have practice on top of practice on top of practice, all modifying different variables in the problem, then I won't ever feel comfortable doing it. There's not – I don't even know if there's enough practice in the world for me to do that. I would for sure be 100 percent confident with physics –

INTERVIEWER: I see.

RESPONDENT: – because I – this is a crazy example, but when I was in high school, I used to be a geometry tutor. Loved – like, I would eat, sleep, and breathe geom – it was cray – it was honestly a little weird. So I loved to tutor geometry. I could just – but I could s – it was almost like I could just see it all in my head. I – and I feel the same about bio chem. Like, I can just see – it's just so much easier for me to visualize all of these things happening. [00:22:03]

I guess not really – I mean, I understand why things happen, but I – it's easier for me to just see what's happening rather than how it's happening. Some – sometimes. Because sometimes I can't – because a mechanism, I can s – I can recall very easily.

INTERVIEWER: Sure.

RESPONDENT: But I just – there's just something about physics that – because that is the "how." Physics is the "how things happen." There's just something – sometimes I feel disconnect, and I don't know – I don't know how. Why. That's why I think I'm bad at physics, is because I can't just see it like I see some other things.

INTERVIEWER: Gotcha. So for you to say you're good at physics, you need to be able to see it, and also have the confidence that –

RESPONDENT: Yes.

INTERVIEWER: – you know all the ins and outs.

RESPONDENT: Right. Yeah.

INTERVIEWER: I see.

RESPONDENT: I'm someone who just threw a problem at me. I would be able to work through it. If – I don't know. Yeah. I think that's what. That's when I would consider myself good at physics.

INTERVIEWER: Okay. [00:22:59]

What do you think the role of physics is in your life right now?

RESPONDENT: Well, I mean, right now as a student, it's just a class.

INTERVIEWER: Yeah.

RESPONDENT: As a person or as a learner, it's a way of thinking. For sure, an absolute way of thinking. Yeah. I think that's the role it plays. And just everything I was talking about, how –

those – these are good skills to have. It makes you look at the world differently, and I think that's very valuable.

INTERVIEWER: Could you tell me a little bit about what that type of thinking is?

RESPONDENT: Well, yeah. So, I mean, a more recent example – I mean, this is from physics, too. It was all the – we just finished our – I have Dr. Quartermeyer (sp?) now. We just finished waves and pulses and stuff like that. So, it just answers questions like why a jet traveling at the speed of light has – it breaks the sound barrier. [00:24:03]

You know what I mean? So the intense – the line with the circles. Like, I can see that. I forgot the name of it right now, but it's like the breaking of the sound barrier where – the, I don't know if you know what I'm talking about.

INTERVIEWER: Ah.

RESPONDENT: I can draw it. But like – and like, this. If you're standing directly under this point, this is when you hear that loud "Boom!"

INTERVIEWER: Oh. Okay.

RESPONDENT: You know what I mean? Like –

INTERVIEWER: Yeah.

RESPONDENT: – just things like that. Just how like, shadows will form different – light will form different shadows through different mass, and stuff like that. I've always wondered – and like, polarized sunglasses. We learned about the polarizing lenses and stuff like that, and how light works and stuff like that. That's physics. That is literally physics. So I thought, "That's cool. That's how – " I've always wondered that. Like, [why am I polarized sunglasses] (ph)? [00:25:00]

It's easier to see in water than without the sunglasses. You know what I mean? So I think that's really awesome. I like – because then I like to just pull those random facts out of my back pocket one day, when I'm with a bunch of people or something like that.

INTERVIEWER: Yeah. Tell them all about it.

RESPONDENT: Yeah. Tell them all about polarized –

INTERVIEWER: When you're at the air show with sunglasses on –

RESPONDENT: (Chuckling) Yeah. Exactly.

INTERVIEWER: Sonic booms.

RESPONDENT: Yeah. Exactly. So, yeah. I think that's why it's very interesting to me. Biotech.

INTERVIEWER: Do you think the role of physics is different from what you thought of – when you – before you took 273?

RESPONDENT: A little bit. Yes.

INTERVIEWER: A little bit.

RESPONDENT: Because I thought physics was all about the collisions and stuff like that.

INTERVIEWER: Okay.

RESPONDENT: I thought it was – I mean, I ignorantly didn't know what physics was. Or I ignorantly thought it was this, this, this, and this. You know what I mean? But you really can't understand what it's about until you take the class. You know what I mean? So my perspective of physics 1,000 percent changed from what it was going into physics. [00:26:05]

Because I really had no idea what physics w – I literally had no idea what physics was.

INTERVIEWER: Mm-hmm.

RESPONDENT: Besides collisions.

INTERVIEWER: Yeah.

RESPONDENT: That's all I could tell you it was.

INTERVIEWER: What do you see yourself doing in the future?

RESPONDENT: I want to go to med school.

INTERVIEWER: (inaudible at 00:26:17)

RESPONDENT: I would really like to go to med school.

INTERVIEWER: Okay.

RESPONDENT: But I still have this really strange passion to do research with like, renewable energy and stuff like that. I just don't know. I feel as if I really am going to get there, regardless how I do it. I know I'm going to have something to do with renewable energy or research. Or some kind of like – just inno – I hate the word "innovative." But just like an innovative form of energy, or innovative form of pollution control, getting clean drinking water. I really want to be involved with that stuff in the research behind that. So, yeah. But I really do want to be a doctor as well.

INTERVIEWER: Gotcha.

RESPONDENT: So I real – I don't know if – I'm considering like a PhD/MD program – [00:27:03]

INTERVIEWER: Oh.

RESPONDENT: – after undergrad.

INTERVIEWER: Okay.

RESPONDENT: Something – because I really don't want to get away from re – because I love doing research. So, I don't know. But I also really want to be a doctor. Really bad. I at least – because – I don't know. Yeah. So. Those are my –

INTERVIEWER: You did some research before, right? With (inaudible at 00:27:23).

RESPONDENT: Yeah. I currently am about –

INTERVIEWER: Oh, you're currently.

RESPONDENT: Yeah. I'm in a biochem lab.

INTERVIEWER: Gotcha.

RESPONDENT: So, yeah.

INTERVIEWER: So what got you interested in the renewable energy?

RESPONDENT: I don't know. I really don't know. I think it was – to be quite honest with you, I took this HPS class last semester. It was about the natural environment. My professor is just an absolute, like – he's just incredible. I have – I liked him so much that I took another HPS class with him this semester, and I'm going to try to take him my senior – I'm going to try to take everything I can to take my senior seminar with him.

INTERVIEWER: That's awesome.

RESPONDENT: I think he is absolutely brilliant, and it's Dr. Rucker (sp?).

INTERVIEWER: Oh, okay. Okay.

RESPONDENT: I love him. [00:28:00]

Like, he is just – he runs his class in such a way – this is tangent. He runs this class in such a way that he helps us build a foundation for thinking about something in a rela – he is the epitome of what HPS is supposed to be. So last semester – this is going back to your question. So, last semester, the class that I took with him was about the natural environment.

There were just so many issues that I really never thought – well, I mean, they were issues, but I never really thought about the ins and outs of the issue and why this is the way it is, and how that is. We just looked at some of those dynamics. I just – it almost really fired me up about some of these issues that people just one, don't care about, or two, are completely uneducated about. You know what I mean? I really – through examining those little dynamics, it really made me want to analyze other dynamics and other things like that. [00:29:00]

Because I really do have this vision of what things could be like. I want to get everyone on board with that. You know what I mean? That's – I really want to do that. So, for renewable energy, I don't really know why – so that's why I want to do something that has, that will impact people all around the world. I really want to be involved with projects that are going to help society as a whole.

So, no matter race, no matter gen – no matter any of that. Humans in general, or animal – anything. Like, I just want – it's a weird perspective and I probably haven't even explored it as much as I potentially could. But I know that's where I want to start with, in terms of my research. With renewable energy, I really don't know why (inaudible at 00:29:50) energy. I learned about it in chem when I was a freshman. Like, nuclear energy and stuff like that. I thought that was so fascinating. I really like chemistry and stuff like that, so I thought that would be an interesting way of starting research, too. [00:30:06]

INTERVIEWER: That makes sense.

RESPONDENT: But again, I think it would be cool to do anything. Like, if it's clean water, clean pollution – anything like that. I really want to help the environment and society as a whole.

INTERVIEWER: So how do you see yourself using physics in that future path?

RESPONDENT: Well, I mean, any form of building a technology is for sure going to require some type of engineering, and engineering is physics. Like, that's – you build something that works, and it works because of physics. So that's the epitome of engineering: building a machine. I mean, if molecules colliding with one another, and this happening because of this. I mean, energy has to be conserved. Where does the energy go? What's happening with the mo – you know what I mean? Just those principles. So that's 100 percent physics. So, yeah. I see it in terms of that. [00:31:00]

Yeah. Sure there's way other, way more things, but I can only think of that right now.

INTERVIEWER: How about in the medicine path?

RESPONDENT: Medicine path. Yeah, that was interesting, because when we filled out that survey for the HPS class when we did the physics and the cross thing –

INTERVIEWER: The crossover thing.

RESPONDENT: Yeah. The crossover thing. That was – I was thinking about that. I mean, other than – see, I wish I could – I wish I knew more about – because from – just from shadowing the doctor that I've shadowed, they've just been primary care physicians and things like that. So it's just people coming in to the office and they have a virus.

The flu or something like that. Then you just basically say, "Oh, yeah. You have the flu. You have to do this, this, this, and this." But I wish I had more experience with other doctors, because I'm sure there are other technologies that involve physics. I mean, like, an X-ray machine, for one, which I don't – I'm not sure exactly how that works. But I know that is physics. [00:32:00]

INTERVIEWER: Sure.

RESPONDENT: Or like, an MRI. Don't put magnets in an MRI. They'll shoot out. (Chuckling) I don't know. It's things like that. And motors? Motors. I don't know when I'll have to use motors as a doctor, but the – I thought it was really interesting. We were just – we just had a unit about magnetic fields. I thought I was interesting how the – I think it's the DC motor works, where the magnetic field – the currents cause it to oscillate. The motor thing to oscillate. So I thought that was really cool. But I don't know if I'll ever have to use that, but I don't know. I thought it was cool. (Chuckling)

INTERVIEWER: Awesome. So, what do you think is important to get out of a course that's outside of your discipline?

RESPONDENT: Hm. I think it's important just to open yourself up to the possibility of gaining new knowledge. [00:32:58]

Because I think that's why – I think that's where a lot of people don't have – not "fail as people," but they almost fail as students. Because sometimes – I know so many of my friends just want to get their college and leave, and go on to work or whatever. Which is fine. That's fine, but for me, that's not how I see things. I see things as, "I want to literally take every experience I possibly can here, whether it be like an interpersonal experience, whether it be a social experience, whether it be an educational experience.

"I want to take all of those things, and really learn from it, and learn from myself through each process." Because I think – like I said, I really believe knowledge is power, and any experience that you experience in life is valuable. So I never want to just wish away time and stuff like that. So I think that's a really important part of it. I know – and like I said, going back to that question, how you ask – why do you ask me, "Why do you think you're required to take physics?" [00:34:02]

I think I'm required to take physics because – I mean, we have to be well-rounded in the sciences, for one. And two, it's just a different way of thinking. I mean, how could you go through life and look at the things you look at and why – I don't understand how someone couldn't question some of those things or not want to understand why things work. So I think just practicing the skill of opening yourself up and being – and embracing new ways of thinking, no matter how hard they are – I think that's so important. And just as a person and as a student as well. I really believe that.

INTERVIEWER: So what do you think is important to take away from that first semester of physics?

RESPONDENT: That I can work my butt off, for one. Because I really did. Rea – I tried so hard. That – I never had to try. Not never. I had not tried that hard in a class in – I don't even know how – like, not even in my Advanced Bio class. [00:34:57]

I was more worried about physics exams – Physics I exams – than Advanced BioChem exams where I had to memorize 20 pathways. I was more worried about physics, to be quite honest with you. So I learned that I really can work my butt off. I learned that I am very open to the idea of learning. Because just going through physics, a class that – a discipline I've never experienced before in my life. Really having a desire to know why this is happening and to really understand the nitty-gritties of it. Or at least, scratching that surface. You know what I mean? So I learned that about myself. Aside from the actual information we learned and what-not. So, yeah. I learned those things.

INTERVIEWER: Awesome.

RESPONDENT: Yeah.

INTERVIEWER: How do you see physics being important to you in the real world?

RESPONDENT: I question everything.

INTERVIEWER: Question everything.

RESPONDENT: I really do question everything, whether it – and I wish – sometimes, I wish I would just write down – like, if I, a question pops in my head, I wish, "I'm going to try this. This is going to be like my reso – like, my goa – " [00:36:04]

Because it's so hard to do. I love them. Very goal-oriented, so I like to make little goals for myself. So once this semester ends, I'm going to make a goal that I write down all the questions I have in my head. So anyways. I really like to question things. So physics would for sure apply to me trying to answer why something happened.

For the longest time, I wanted to know salt melts ice. I wanted to understand, "Why does this happen? Why is this a thing?" So, just little things like that. I can look around and just question any dumb thing. You know what I mean? Sunsets. Like, why are those colors there? Just things like that. So I think that's why – how it's going to apply in the rest of my life.

INTERVIEWER: Why do you think you ask those types of questions? Why do you think you're inquisitive about (crosstalk) –

RESPONDENT: I don't know. I mean, I think ever since – I think that's just the nature of who I am. Because ever since I was a kid, I was very observant. [00:36:58]

I preferred to just observe things rather than be, take the lead on things. I mean, I do take the lead, and I also have the side of me that is very like, "Okay. I am the leader. You follow. You do this."

INTERVIEWER: Yep.

RESPONDENT: So – but there's also a very big part of me, I think it's more of who I am, that likes to take things slow and just be really sure about what I'm doing. So that involves really analyzing each – bits and pieces of different things. So then that leads me to question why this is. I don't know. I think that's just who I am. I question things. I don't know. Because I'm a little more analytical. I don't – I really don't know.

INTERVIEWER: Mm. Now, you touched on this question, I think. How do you see yourself using physics in the real world? Like, actually using it.

RESPONDENT: Right. So like, not at work and stuff? [00:38:00]

INTERVIEWER: It could be work.

RESPONDENT: Okay.

INTERVIEWER: What do you think of when you hear "real world"?

RESPONDENT: When I think of "real world," I think of – I don't know. It just – the – it never really had a meaning for me That's why I'm struggling to define it. Because "real world" is like – like, right? I am the real world. You know what I mean?

INTERVIEWER: Yeah.

RESPONDENT: I mean, I see using it to just talk about physics, sometimes, with – because if someone asked how polarized sunglasses work, I would for sure just pull that knowledge out of my back pocket and be like, "Listen. This is how that works." So I mean, in term – that, I would use it that way. I don't know.

Like, when I have a family one day, I hope that I can have kids and start teaching them about why things work and stuff like that. I think that would – my knowledge that I'm gaining now and understanding of things is going to help me educate my own kids, and stuff like that. Because I want them to be just as knowledgeable. [00:38:59]

I want them to be more knowledgeable than I am, but they have to start somewhere. I hope I could shed some insight and way of thinking to them. I don't know. I don't know. I mean, I don't know how I would use physics other than that.

INTERVIEWER: That's fair.

RESPONDENT: I mean, research. Like I said, research.

INTERVIEWER: Yeah.

RESPONDENT: Research. I'm sure I could use it. But like I said, doing physics, for me, is still – I'm still stuck in this idea of – so, one, seeing something and explaining why it happens. So, example: polarized sunglasses. Two, sitting down at a whiteboard with equations all over the place, and analyzing the equations. So that's the part I'm not sure about. I'm sure that can use a little more modifications and reamping and stuff like that. But as of right now, I still see it as like, the equation, and like, I'm not good at physics, so I can't see myself doing that right now.

INTERVIEWER: Fair enough. Have you seen any connections between physics and your other courses? [00:40:02]

RESPONDENT: Oh, yeah. Yeah. All the time. I mean –

INTERVIEWER: All the time?

RESPONDENT: Yeah. I mean, and even thinking back to physics in gen – or, other classes in general. It's cray – because I – so I tutor – I'm also a student tutor, so I tutor orgo, chem, and then biochem.

INTERVIEWER: Mm.

RESPONDENT: And bio, but – I mean, bio's just my [rising fact] (ph). So. Anyways. So, like, I was just helping someone last week with – it was spectroscopy and things like that. So, the absorption spectrum and the ref – the reflective. Not the opposite of absorption. I can't even think of the word right now.

INTERVIEWER: Emission?

RESPONDENT: Emission. Emission spectrums. So they were asking why that happens. So – I mean, there's als – you can give the explanation about, "Oh, electrons are jumping to higher energy states and then back down." But then they ask, like, "Okay, so what is this light? What is this light entity?" [00:41:02]

So that gets into electromagnetic waves, and – the wave lengths and the amount of energy in each wavelength, and things like that. So, I can – it's almost like I have been learning physics all my life, and I just haven't really known it. Some of the equations haven't been in a physics classroom. So it's almost like, "Okay. I'm still associated with chem," and stuff like that. So, in terms of that, I – physics, I've been seeing all my life. It's just now getting to practicing it and understanding the variables and stuff like that. So I see it all the time in my classes now.

INTERVIEWER: Gotcha.

RESPONDENT: I [make it up] (ph) – it’s easier for me to identify physics now. For sure.

INTERVIEWER: Mm. So you talked about the relationship between biochem and bio. Chem. And physics. That you’re seeing the connections.

RESPONDENT: Yeah.

INTERVIEWER: Are there certain connections for bio and physics, and certain connections for chemistry and physics? [00:41:58]

RESPONDENT: Mm – if I had to – see, the way I’m visualizing it, is like, bio’s in the middle, and then there’s chem, and then there’s physics.

INTERVIEWER: Okay.

RESPONDENT: Why I see it that way, I’m not sure. Because when I think of bio, for me, bio is just straight memorization. It’s just knowing that pulimaries (ph) is just going to make a trans – or, copy DNA, and that’s just how it is.

INTERVIEWER: Yeah.

RESPONDENT: Then, the chemistry side of it is why this is happ – the chemistry explains this process.

INTERVIEWER: Uh-huh.

RESPONDENT: But then there’s also another explanation of why this happens, for the bio. Then – but at the same time, physics can move around in a circle to this side. Too. Because physics has to do with these charges, and charge repulsion. Why breaking an anhydride bond is very exergonic (ph). You know the physics behind – there’s going to be a lot of charge-charge repulsion. That will increase entropy and things like that. [00:43:01]

So, [base decking] (ph) and DNA.

INTERVIEWER: Mm.

RESPONDENT: The hydrophobicity effect. Entropy. You know what I mean? So, it’s all – it’s almost like – but, like – because bio is almo – I don’t want to say it’s like a cop-out of the sciences, because I – it’s so important. I mean, we need biologists. It’s like so important. But there are so many ways you can think about biology. Because there’s the biology that’s like, field biology, where it’s observant, the observational studies and what-not.

So, I’m not sure how physics has to do with that type of stuff. Because that’s a lot of, like – almost like psychology. Because how animals interact and what-not. But I mean, the underlying thing is their chemical nature and stuff like that. So that has to do with physics. I mean, chemistry. And chemistry has to do with physics. You know what I mean? So, in a way, I think I see chemistry and physics way more related than physics and bio.

INTERVIEWER: Okay.

RESPONDENT: But only because – only because physics explains the way things work, and so does chem.

INTERVIEWER: I see. [00:44:00]

RESPONDENT: And they complement each other very well.

INTERVIEWER: I see.

RESPONDENT: And then they explain biology.

INTERVIEWER: Gotcha.

RESPONDENT: And that's just the way I see it. I'm sure that's a very over-generalization, very ignorant –

INTERVIEWER: I know.

RESPONDENT: Yeah.

INTERVIEWER: Yeah. I know. Okay.

RESPONDENT: (Chuckling) – just an ignorant way of seeing it.

INTERVIEWER: No, I don't think it's ignorant at all.

RESPONDENT: (Chuckling)

INTERVIEWER: I don't think (inaudible at 00:44:15).

RESPONDENT: Yeah.

INTERVIEWER: Do you think the first semester course changed your interest in physics?

RESPONDENT: Yeah. Yeah. Because it really – because like I said, I liked – I'm very attracted to understanding the way things work. And physics is that. Physics is literally that. So I was very attracted – I became very attracted to physics. I mean, if you brush away all the frustration and like, how difficult that the – errgh! Sometimes, about it. I really am interested in physics. That's why – it's almost like I keep learning more in-depth stuff, whether it be bio chem, whether it be physics. I feel more comfortable understanding the real world. You know what I mean? [00:44:58]

And so I think – yes. After taking physics, it might – my passion understand physics really became heightened. I want to explore these different concepts and what-not. So, yes. I think so. Very confidently. Yes.

INTERVIEWER: Awesome.

RESPONDENT: Yeah.

INTERVIEWER: The next question is going to be a famous one, because we've repeated it, now. When I mention diffusion, what comes to mind for you?

RESPONDENT: Diffusion? Yeah. Entropy. For sure.

INTERVIEWER: (Crosstalk)

RESPONDENT: Entropy. Entropy. Momentum. Energy conservation. I was going to say Coulomb's Law, but I don't know if that exact – I mean, it applies, because that has to do with two charges, and stuff. I mean, it depends on what we're talking about diffusing. But, in general, maybe – but that's more like bond energy and stuff like that. But, yeah. Those are the first things that came to mind.

INTERVIEWER: Okay. Could you give me a definition of diffusion? [00:46:01]

RESPONDENT: Whoo. That's hard.

(Pause from 00:46:03 to 00:46:12)

RESPONDENT: It's literally like a driving force that –

(Pause from 00:46:18 to 00:46:24)

RESPONDENT: – a driving force that increases the entropy of the universe? I really don't know. I really – it's very hard. I don't know. I really don't know.

INTERVIEWER: Pretend I was a classmate.

RESPONDENT: Okay.

INTERVIEWER: How would you describe diffusion to me?

RESPONDENT: Oh, I – in terms of that, I –

INTERVIEWER: I go, "Hey, what's diffusion?"

RESPONDENT: I would just say, “Molecules or anything spreading out –

INTERVIEWER: Anything spreading out.

RESPONDENT: “ – from an origin.”

INTERVIEWER: From an origin.

RESPONDENT: Yeah.

INTERVIEWER: Okay.

RESPONDENT: Yeah. I think so.

INTERVIEWER: Okay.

RESPONDENT: (Chuckling) I don’t know. I’m thinking about dropping (chuckling) salt in water, and then I’ll just, letting it – you know, like a salt cube. Just – it’s – dissociates. [00:47:05]

INTERVIEWER: Disassociates.

RESPONDENT: It diffuses throughout the entire container.

INTERVIEWER: Okay.

RESPONDENT: But it’s just so much – there’s way more than that.

INTERVIEWER: Right.

RESPONDENT: Diffusion is huge.

INTERVIEWER: Can you describe the process of diffusion?

RESPONDENT: Yeah. I mean, I think so. It has to do with – so, first, it has to do with just increasing the entropy of the system. So, everything wants to be spread out. That has to do with maybe like a temperature gradient or some type of uneven gradient. So the gradient is somewhat of that driving force, henceforth “diffusion.” But then it also has to do with once things start to spread out, there’s also going to be momentum between molecules that – or whatever we’re talking about, bumping into one another. [00:48:02]

So the forces have to be equal and opposite. there also has to be conservation of energy, so if one’s moving faster than the other, the energy is transferred or whatever. So, yeah. I guess that’s the process. Then it – once it reaches an equilibrium point, which is when everything is – the gradient doesn’t really exist anymore in the system, then we are at equilibrium, and diffusion has happened.

INTERVIEWER: And diffusion has happened.

RESPONDENT: Yeah.

INTERVIEWER: So you mentioned that there's some kind of a gradient, and that things move – it's like the motivator.

RESPONDENT: Mm-hmm.

INTERVIEWER: How do I know which end of those, the gradient I'm on?

RESPONDENT: Well, yeah. So that's what I was trying to get to, but my way of explaining things sometimes is very annoying. (Chuckling) [00:48:55]

But I'm particularly thinking about a demonstration we did in class where, like, the left side of the class had way more pieces of paper than the right side of the class. So it was easier – like, it was easier for molecules to – I guess it was simulating, like, bumping off of each other and all the momentum stuff. And then to move over to the other side of the class where there was nothing, and then give someone the piece of paper or whatever.

So – because everyone had two pieces of paper, and you were supposed to give it to anybody. We were trying to get it – I forgot exactly how it went. But that's how I'm seeing it. I'm seeing it how the paper move throughout the classroom after five seconds, or ten seconds, or fifteen seconds. So that's how I'm seeing it, and, yeah.

INTERVIEWER: So if I'm a piece of paper, how do I know which way to move?

RESPONDENT: Well, so – okay. So, if you're bumping off of other things, that's like the random motion. That's random motion. One. [00:50:01]

Two, if there are any charges involved, you want to – there's charge-charge repulsion, or charge-charge attraction and what-not. So it has to do with it. Then, energy just moving from higher regions to lower regions. So that energy can be like, thermal energy. So, heat, for instance. Yeah. I think that's all I can think of right now.

INTERVIEWER: Okay.

RESPONDENT: Yeah.

INTERVIEWER: I remember back when we'd first talked about – I think it was physics in general. You're like, "Well, it must be physics."

RESPONDENT: Mm-hmm. Yeah.

INTERVIEWER: The “why” – why it happens. Has that – is that been more clear for you, now that you’ve had a semester and a half?

RESPONDENT: Yes. And that – I specifically think of the Gibbs free energy equation. [00:51:01]

Delta G equals H delta H times T minus S. So I think of that equation, and it was like the T and the H – so, enthalpy, and then the temperature, obviously. That’s like chemistry. I know that. But then the entropy was like, “Okay. This is physics. This equation makes sense because of the physics.” Yeah. So, yes. I – my understanding has been molded in a few different ways, for sure.

INTERVIEWER: How does the idea of diffusion connect to biological molecules or situations?

RESPONDENT: Oh my God. (Chuckling) It’s like, everything.

INTERVIEWER: It’s everything?

RESPONDENT: Yeah. It’s literally everything. It’s how things mo – it’s sometimes how things move through the blood, and how things move within a cell. Diffusion is a lot. Like, diffusion is literally the biggest deal in the world, in science, I feel. Thinking about it now. [00:52:00]

INTERVIEWER: It’s the biggest deal in science.

RESPONDENT: I mean, I think it’s one of them. Because I think I really – going through bio chem, and really getting down to the last hydrogen. It’s like, if entropy is increased in the system, that’s a favorable reaction. All of those reactions sum to a process. Those processes are what we see. So, that really is such an important driving force to anything we see. You know what I mean? I still wish I had a little more understanding that I really could just sit down and say, “Diffusion!” But, like I said, sometimes my skills are a little bit shaky, and I – it takes a minute to make some of those connections.

INTERVIEWER: Sure.

RESPONDENT: I have to see things from different ways, so.

INTERVIEWER: Yeah.

RESPONDENT: But yeah. I think diffusion is very important.

INTERVIEWER: So, reflecting back about what you thought about diffusion at the beginning of the course, and now what you think. [00:53:02]

What do you think you’ve learned about diffusion in the first semester?

RESPONDENT: Of physics?

INTERVIEWER: Yeah.

RESPONDENT: Energy conservation.

INTERVIEWER: (Crosstalk)

RESPONDENT: It's a huge thing.

INTERVIEWER: Yeah.

RESPONDENT: Because that concept – I mean, I knew what it was, but I never – it was just something that was so not practiced, for me. It was almost like opening up that door, just led me to this huge empty room of like – I never knew this room existed. You know what I mean? So that was a huge deal for me, because that – then that started to tie in with the forces, and it started to tie in with – I don't know.

Energy conservation just tied in to everything, for me. Like I said, I wish I could like, pull the string, and I – it wouldn't break in the middle. So I could get what's at the end of the string. But sometimes that is so hard to get in my head. Because I needed to, like, visualize it along each step of the way. [00:54:02]

Sometimes my visualization was not there, and therefore I couldn't pull the string without breaking it.

INTERVIEWER: Gotcha.

RESPONDENT: You know what I mean? So I wish I could grab the string for you and tell you what's on the other side and why this works. But I just – mm. I can't yet. I need – I need to be an LA, and I need to take it again, and I need to really understand everything that's going on. And understand all those connections. You know what I mean? I really want to master at least these general, basic properties of physics. Physics I and II. That's what I really want. I wish I would have taken it in high school so I could at least – I wish I would have came in at least with some foundation. Because my foundation was noth – like, absolutely nothing.

INTERVIEWER: Yeah.

RESPONDENT: Especially with the – when we started off the year with all the position, velocity, and acceleration graphs. (Chuckling) I was like, "Oh my God. Physics is impossible. Like, I have no freakin' clue what's going on." So, I wish I would have had some understanding. But, would've, should've, could've. [00:55:01]

INTERVIEWER: Thinking back on those – position, velocity, and acceleration – is it more doable now?

RESPONDENT: Piece of cake. Piece of cake. I'm embarrassed that I was strugg – I know. (Chuckling) I'm just – I'm hard on myself.

INTERVIEWER: Yeah. You're really hard on yourself.

RESPONDENT: I'm very hard on myself. So.

INTERVIEWER: Yeah.

RESPONDENT: Yeah. That's also something I learned from physics: I'm very hard on myself. But, yeah. I – that is like, I wish I could take exam one over. I wish I could take it over.

INTERVIEWER: Yeah.

RESPONDENT: And I wish I – the cheetah problem. I don't know if you –

INTERVIEWER: I think I remember the cheetah problem.

RESPONDENT: Okay. I felt like – I mean, I wasn't – some of my friends almost had a panic attack because of the cheetah problem.

INTERVIEWER: Oh, no.

RESPONDENT: But I really could see it very nicely. I mean, I tripped up on, "At what time will the cheetah catch the gazelle?" or whatever. But, I wish I could retake that over. Or just like, work through it, or something like – that would be a fun activity for me to do. Just to go back to that exam and just see things so clear. [00:56:01]

That would give me such fulfillment.

INTERVIEWER: Yeah.

RESPONDENT: To just see it all in my head and just be like, "We're good."

INTERVIEWER: Nice. Yeah.

RESPONDENT: You know what I mean? So, yeah. Yeah. Yeah.

INTERVIEWER: So, I think it's pretty unique when a student says that they wish they could just redo the –

RESPONDENT: Yeah.

INTERVIEWER: Just for fun.

RESPONDENT: Yeah. Just for fun. In exam two, the freakin' – the ramp problem. The very first –

INTERVIEWER: Oh.

RESPONDENT: – problem that everyone did so bad on. Aaahh! It drives me nuts. Like, I wish I could just – hhhh – because if I just maybe had a little more time with, like, Vashti, or a little more time with one of the LA's, or – preferably Vashti. Because I loved coming in here for Office Hours. Just – that was so helpful for me. So I wish I would have just come in here and like, could see this ramp in my head with all these forces. I – mm. But, again, would've, should've, could've.

INTERVIEWER: Yeah.

RESPONDENT: I learn from my mistakes. So.

INTERVIEWER: And then you got a 4.0.

RESPONDENT: I mean, I got a 4.0. So it was okay. But, still.

INTERVIEWER: (Chuckling) Yeah, but still.

RESPONDENT: Still.

INTERVIEWER: But, still.

RESPONDENT: Still. [00:56:58]

INTERVIEWER: And you said you're in Dr. Quartermeyer's (sp?) class right now?

RESPONDENT: Yes.

INTERVIEWER: Can you tell me a little bit about the physics class?

RESPONDENT: Completely different.

INTERVIEWER: How so?

RESPONDENT: Completely different. It is all lecture.

INTERVIEWER: All lecture.

RESPONDENT: It's a hundred and thousand percent lecture. On Fridays, we have exams. I mean, labs. On Wednesdays, we do tutorials. But it is a [world win] (ph) different. It's like, we learn this equation. This is the equation. We get some (inaudible at 00:57:28) kappa. We do the homework, and then that's it. Then – yeah. I mean, I – yeah. That's, I guess, what it is.

Then, the tutorials are just really hard physics problems that go – that start off really small and stuff. So it starts with flicking up rope and making a pulse, and then analyzing the pulse going through rope with the lower mass density, or one with the higher mass density. This one goes faster, and this one doesn't get reflect – things like that. [00:58:00]

So that's what the tutorial is. Then, the labs are just whatever concept we're focused on, on that day. But, we do a lot of programming.

INTERVIEWER: Okay.

RESPONDENT: Yeah. With V Python, which has been interesting.

INTERVIEWER: Do you like it?

RESPONDENT: In Vashti's class, I was like, allergic to V Python.

INTERVIEWER: Allergic!

RESPONDENT: I hated it. I absolutely hated it. It made me get hives and cry, and have like a seizure.

INTERVIEWER: Yeah.

RESPONDENT: But this semester, I have been feeling very comfortable with it. I don't know – after like, the first programming project, I was a little overwhelmed. But second one, I did in 10 minutes. Literally 10 minutes. It was a charge going through a mag – an elect – was it magnetic? I think it was magnetic, because it oscillated like a wetness circle. The circular motion. I think it was magnetic. Yeah. You shoot it from this little box that goes into the field. Then it's like a game where you have to hit the back of the wall or something like that. [00:58:59]

So, I felt so much more comfortable with programming this semester, which has been interesting. And I feel as if –

INTERVIEWER: What do you place that? Why was it different this time?

RESPONDENT: I think it's because I really took the time to understand it. We really – I mean, we had to – the first programming project wasn't that difficult or anything, but he wanted us to really understand the physics behind it. For me, it was – I just didn't make that disconnect last semester where the code is, they're just solving equations. You know what I mean?

I mean, half the battle is understanding V Python. That's for sure half the battle, and understanding the abbreviations and the nitty-gritty stuff. But at the end of the day, everything in that code is physics. Like, it's just – whether it be updated position based on like, a velocity that was, that depends on energy conservation. [00:59:59]

Or Coulomb's Law, the forces on that, the charge, experiences from other charges and stuff like that. So. It – I can visualize what's happening.

INTERVIEWER: Gotcha.

RESPONDENT: That's how, why I've learned V Python. Or, I've learned to be comfortable with V Python.

INTERVIEWER: So, you said it was completely different.

RESPONDENT: Yes.

INTERVIEWER: How do you feel about the two different styles?

RESPONDENT: I was trying to think about it. I don't know. I don't know. I feel like I'm more in my comfort zone for sure this semester. That's number one. One hundred percent. I felt as if I did not have to get used to a learning style. Which, I don't know if it's going to help me or if it's going to, whatever. But we don't sometimes go into like, the depth that we used to with momentum principles or energy conservation and stuff like that. [01:00:59]

So that's something that – I mean, I can do that on my own time, which I've had – because that's how I learn something. I really do go through the nitty-gritties and stuff like that. Understanding the interference pattern that, like, a double-slit laser, a light will show or something like that. I had to really work through that. I watched like 20 million YouTube videos on that stuff.

Or the harmonics, like the – going from like, the first – the first harmonic, and second, and all that – all the waves and stuff like that. Then cutting the pipe in half and stuff like that. So I think ger – Dr. Quartermeyer's (sp?) class is much more straightforward and to the point. This is what we need to know, or what we need to know, or what all these white guys making the curriculums and stuff said we need to know.

INTERVIEWER: Right.

RESPONDENT: But I think Vashti's class was more about understanding why it happens, which is – like – I mean, I like both for different reasons. [01:02:01]

INTERVIEWER: Yeah. Okay.

RESPONDENT: You know what I mean? And I think my – I really don't kn – I really – it's really honestly difficult for me to say.

INTERVIEWER: Yeah. That's fair.

RESPONDENT: It's really difficult. And I wish I had more of a concrete answer, because I have thought – I really have tried to think about it. Yeah. It's just – I feel more comfortable in Gerd's class. Yeah. Just because I didn't have to – I – and I don't really feel left behind. I felt left behind sometimes in Vashti's class. Yeah. I just wish there was a little more structure to Vashti's class. I don't know how and what that structure looks like, but I just – I feel like I need, I needed a little more structure –

INTERVIEWER: Gotcha.

RESPONDENT: – or something. You know what I mean? Or I needed like, a big picture before I dived into the nitty-gritties. I needed to at least know – like, I needed to at least see the equation. [01:03:02]

Because like, all the momentum and stuff, and even the force stuff. Like, we had to derive force equals MA. We had to derive that through one of our labs. That – I – it was just so hard for me to understand why we were doing the lab, what its purpose was. Without at least seeing the equation and how it worked with the numbers, and stuff like that. Which, I don't know if there's an easy way for doing that with the mechanical physics or whatever. But, I wish that there was just something a little more structured in there.

Because I – at times, I didn't even – it was like I was being asked to step somewhere and I didn't know where to step. You know what I mean? That was so difficult for me. With Gerd's class, it's like he gives us all the pieces. He lays it all down for us, and it's just up to us where to step. You know what I mean? Just – and I feel as if with Gerd's class, it's easier to get into a little more complicated problems and stuff like that. [01:03:58]

Just because – and, but that's all – it's so – it's such an interesting way, because that all has to do with just looking at these equations and manipulating equations. But with Vashti's class, it was not like that. It was like, you had to actually understand the equation before you even started to touch with it –

INTERVIEWER: Yeah.

RESPONDENT: – started to work with it. So that was like – that's been a really big difference, and I don't know which way is better, and I don't know which way anything. All I can tell you is that I'm more comfortable, I think, with Gerd's way.

INTERVIEWER: Yeah.

RESPONDENT: I think with Gerd's way. And I think there's a lot of things that play into it with like, last semester and stuff like that. Which I said, sometimes I felt frustrated, sometimes I felt left behind, and things like that. So I think that has to do with it. I just wish there was some element in the class that made students who didn't know where to step feel a little more comfortable about even trying to take a step.

INTERVIEWER: Got –

RESPONDENT: You know what I mean? And I know that's so arbitrary and so hard to even understand, really, unless you're in my brain and –

INTERVIEWER: Yeah. [01:04:59]

RESPONDENT: – you experience what I experience. But, that's what I felt. Like, that's what I feel now. And I wish.

INTERVIEWER: Gotcha.

RESPONDENT: Because I feel like I'm able to take more of a, I guess, leader position in this class than I was in Vashti's class.

INTERVIEWER: I see.

RESPONDENT: I always felt like I was always following what the people next to me were doing, or trying to understand their way of thinking. In Gerd's class, it's almost like I feel like I'm – I feel so comfortable experimenting with a different perspective from someone else, and experimenting with substituting this into the equa – you know what I mean?

So I don't know how Vashti's class could be altered in that way. Because I'm sure that's how it worked for a lot of other different people, and it did work for me. It really did work for me, especially once I got used to her way of teaching. It was so much easier to study for exams, but it did take a minute for me to get used to that class.

INTERVIEWER: The last question I have, it's going back to – you mentioned the first semester course was a challenge, but it was a satisfying challenge.

RESPONDENT: Yeah. [01:05:58]

INTERVIEWER: And that in this one, in the second semester class, you feel more in the lead.

RESPONDENT: Yeah.

INTERVIEWER: Is it still a challenge?

RESPONDENT: Oh. Yeah.

INTERVIEWER: Okay.

RESPONDENT: One hundred percent. Yeah. Like – and I really – okay. And then another thing, is his exams – because I get like, really anxious with exams. His exams, first off, they're seven problems, which was nice. We always – we know that there's going to be seven problems in the exam.

We know that only five – because he drops two of the questions. Like, our two worst questions, he just completely drops. So it's almost like I like having that safety net under me. That helps me think – I just feel more comfortable preparing for his exams.

INTERVIEWER: I see.

RESPONDENT: You know what I mean? So that was one thing. So I just – I don’t know. I really don’t know how to explain it. I mean, because there are some things that I really wouldn’t take a lead on. I mean, I woul – I mean, I obviously wouldn’t stay up in front of the class and teach everyone about electromagnetic fields or –

INTERVIEWER: Sure.

RESPONDENT: – things like that. [01:07:01]

But I – I don’t know. It just – I feel like I have more freedom to think about things the way I need to think about it. You know what I mean? And I don’t know if that comes with understanding the way he teaches, or – I don’t know what it is. But I remember just being so lost all throughout momentum. I was like, “What the hell is momentum?”

Like, I know what it feels like, but I don’t know what it is. You know what I mean? I just – ahh. And then when we started to add force to it, I’m like, “Well, I don’t even understand the position. What – how am I supposed to – “ You know what I mean? So it was – that was just so difficult for me, and I don’t know how or why. But I just remember it being very hard.

INTERVIEWER: Yeah.

RESPONDENT: Yeah. So, but – this class goes way faster. Like, way faster. Like, we learn waves one week, and then the next week is – I mean, obviously, sound is waves, too, but – it’s just so different. You know what I mean? So, sometimes it’s hard to see where things can act.

INTERVIEWER: Gotcha.

RESPONDENT: But I think it’s easier for me to see how things work to see things connect, rather than work to understand the underlying motions and concepts of an equation, like I had to do. [01:08:07]

INTERVIEWER: Gotcha.

RESPONDENT: Because I saw how everything connected in Vashti’s class.

INTERVIEWER: Yeah.

RESPONDENT: I just couldn’t get to where I could think, look at the equation and be like, “Oh, this is going to do this, and this is going to do this.” I could not get to that point.

INTERVIEWER: Gotcha.

RESPONDENT: I mean, I did, but it took very long to do so.

INTERVIEWER: Yeah.

RESPONDENT: It took until exam three. That's when I could see it. You know what I mean? Maybe that's just fault on taking Physics I for – like, getting – have – having to get used to physics. Because I'm – I don't know if I learned these concepts first semester, and then learned first semester concepts second semester, if it, things would have been different in getting used to physics in general would have been just as much of a struggle. I don't know.

INTERVIEWER: Yeah.

RESPONDENT: I think there are a lot of different ways –

INTERVIEWER: But if you'd started in this class – yeah.

RESPONDENT: Right. So I don't know if I would have understood mechanical physics e – like, better this semester after taking Physics II and understanding light waves and stuff like that. I don't – I really don't know. [01:08:57]

But that's just – from how I saw it, and from the way I took it, that's how I saw things.

INTERVIEWER: Gotcha. How many more semesters do you have in this year?

RESPONDENT: Two.

INTERVIEWER: Two more?

RESPONDENT: Yeah.

INTERVIEWER: So, you're a junior?

RESPONDENT: Yep.

INTERVIEWER: So, next year is your last year?

RESPONDENT: Mm-hmm.

INTERVIEWER: It's exciting.

RESPONDENT: Yeah. I mean, I'm terrified, but I'm excited.

INTERVIEWER: Awesome. And Paula, this has been a great chat –

RESPONDENT: Yeah. Of course.

INTERVIEWER: – as usual.

RESPONDENT: Yeah.

INTERVIEWER: Do you mind if I follow up with you –

RESPONDENT: Sure.

INTERVIEWER: – in the future?

RESPONDENT: Sure.

INTERVIEWER: Awesome. Awesome.

RESPONDENT: Yeah. Because I think – I mean, I'm sure you'll want to be interested to hear how I finished off –

INTERVIEWER: Yeah.

RESPONDENT: – with Physics II.

INTERVIEWER: It'll be awesome.

RESPONDENT: Yeah. I need a (crosstalk)

INTERVIEWER: Also, as you get to, getting ready to graduate, pick your brain a little. Thinking about where you're headed.

RESPONDENT: Yeah.

INTERVIEWER: Cool.

RESPONDENT: Yeah. I mean, I'm scared, but hopefully, it should be fine. I'm just worried about getting into med school. That's – and I – but I don't want to make j – because everyone's like, "Oh, you'll get into med school." I'm like, "Yeah, I know I'll get into med school. But I want to get into a – "

INTERVIEWER: Yeah. "I'll get into a med school."

RESPONDENT: "Oh, I want to get into –

INTERVIEWER: It's like, "Duh."

RESPONDENT: " – a good med school."

INTERVIEWER: Sure.

RESPONDENT: I really want –

INTERVIEWER: Do you have a favorite?

RESPONDENT: No. I mean, I keep wracking my brain with the top schools of the nation. [01:10:04]

Like, the top 20 med schools.

INTERVIEWER: USUs, (crosstalk)

RESPONDENT: Yeah. All those stupid – I really shouldn't look at any of that stuff. But I don't know. I really want to study to go to some of the orientations and stuff like that. Because I'm going to take a gap year. So I'm not going to take the MCAT this summer. I'm going to take that the summer as I graduate.

INTERVIEWER: Okay.

RESPONDENT: So next May or whatever.

INTERVIEWER: May. Okay.

RESPONDENT: Next June, or whenever it is. So then I'm going to apply next summer, and then take that gap year. Just because I want more experience with stuff, and I want to try some other things.

INTERVIEWER: Yeah.

RESPONDENT: Like, I want to do a little more volunteer work.

INTERVIEWER: Sure.

RESPONDENT: Maybe travel somewhere and do some – you know what I mean? So, that's – I'm for sure going to take a gap year.

INTERVIEWER: Before locking down for four years.

RESPONDENT: Yeah. Exactly.

INTERVIEWER: Yeah. Okay.

RESPONDENT: Or like, eight years. Whatever it's going to take.

INTERVIEWER: Yeah. Four years plus residency.

RESPONDENT: Yeah. Plus [hot-ass stuff] (ph), plus if I do the PhD program, then.

INTERVIEWER: Yeah. Oh, yeah. I forgot. Yeah.

(Crosstalk)

INTERVIEWER: – too, that'd be a little bit more –

RESPONDENT: Yeah. So, I've got a lot of school left to me. [01:11:01]

INTERVIEWER: Exciting.

RESPONDENT: Yeah. I'm excited for it.

INTERVIEWER: Awesome. Awesome.

RESPONDENT: It's just getting there makes me nervous. But. Yeah.

INTERVIEWER: It will happen.

RESPONDENT: Yeah. I hope so.

INTERVIEWER: And hopefully I see you as an LA. That would be awesome, too.

RESPONDENT: Yeah. I mean, I hope so.

INTERVIEWER: (Chuckling)

RESPONDENT: My interview is next Thursday.

INTERVIEWER: Oh, it's already been scheduled.

RESPONDENT: Yeah.

INTERVIEWER: Oh, okay.

RESPONDENT: So, I have it next Thursday in fi –

**END TRANSCRIPT**

## APPENDIX S

## TRANSCRIPT: MILES INTERVIEW 4

# TRANSCRIPT OF AUDIO FILE:

# LB273-11.15.17-MILES_LAINTERVIEW1

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*The text below represents a professional transcriptionist's understanding of the words spoken. No guarantee of complete accuracy is expressed or implied, particularly regarding spellings of names and other unfamiliar or hard-to-hear words and phrases. (ph) or (sp?) indicate phonetics or best guesses. To verify important quotes, we recommend listening to the corresponding audio. Timestamps throughout the transcript facilitate locating the desired quote.*

**BEGIN TRANSCRIPT:**

INTERVIEWER: All right. That’s the one. Thank you. Cool. It’s the same kind of spiel that we usually say. I mean, I guess you don’t have any instructors anymore. Physics instructors. So I don’t have to worry about grades. But, yeah. That’s your identity.

RESPONDENT: Okay.

INTERVIEWER: Do you have any questions before we start?

RESPONDENT: No.

INTERVIEWER: Cool. So, the point to this interview, for me, is to get a sense for how you’re doing now that you’re on the teaching side of physics. So, my first question is just, “Can you reflect for me? Because you took two semesters of physics on the teaching side.”

RESPONDENT: Yeah. Well, so, overall, as a student, I think why – I experienced two very different styles of teaching. Right? So I experienced this studio physics that Vashti does. Katie (sp?), Vashti. Do (ph). And then I experienced the very classical lecture style of physics when I took the second semester with Dr. Quartermeyer (sp?). [00:01:03]

To be quite honest with you – and I’m not sure if it’s just because I’m looking, if I’m just seeing all this material again – but I’m having better recall of first semester, then second semester, by far.

INTERVIEWER: Cool. Okay.

RESPONDENT: Yeah. So, for instance, a lot of the kinematic equations are just kind of like, type – like, an innate type of thinking about them. You know what I mean? But I really – the only equation from second semester I could tell you off the top of my head was the electro-static force. But I think that’s because I also saw that in first semester, too.

INTERVIEWER: Oh. I see.

RESPONDENT: So, but I don't – I really don't know if that's a thing or not. But, yeah. So I noticed – I for sure noticed that while teaching this semester. Then I'm just really starting to understand how everything's finally connecting. [00:01:58]

INTERVIEWER: Mm.

RESPONDENT: You know what I mean? As a student in first semester, I really could not see that. I think I really struggled with – I even said that in a lot of the interviews I had. I wasn't able to visualize why we were learning these equations by these, all these white men who ha (ph) – were like visionaries. You know what I mean? Like, why would be learning all that stuff? So I'm finally starting to understand all of that stuff. Especially when it comes to all, like, the mechanical physics or classical mechanics. Whatever it's called. And I'm also in P. Chem. right now. So, I don't know if that helps. I don't know if it makes my opinion more biased or my outlook on physics in general a little bit more biased. But I thought you might ask a question like this –

INTERVIEWER: (Chuckling)

RESPONDENT: – because I – it's just so interesting. [00:02:54]

Even when I was just studying for my last P. Chem. exam, it was like these equations that used to just scare the hell out of me, in that it just looked like a bunch of letters thrown around. It was more intimidating then. Even – I couldn't even put forth understanding because I didn't even care th (ph) – it's almost like I didn't care as much. But it's almost – now, looking back at all of this, and looking at how much I actually do know. And applying it in different places, like P. Chem., for instance. It's almost inspiring that the people who made these equations, and the same people who frustrated me when I wasn't applying myself, just how differently they saw the world. You know what I mean? It's just very inspiring, in a way. As stupid as that sounds. But –

INTERVIEWER: I don't think it sounds stupid at all.

RESPONDENT: Yeah. I mean, I think it's very – I – looking back at everything now and knowing what I know now, last semester – I mean, last year. Especially first semester. I really wish I would have applied myself a lot more. [00:04:00]

INTERVIEWER: Mm.

RESPONDENT: But I just didn't know how to. It was a new environment that I didn't know how to tackle. I've never been in an environment like that before, so. Yeah.

INTERVIEWER: You mentioned that there are some connections and applications to P. Chem. Can you say more words really quick?

RESPONDENT: Yeah. Well, so most – what I've been seeing mostly, is – because the first, like, whole half of P. Chem., we treat everything like we treat atoms – everything – as – like, with classical mechanics. So, like, Boltzmann constant and things like that. I've seen the Boltzmann constant before – in second semester, specifically. I don't know how I saw it, to be quite honest with you. But I know I saw it. Then I just understood, like, all – especially how, like, the Arrhenius equation. It describes the fraction of molecules that can have enough energy to react.

INTERVIEWER: Wow.

RESPONDENT: You know what I mean?

INTERVIEWER: Yeah.

RESPONDENT: So, and that incorporates temperature, for instance. [00:05:01]

So, I was finally starting to understand how temperature – well, I mean, I – you don't understand temperature? We live with it. We check our phones for temperature and things like that. But you – I finally was able to visualize that relationship between increase in the temperature increases the probability of these molecules reacting, and blah, blah, blah, blah, blah. So then, that just – it almost made me innately s (ph) – my brain almost was grip (ph) – trying to grab on to things that I knew.

And what I knew was from first semester, when I came to, like – I think we did a unit of systyst (ph) – sta (ph) – statistical mechanics with entropy and stuff at the end of my semester. I don't know if we've gotten to it. We – well, no. We haven't gotten to it while I – teaching. But I don't know if we will. Anyway. So I just started to think about all that stuff, and like, the probability of these molecules having enough energy to react. And, "Well, that's favorable, so the reaction happens. Entropy increases." [00:06:02]

Just like, little minor things like that. It's just – I never thought about things in that, from that perspective before. I don't know why I didn't or why I couldn't. But just little things like that, I'm starting to make connections with.

INTERVIEWER: Okay. Have you –

RESPONDENT: Or diffusion.

INTERVIEWER: Oh. Yes.

RESPONDENT: Diffusion was another thing that I started to draw into. Because I complete (ph) – I feel like I just missed – like, I knew – I felt like I knew what it was when I took the class. I described it, but I think I just missed some of the really key points of what, at least, this class wants students to understand about diffusion with respect to physics. You know what I mean? So –

INTERVIEWER: Yeah.

RESPONDENT: – and then we got – we did this new lab that I loved.

INTERVIEWER: (Chuckling)

RESPONDENT: Loved so much. I thought it was such a cool lab. I wish I would have – well, actually, no. It was more fun for me teaching it than doing it. But, yeah. Just things like that. [00:07:00]

I miss –

INTERVIEWER: So, the microscope lab?

RESPONDENT: Yeah. I just miss the whole – and then even how – I think that lab just tied so well into the computational stuff they did right before it. Where they had to derive that code of what the velocity looks like, and the code – and the, that the velocity equation came from, like, conservation of energy and conservation of momentum. So just, I think that tied so well into diffusion, especially with respect to what Vashti wanted them to understand diffusion was, when it came to physics. All those principles. Yeah. I thought that was just so cool. So cool.

INTERVIEWER: I remember talking to you after you had done the diffusion unit as a student, and you telling me that it was still a little shaky. That, like, "I should know this. I'm not really sure what the big picture is. I need to visualize it." Then, now, you're articulating the sections between equations and principles and –

RESPONDENT: Yes. [00:08:00]

It's –

INTERVIEWER: Tell –

RESPONDENT: – quite honestly, very remarkable how clear everything has become. Like, I'm truly not afraid of physics anymore. Like, I was very scared of physics. Because it was just a way of thinking I never had to do. It was something that just didn't come easily to me, and so maybe subconsciously I was trying to resist it a lot. That's maybe why I struggled quite a bit when it came to trying to learn physics in a studio style. I really don't know. But that's what I can come up with. But it's almost like, "Why don't we all think like this?" now. You know what I mean? It's just such a logical way of understanding things that I think we just glaze over in some of our classes. You know what I mean?

INTERVIEWER: Mm-hmm.

RESPONDENT: I don't – I wish I could articulate it a little better, but I just – it's ver (ph) – the whole – my whole perspective of physics has just changed. [00:09:01]

Like, I never would have thought it would have changed. Ever. Even when I – because I was very apprehensive about becoming an L.A., just because I wasn't confident on some of my physics background and making those connections and helping students understand these connections. Because I was not confident on that. But to be honest with you, the past – probably the past month – I have felt so confident in the classroom. Just – I don't know. It just – it's more – it's just different. It's very different. Seeing everything again.

INTERVIEWER: So, I want to follow up on the thing you said about not fearing physics anymore. But before I do that, I want to ask you about, "When did the diffusion thing click for you?"

RESPONDENT: Yeah. I think that's a – yeah. It was very interesting. I think it, to be quite honest with you, clicked while I was explaining why – the purpose of the lab to one of the students. Because I – they were struggling to understand why they were looking at these vibrating beads on their screen. [00:10:05]

I was like, "Well, think back to the computational thing," blah, blah, blah. It was almost like when I thought about how they had this one activity where they were trying to understand the final velocity of a bigger molecule bouncing off of the smaller molecule – what its velocity would look like based on the energy conservation principles.

And then just looking at these beads in a s (ph) – it was almost like I just – it's almost like I didn't even believe that there were other molecules in the solution, and that it wasn't just only the gel beads in the solution. That there were water molecules buzzing around, and stuff like that. They did have energy. Molecules do not stop moving. So, it was just – I think it was there that I final (ph) – it just clicked. Like – yeah. It was really interesting. It was one of those expeer (ph) – just teaching overall has been one of those transformative experiences. [00:11:01]

You know it's going to be beneficial for you. And you know it's going to take work if you want to be good at it. Right? But it's not like you can anticipate the exact outcome. Like, the exact psychological consequences of trying to teach this material to students who've never seen it before. You know what I mean? So it's been very – all – like, every concept we've looked at, like, in class, me teaching it, has just been – it's almost like I'm learning more by teaching it. Well, and I knew that would happen. But it's a new understanding of the material, for sure. Completely. Yeah.

INTERVIEWER: Would you credit that to this epiphany about diffusion to revisiting the coding, or that microscope lab that was –

RESPONDENT: I think it –

INTERVIEWER: – where you saw the beads?

RESPONDENT: Ri (ph) – I think it was the combination of everything, to be hon (ph) – just all the activities leading up to that lab. [00:12:00]

I thought that lab did such a fantastic job of just tying everything that they had done. Because they've done – they did, like, three mini activities up to then. Including the coding activity, of course. And I just all – I think the lab did such a good job connecting all of it.

INTERVIEWER: Hm.

RESPONDENT: You know what I mean? So I thought that was really cool. It was really cool to see. The only thing I really wish the class would do a little bit more is focus more on a microscopic level of all of these principles. I think maybe that's where my understanding of everything started to get shaky. Because we were trying to apply these mechanical models of IO lab, carts crashing into each other, molecules on the – er, the balls on the screen. We were trying to model all that with those – we were trying to model these mechanical things with these mechanical models, I guess. [00:13:06]

But all of that could apply to molecules and ca (ph) – and atoms and things like that. I think a lot of students are more comfortable with that than the idea of physics itself, like, just as a way of representing all these things. You know what I mean? So I think if we apply – if we could apply some of this stuff a little bit more. Like, these principles a little bit more to the microscopic level, A.K. the things people are more comfortable with, I think maybe some of those things would become way more evident.

You know what I mean? Because we could even do – like, I feel like the class could've even – like, they could have spent maybe a week on – I don't know. Like, what do you – I think it's like, the partition function or something. Where it's like, the total energy equals all of the forms of energy molecules can have, like transay (ph) – translational, rotational, vibrational, and then electro-whatever. [00:13:59]

I feel like that could have just been thrown in there for a second so they understood that, like, "Yeah, water can have all of this energy, and that all that energy is in – you're looking at it right now. You just can't see it. It's a macroscopic level. Like – but it's still there." So I – that's the only thing I wi (ph) – I think would make it easier for students. Because when I was teaching the diffusion lab, for instance, a lot of people were missing the point that water is still in there.

Because they couldn't see it. You know what I mean? And it's not like they didn't know it was there. It was just something that they were taking for granted. They weren't trying to model it with physics. Because they didn't know how to. They weren't exposed to it. So, I feel like that is something the class could definitely benefit from.

INTERVIEWER: So take things down to a smaller scale.

RESPONDENT: Absolutely. Especially because a lot of the people coming into physics – at least, it – when I was – when I took physics, I felt like it was, "We all took bio. [00:15:00]

"We all took orgo. We all took chemistry. Some of us took, like, biochem. already." So it was just – things like that, I wish we would've modeled with the – because we can do it. And that's what I'm learning: we can model things like that with classical mechanics. First semester is supposed to be classical mechanics. Or a lot of it is, at least. We can model things that people are comfortable with, with stuff like that. So I think maybe that would help. Help people understand,

and be more comfortable with physics, and be more willing to apply it to things that they're not as comfortable with. A.K., like, these macroscopic things.

INTERVIEWER: Wow. There are so many things I want to ask you. Okay. I've gotten one question done.

RESPONDENT: Oh.

INTERVIEWER: (Laughter)

RESPONDENT: Sorry.

INTERVIEWER: No. So, I want to keep following up, because I'm planning. Interesting. [00:15:54]

The – so I remember very clearly – I don't think I'll ever forget. Paulo (ph), in the first interview, was saying – to be hon (ph) – 12 (inaudible at 00:16:04) – I'm most nervous about physics.

RESPONDENT: Yeah. I was.

INTERVIEWER: And you told me stories about students at MCAT. Tutoring. Kaplan. Whatever. They were pulling their hair out. It was a very real fear. Now you're saying you have no – you're comfortable in the classroom, you're teaching students.

RESPONDENT: Yes.

INTERVIEWER: Maybe like, the, where you were. Tell me that trajectory. What happened? What was that journey like?

RESPONDENT: It was just – it was – I didn't know it was happening until I started to look at all this stuff again. Like I said, I think a lot of it really has to do with me having a little bit more maw (ph) – knowledge of physical chemistry and the classical models for chemicals, molecules, whatever. So I think a lot – that has to do a lot with it. Because at the same time I was taking this class and trying to study for exams and stuff like that, I was teaching such similar stuff. [00:17:00]

Like, such – the concepts were all the same. It was just a – it was just the difference of how we were modeling it and two different places. You know what I mean? It was almost like I wasn't willing to understand that it's – physics is physics. Like, you can do it in both – at both scenarios, I guess.

INTERVIEWER: So, this is P. Chem. and physics? Mm 'kay.

RESPONDENT: Yeah. P. Chem. Yeah. So, P. Chem. It's – the first semester, like I said, it's pretty much all, like, classical mechanics modeling. All that stuff. And then – yeah. Physics I here –

INTERVIEWER: Got ya.

RESPONDENT: – while I'm teaching it. So, yeah. I – yeah. It's just – it's really weird. It's like, every tie (ph) – every day, I go – every day, I keep teaching. Like, the more and more I keep teaching, I guess, the more and more I just – I feel very comfortable with everything, and I'm not scared anymore. I'm not nervous to not know something. It's really – I don't know what happened. (Chuckling) [00:18:01]

I mean, I did. I do. It was me studying at home and ripping my hair out to understand this stuff. To have them, like, the le (ph) – so, maybe just a little tangent. The last exam I just had. P. Chem. While studying, I had more "Aha!" moments while studying than I've ever had in my entire life.

INTERVIEWER: Really?

RESPONDENT: Yes. Yeah. Like, I truly – and it was all about thermodynamics and stuff like that. And reactions and things. But it was – I never studied so well for something in my whole life, I don't think. Or I didn't understand that you could – the potential of studying could make you feel that way. Because I just – and I don't know if it had to do with – I feel like it must. It must have to do with just me seeing all of this stuff again, and just getting more and more comfortable with it. So.

INTERVIEWER: You're crediting physics for your ability to study?

RESPONDENT: I feel like yes. [00:18:59]

To be completely honest with you, yes. And especially, I think a lot of that – I think truly, I think a lot of that could be attributed to when students have to come up with their own experiments and design their own experiments in the class. I think that it helps – m (ph) – like, when we have to prove them. The L.A.s or whoever has to approve their experiment, make sure it's good. I think it's having to think about that stuff, like, on the fly like that really has – like, really helps practicing these skills of analyzing.

Not fast, but just analyzing without having any heads-up on it. You know what I mean? It's almost like a mini testing yourself moment where if you understand what you're doing, then you can understand what they want to do and how it relates to the big picture that they might not be able to see yet. I think that really sets a student from an instructor apart. I really believe that. So, yeah. [00:19:59]

I think practicing that in the classroom while teaching in Physics I re (ph) – has really helped me study, like, a – in a lecture-style physics environment. Because my P. Chem. is all lecture.

INTERVIEWER: Oh, okay.

RESPONDENT: Like it's – yeah. And it's not lab-based. Nothing. It's all – as stupid as it sounds, it's really studying reactions, like equilibrium, without even looking at a solution of anything. It's like looking at it on a whiteboard. So. It's really interesting, to be quite honest with you.

INTERVIEWER: So, what do you think the studio environment contributed to you now succeeding a, completely lecture?

RESPONDENT: Yeah. I think it has – like I said, I think a lot of it – a lot, a lot, a lot – has to do with students having the ability to design their own experiment. But to be honest with you, I only think that's effective when students can truly grasp the point of what they're doing. [00:20:56]

While doing this class again as an instructor, I think sometimes the objective of activities are missed. I think that's a serious flaw in this class, because – and it's not like no one's trying to just – I don't know. Like, not trying to help students to understand, "Yes, this is the point of this activity. Yes, it's useful." But I think students sometimes need that little push.

Which comes in the form of – in my opinion and the way that I see it, the way that I learn – it comes in the form of someone, A.K.A. an instructor-type person, explicitly saying that. I know this class is really about, like, not lec (ph) – no lecture, no giving the answers, blah, blah, blah, blah, blah. I ask questions throughout the answers. I understand all that. But in my opinion, I think it would be more useful for students to understand the exact main point they need to get from that activity. [00:22:01]

INTERVIEWER: Mm-hmm.

RESPONDENT: You know what I mean? I think the activity should serve them to prove that to themselves. Because you can feel uncomfortable with an equation. You can feel uncomfortable with the concept. But if you work through it in small steps like I think these worksheets are supposed to – these in-class activities are designed to do – I think it's easier for students to grasp it, visualize it, and apply it.

INTERVIEWER: Got you.

RESPONDENT: And I think that that – the making their own lab, creating their own lab – comes from that.

INTERVIEWER: Mm.

RESPONDENT: You know what I mean? And for instance, lab three. I love lab three, because students can do –

INTERVIEWER: What's lab three?

RESPONDENT: Lab three is they can do whatever they want.

INTERVIEWER: Oh.

RESPONDENT: Pretty much.

INTERVIEWER: I see.

RESPONDENT: As long as they relate it to work and energy.

INTERVIEWER: Got you.

RESPONDENT: And so, like, es (ph) – particularly one group, they – right after, I think, Dan finished explaining – this is the morning section that I teach. Right after Dan explained, like, "This is your handout for lab three. Come up with proposals. We'll review," blah, blah, blah, blah, blah. [00:22:59]

It was like this one group that – they don't struggle at – it's just almost like they feel very overwhelmed with everything. So they get – they don't, like – I don't want to say that they don't try, because I think they're good students. I just think that they don't know how to apply themselves. They quickly called me over. Like, without – right after Dan was finished. They're like, "What are we supposed to do? Like, drop an egg from a building? Like, I don't understand."

Instead of, like, saying – instead of not, like – I guess, not reprehending (ph) them or – for not trying, or whatever – I really was like, "You can do that." Like, "Why not? Apply to physics." Like, "How would that apply to physics?" So just, it's like they have it in them and they just need to believe it. They need to prove to themselves that they know what they're doing, that they can make somethi (ph) – they can model physics with an egg dropped from a building. They can model work from that. So, just – yeah. The class does a pretty good job, I think, with the content. I think the content is good. But I think the way it's executed sometimes is not so good. [00:23:59]

INTERVIEWER: Embed (ph).

RESPONDENT: Could be improved. I really believe that.

INTERVIEWER: Yeah. Great.

RESPONDENT: And just – but that's me speaking as a – when I was learning this, what I wished I would have had.

INTERVIEWER: Right.

RESPONDENT: So, I don't know if that's necessarily true for everyone.

INTERVIEWER: That's fair. Yeah. I'm going to have to keep myself disciplined, I'm realizing, because we're already 23 minutes in.

RESPONDENT: Okay.

INTERVIEWER: All right.

RESPONDENT: Sorry. (Chuckling)

INTERVIEWER: Question two.

RESPONDENT: Okay.

INTERVIEWER: No, that was – that's me finding (ph) everything you're saying to be interesting. Is there an activity that you did not like when you were a student, but now as L.A., you find yourself liking?

RESPONDENT: Debut (ph) – diffusion. Computational diffusion.

INTERVIEWER: Oh, yeah.

RESPONDENT: I thought that would – well, the coding – even that – I mean, I'm not – I'm much more comfortable with coding.

INTERVIEWER: Mm-hmm.

RESPONDENT: Right? That was another "Aha!" moment I had. When I f (ph) – looked at the first coding activity that we did. I was like, "Why was I so nervous about this?" But anyway, yeah. I think the diffusion one was definitely something looking back on, I really could have – I could have really understood that. [00:25:02]

Another activity. I don't remember what, exactly, it was called. But I'm pretty sure it was – I'm not thinking about it the right way. But it's the first activity they saw where they realeye (ph) – where they could've – where they learned that they could break forces up into components. And I can't remember exactly what that wa (ph) – if it's a –

INTERVIEWER: It might have been some of the weight one? The three weights?

RESPONDENT: Maybe that – I think maybe that's what it was.

INTERVIEWER: Okay.

RESPONDENT: And I've ranted and raved about this before, but –

INTERVIEWER: (Chuckling)

RESPONDENT: – F net. F net. Like, I never realized how important F – that was one of the concepts that – because we had three exams last semester. That was one of the concepts that I, on the second exam, came – the – went completely went over my head. I got a whole problem wrong because of it. Because it's just such an import (ph) – I believe it's an important thing, looking back on it. [00:25:59]

So, like, I came in Office Hours with Vashti after that exam. I just – it wa (ph) – that's when I realized that I was really missing some critical points in this class. By the way I was studying, preparing, applying myself in the classroom. What have you. But yeah. I think those two activities have definitely been – looking back on it, I can't believe I didn't apply myself or understand it fully, and I just accepted that.

Like, I accepted that it was okay that I clearly see it. So. Just the type of person I am. Because if I feel like I'm shaky on something, I'm usually one to tackle it and just get to the problem. Like, "Why am I so uncomfortable with this?" But in physics, I was not like that. Which is something quite interesting. But I think that just has to do with being uncomfortable with physics.

INTERVIEWER: Got you.

RESPONDENT: Yeah.

(Pause from 00:26:53 to 00:26:59) [00:26:59]

INTERVIEWER: Of the activities we've done this semester, which activity or set of activities do you think are the most valuable for a student in, like, the life sciences? Like bio, microbio, pre-med, and biological sciences?

RESPONDENT: Gosh, I think any of them. If you look at – if you – if you're interested in modeling biological sciences with respect (ph) – like, with physics tools.

INTERVIEWER: Mm-hmm.

RESPONDENT: Right? This toolbox kit that they, Vashti says that they have with all these equations. I think any of it. Almost all of it could be applied. And people have applied it, classically. With classical mechanics. So, but in particular? Gosh, that's a hard – I think that diffusion had so much potential. Like, the diffusion lab had so much potential. They could have, like, had some in water baths that were heating up. Others that were on cold ice or something. I don't know. I think that could have really helped a lot. I really think that needs to be incorporated into the lab somehow, some way. [00:28:06]

Because I think that would – because temperature is something that people are so comfortable with. Right? And it has so much potential to just be really unpacked in this class. I don't know. I wish the class would focus a little bit more on that. But –

INTERVIEWER: Let's see.

(Pause from 00:28:25 to 00:28:30)

INTERVIEWER: So, after taking two semesters of physics and now teaching physics, do you feel more confident in your ability to do physics?

RESPONDENT: Oh my gosh. Yes. I'm not as confident with the stuff we learned second semester. Like, to be honest – like, to be quite honest with you, like, electric fields, magnetic fields, that stuff is still – I know this. Like, I know this.

INTERVIEWER: Yeah. (Chuckling)

RESPONDENT: But –

INTERVIEWER: Is that the right hand rule?

RESPONDENT: Yeah. The right hand rule. But other than that, it's just – and like, what do you call them? [00:29:02]

Circuits. Circuits scare the hell out of me. I'm praying to God there's not one on the MCAT.

INTERVIEWER: (Chuckling)

RESPONDENT: But literally praying. But other than that, I really do feel like I'm more confident in my ability to do physics. Or at lea (ph) – and maybe not "do physics," like, "get the right answer to a problem." But at least think about them. Think about something in a very logical way. A.K.A. in terms of, like, physics equations. You know what I mean? So, yeah. I do believe that. At least, with respect to, like, classical mechanics and the stuff I've seen.

INTERVIEWER: Got you. What do you think made the difference between the first and second semester, where the first semester you feel more comfortable and the second semester you feel less comfortable?

RESPONDENT: I know. I wish – I'm going to have a bad answer for this, because I just – I really don't know. I don't know how semes (ph) – second semester was taught in the studio-style classroom. I really don't know. So, I don't want to give, like, a bad answer or –

INTERVIEWER: Oh. Okay.

RESPONDENT: – a bias. You know what I mean? [00:30:01]

Because I know how I learned everything, but I know Vashti's class learned things way different.

INTERVIEWER: Oh, yeah. So don't worry about trying to speak on the, this – the Vashti's version of the second semester. I'm curious what your experience was.

RESPONDENT: With my –

INTERVIEWER: – like, learning. Right. So, you took away a lot more from the first semester, it seems like than the second semester. So, I'm curious. From your experience, what made that difference for you? Knowing that they were two different environments that you've studied in.

RESPONDENT: Yeah. So, I think a little piece of it is definitely the fact that I'm in another cla (ph) – physics classroom right now. Like, P. Chem. So I'm seeing stuff I learned one time, again, in there. And then in the same environment that I used to be in. So I think that has a lot to do with it. Because second semester, at least from what I understand, it's about, like, fields. There's like, quantum in there a little bit. [00:31:00]

At least what my experience was. It was more – I don't know. I just – I really don't think concepts were – I think they were just maybe presented a little bit too explicitly. Maybe. Because it was lecture style. So, it wasn't like we had the ability to think about – I mean, we did. We were presented with that opportunity. But, like, as a busy student, sometimes – for instance, our last lab report, we could have done anything.

Like, first semester. But we didn't. We just did something that was easy, because we were all like – we didn't have time. So, but I think, like, if we were able – if we had that ability to think about things with freedom a little bit more often, I would've maybe thought about concepts a little better on my own time rather than just seeing it in the classroom. [00:32:00]

I think. And then, like I said, second semester was just a lot – it was all lecture and it was all, like, numbers. Like, doing calculations. Which, sometimes you can't do that if – you can't do it confidently if you don't understand what that equation is saying fully. At least, for the way I learn it. I didn't visualize. I could not visualize certain things.

INTERVIEWER: I see.

RESPONDENT: I don't know if that answered the question. But –

INTERVIEWER: I think so. So, and after the two semesters of physics and now teaching, do you feel there are skills that you've developed?

RESPONDENT: Oh, yeah.

INTERVIEWER: Yeah?

RESPONDENT: Yeah. I think just like, a – like, simply put, is just my understanding of the content and the understanding of the equations. Where they come from, blah, blah, blah. So I think that, for sure. And then also just me as a – like, a teacher. [00:33:02]

Just being patient. Having to explain something differently. Not feeling discouraged if someone doesn't quite understand a question you ask. Or a student is more resistive, I guess, to you. So I think those are definitely some of the most obvious skills I've learned. Then, honestly, I think it's just a different type of teaching. Physics.

Because it's really interesting how different – at least in my opinion – how different physics is from the other sciences. Because it's almost like – it's like it's a science of its own. You know what I mean? It's just – it's something that applies to everything. It's almost more of a math. It should be categorized as, like, a math statistics-type, like, science, rather than like, "Chemistry. Orgo. Bio. Biochem." [00:34:04]

Like, that's – it's just different. Because it's – math, you – in math, you can model things, right? Physics is modeling things. I mean, there are concepts which – but those concepts are like, people discovering these equations from other things, whether it be, like, bio, chem. – like, physics of mechanical things, like springs and stuff like that.

So, I think just the skills of teaching, understanding content, and then just thinking about physics itself differently and looking at it from a completely different re (ph) – perspective that I never really knew I had any, or never knew I would. It's just I think those are the most three, like, prominent skills that I've gained so far.

INTERVIEWER: Got you. Do you feel proud of anything this semester?

RESPONDENT: Yes. Putting myself out there. Yes. A hundred percent. Because I was scared to be an L.A. [00:35:01]

I was very, very worried about it. Not "very, very worried about it." I was moe (ph) – I was in – I was excited to do it because I knew I would see things again. Right? Like I said earlier, I said it was going to be one of those transformative experiences. Because I have taught other sciences before. I used to be a Biochem. II tutor – and I love biochem. That's my major. It just comes – not – I mean, it does com (ph) – the thinking comes easily to me. Right?

So, then comes the work on my part of memorizing certain pathways and things like that. But that's all stuff that I'm willing to do because the way of thinking is there for me. It wasn't like that with physics. The way of thinking about physics wasn't there for me. So I had struggled with even applying that thinking to these problems and exams and things that I was being asked to do for a grade. There was just a lot of pressure. I think after my experience at – especially first semester. Because first semester, I think I struggled more than second semester. [00:36:02]

In second semester, it was more like, "Here's some numbers. Plug them in." Like, "If you're lucky, you'll get the right answer." You make some sense of it, but you don't – in my opinion, I didn't visualize anything. So I'm proud that I was able to – even after my experience of, just be uncomfortable in physics and struggle through it as bad as I did, I was able to pick myself up back off the ground.

Give it a fair, unbiased shot, and say, "Okay. Here we go." Like, "Let's do this again. Let's see how this goes." On top of it, I was trying to verify my knowledge of physics while expect (ph) – while trying to teach it to someone else. I don't think there's necessarily anything wrong with that, because I think that's what any L.A. should do. I think you always have the potential to learn new knowledge. You have the potential to grow and see things differently. [00:36:55]

So it's not like – when – like, aft (ph) – the – even the best in the – the highest and whatever students when I was taking the class, they even have – they could have been L.A.s. They had the potential to grow. You know what I mean? So, I just think it's being willing – being open and willing to learn again. And better my knowledge on behalf of being an L.A., I guess. I don't know. Yeah. So I think that's a pretty – a good accomplishment. I mean (chuckling) I'm leaving MSU with – not – with no fear of any science. You know what I mean? And that was –

INTERVIEWER: Oh.

RESPONDENT: – like, coming into – well, I mean, maybe some electric fields and magnetic fields and circuits. Things like that.

INTERVIEWER: Second semester. (Chuckling)

RESPONDENT: The second semester –

INTERVIEWER: (Chuckling)

RESPONDENT: – I'm a little afraid of, to be completely –

INTERVIEWER: I see.

RESPONDENT: – honest with you. I really am. But –

INTERVIEWER: Are you staying there to be an L.A. for rushing (ph)?

RESPONDENT: I'm really trying to decide. I really want to.

INTERVIEWER: I see.

RESPONDENT: The only thing is, is next semester – well, I take the MCAT on June 16th.

INTERVIEWER: Okay.

RESPONDENT: So –

INTERVIEWER: That's a study time?

RESPONDENT: Yeah. [00:38:01]

So I'm going to study. Study in January. And my schedule, I had to quit, like, two of my other jobs to just hold this one. So, I want to make sure that I'm making responsible decisions and I'm going to have enough time to study for the MCAT.

INTERVIEWER: That makes sense.

RESPONDENT: So I'm going to actually talk to Vashti. I just want to see what she says about it. I just – I would be interested to hear her opinion. And advice.

INTERVIEWER: And she's done with students.

RESPONDENT: Yeah.

INTERVIEWER: Trajectories and jobs.

RESPONDENT: Exactly. So I think it would be interesting to talk to her about it. Yeah. So I'm still up in the air. But to be honest with you, I would only want to be in Vashti's sect (ph) – like, to – I – I'm going to be completely honest with you. I would only want to work with Vashti. And not like – not that I'm unwilling to work with anybody else. But I am so – I want to know what second semester was like. I want to know what I missed. So, yeah.

INTERVIEWER: So, I want to ask you something. From early on in the semester in 273, I remember you telling me that you were intimidated to go up to Vashti. [00:39:00]

RESPONDENT: I was.

INTERVIEWER: And then now you're like, "I want – I know I want to work with this person."

RESPONDENT: Yeah.

INTERVIEWER: Tell me that?

RESPONDENT: Sure. Yeah. I think that's also something very – that I thought was very interesting. Just because I – I'm – I feel like I pride myself sometimes understanding and knowing and believing that I'm a sociable person. Like, I can talk to – I'm not afraid to talk to people. Even the scariest of people.

Even the – but I just – I think I was just – I think me feeling so uncomfortable about the topic of physics, the subject of physics, really swayed a lot of my perspective on the other L.A.s in the room, the instructor herself. The room, the classroo (ph) – just everything. It's just – it's such a different way. Physics itself is such a different science. In that environment is even more different. So it just – it threw me off, I guess. [00:39:59]

It really made my compass go like, "Where are we going?" So I think that had a lot to do with it. Because – and subconsciously, maybe some other stuff was going on. Like, I just, "Why is she forcing me to do something that, like, she's not explaining it?" Me basically having – like, not anger, but a little animosity toward physics and taking it out on her. You know what I mean?

INTERVIEWER: Yeah.

RESPONDENT: Unfortunately.

INTERVIEWER: Right.

RESPONDENT: And being completely honest, I think maybe that's what happened. But like, I think she – I think she's great. And it's actually – watching her teach this – like, her – this style of physics, it's inspiring. Because you know this – she's passionate. You can just tell that she believes in this way of thinking so – and learning – so much that – I think she does a phenomenal job of teaching. You know what I mean? So it's just – she's really someone that I definitely look up to. Because I can tell that she does this because she, like, she truly believes in it. [00:41:02]

It's not just like, she went to grad school and got her Ph.D. and stuff that she did believe in. It was something that she just – she was following this path of people who've done it before her, and [say it's] (ph) successful, and blah, blah, blah. But you can truly believe that she – you can see that she truly believes that this works. So, just her work ethic. I think she's a great person. I think she's a great professor. I have no complaints whatsoever about Vashti.

INTERVIEWER: That's great.

RESPONDENT: And I have no idea what I was thinking first semester, because she's so nice. Like, she's very nice.

INTERVIEWER: But I mean, I – like you said, right? There – when you're not comfortable with –

RESPONDENT: Yeah.

INTERVIEWER: Yeah.

RESPONDENT: And I mean, it's just that, unfortunately, that's what happens. It's the same thing with patients in a hospital. Like, if people are afraid of hospitals, afraid of doctors, they're going to take it out on doctors. They're going to take it out on nurses. They're going to – I don't know. Yeah. It's the same thing. So.

INTERVIEWER: Did anything seem hard or impossible at first in physics, but eventually you were able to understand? [00:42:03]

RESPONDENT: Everything. Truly, like, everything. And I think, like, foresee myself to become an L. – not foresee myself. But being willing to become, to be an L.A. I just really – made me understand that whole thing. And like I said, just something as simple as F net. Like, the F net equations. How you can split forces up into two dimensions. Three dimensions, if you want. So I just – it's not that they seemed impossible last semester. It was just that wasn't, like – maybe just wasn't willing to open my mind like that. Expand my perspect (ph) – I don't know. So, but I think – yeah. So I think yes, of course there were. Pretty much everything. I had potential to learn everything better. I had potential to visualize everything a little bit better. But I didn't, because I didn't know how to. [00:42:55]

INTERVIEWER: Mm. Some people think that to be good at science or physics, it has to come easy to you. On the spectrum of agree to disagree, where would you put yourself?

RESPONDENT: Well, I mean, I don't necessarily believe that anymore. I used to. Right? I said it. Like, I said, "Biochem. The way of thinking as a biochemist, comes easy to me. Therefore, like, I'm good at it. Like, I never got below a certain percentage on any of my advanced biochemistry exams." Like, that – to me, people would perceive that as me being, like, a smart student. But, yeah. No. I don't.

I don't pert (ph) – necessarily agree with that anymore. Because I – I mean, I think I'm s (ph) – more well-rounded. Er, better off than I used to be, now that I feel much more comfortable with physics. Because it's just – I – that's one of the sciences. Like, I think I'm sm (ph) – more smart than someone else who doesn't understand it at my caliber. Yeah. Of course. But I think that's a true – that's a real thing. [00:44:00]

Like, I used to believe that. That if you're smart because it comes easy to you. So. Yeah. I mean, some things just don't come easy. You have to practice. You have to see it a few times. But that – for me, that goes into a completely different discussion. I don't even want to start talking about it because –

INTERVIEWER: (Chuckling)

RESPONDENT: – I don't want to, like –

INTERVIEWER: Sure.

RESPONDENT: I want you to be able to get your head –

INTERVIEWER: Yeah.

RESPONDENT: – out of it.

INTERVIEWER: No. What were you – I – now you got –

RESPONDENT: Well –

INTERVIEWER: – you can crea (ph) –

RESPONDENT: I just – because I – just the type of person I am, sometimes I hold myself – I perceive the standard I hold myself to is this, like, one. Like, I'm by myself like I'm a lone wolf standing. It's almost – it's just like, I lose the understanding. That. I'm so worried about holding myself to this standard that I really – I lose understanding that we're all different and we all learn at different speeds, and we all learn different ways, and blah, blah, blah. [00:44:57]

So, if I don't get something ca (ph) – because the, my neighbor or my group understood it before me or better than me, whatever, I think, "Wow. I'm stupid." Like, "I'm not smart. They're smarter than me." So I think a lot of that question really has to do with – it, like, it's – the answer would be so different based on any person. Because every person holds themselves to different standards. Everybody has a different self-image of themselves. Different confidence levels. I think all of that stuff plays into how you perceive "smart" and how you perceive "stupid."

INTERVIEWER: Got you. What do you credit to the change from agreeing to this statement to now disagreeing with it? That to be good at science or physics, it has to come easy to you?

RESPONDENT: I think it's because I'm – I think I would feel comfortable thinking about any physics. [00:45:57]

Well, pretty much – not "any," because there are some crazy physics concepts. Like –

INTERVIEWER: (Chuckling)

RESPONDENT: – so – but to an extent. I'm comfortable with some of these concepts that I used to not be comfortable with. I've worked at them and I've thought about them in a different perspective. So I – I'm learning how to think like, physi (ph) – think with respect to physics. Right? I'm not trying to force a physics understanding with a biochem. background. I'm not forcing myself to learn physics with an understanding that I'm comfortable with.

I'm actually learning on the way. I'm learning about and building the way I think about physics in its own kind of way. In its own cool, funky little way. So, I think that. That's why I now disagree with it. Because I used to not think that I could teach physics, for instance. Right? Like, I – someone told me I would have been an L.A., I would have been in this position now a year ago, I would have said, "You're out of your freaking mind. There's no way." [00:47:02]

So – because I thought I was stupid. I was stupid when it came to physics. I don't think I'm stupid when it comes to physics anymore. So, yeah. I think that has a lot to do with it.

INTERVIEWER: Do you think physics is important to you?

RESPONDENT: Yes. To be honest with you, I like – I think about how I could've – I love physical chemistry that I'm (inaudible at 00:47:26) now. I love it. I think it is so interesting. And so I'm really starting to appreciate – like I said, these equations that used to scare me and frustrate me and look like the craziest things – because of all of these stupid symbols and blah, blah, blah – are now just so interesting to me. That someone way, way, way, way back in the day, thought about the world that differently. Had that deep of understanding of these things that we can't see, and came up with these equations that modeled them. [00:48:02]

That was – to me, that is – it's insp (ph) – it's truly inspiring. Because I think a lot of people take for granted, like, these famous people who are, who got Nobel prizes for figuring out all this stuff. But it's truly – like, they deserve that. So, I think physics is so important to me, now that I'm understanding that that's what it was like back then to just see the world so differently.

And like – and I – my whole objective of majoring in one of the hardest majors at Michigan State – arguably – is that I cou (ph) – I wasn't afraid of this way of understanding. It was to tackle this way of understanding and try to, in four years, wrap my mind around this way of understanding the world around us like that. Like these people did. That – because I think that's so empowering. When you understand the world around you, and – with respect to all the different sciences – combined, separate; whatever. I think that's just so empowering. [00:49:05]

I think it stretches beyond, like, the stupid grades of college, and all of the stupid pressures and things like that. I think physics has become so important to me now that I could understand what I'm looking at with respect to these equations and physics and things like that. So, yeah. I think it's important to me. I never thought so.

(Chuckling)

RESPONDENT: I never thought I would.

INTERVIEWER: Now that you're getting ready to graduate, do you think you'll look back on your 273 and your L.A. experience as being important to you? Like, preparing you for –

RESPONDENT: Oh, yes.

INTERVIEWER: – the next step?

RESPONDENT: Yeah. So not only conceptually on the MCAT – right? Because I'm going to see all this stuff again on the MCAT. So I think that – I mean, that's obviously important. That's going to influence how good of a grade I get. It could, potentially, and it probably will. So. And by the grade that I get, it's going to determine what med schools I get into. [00:50:07]

And by that, it's going to dip (ph) – it's going to affect how much understanding I get in med school. Like, how much learning I get. How much experience. Because every med school's different, right? Best ones have different ways of teaching. They're the best because they're the best for a reason. Right? And so I think as stupid as it sounds, is like, small – on small scales, it is now. I think what I'm doing now – and the way that I'm taking this and treating this with seriousness and an open mind and things like that – is really going to affect my future. I really believe that. And, I mean, yeah. So, not even that way, but also just me as a person feeling like – feeling the need to understand this whole science world. This community that thinks so differently about things. I think that's where a lot of my fulfillment comes from. [00:51:02]

Because this is – science is something that I really believe in. Right?

INTERVIEWER: Mm-hmm.

RESPONDENT: And I'm really passionate about. And so, just – whenever I understand something better – right? Because we all have potential to understand things better. It's – I get a sense of fulfillment. And that fulfillment affects me. And happiness and confidence and things like that. So, I think – yeah. What I'm doing has many different applications for my future.

INTERVIEWER: So, when you were first told that you'd be an L.A. in this course, what did you think initially?

RESPONDENT: I don't know. So, yeah. It was kind of weird. Everything kind of happened really weird. So when I first found about it, it wa (ph) – we were – it was still in school. Like, last semester. Yeah. Last year. So I was – I mean, like, I was excited about it. [00:51:58]

I was willing to see all this stuff again. And – someone told me right bef (ph) – because when I was shaky about it, and before I actually applied, I forgot who told me that an L.A. – because I was worried about all the common things. Someone told me that an L.A. – what does an L.A. stand for? "Learning assistant." Right? That's different from a teaching assistant. That's different from a professor. You know what I mean? So that really helped me gain a little bit of confidence to be really excited about the experience as a whole.

So I was – I'd say initially, I was very excited when I first found out. But then, when we started to do our training and stuff at the beginning of the school year at the end of the summer, I – so, I had just – I was going through some stuff with my family. So I was kind of distracted, to be completely honest with you. So, it wasn't really until, like, a few weeks into school. That's when I really started to embrace it fully. [00:53:01]

So, and I was – I started to feel scared at the beginning, before I really embraced it and things like that. But initially, I'd say, like I said, I was happy about it. But there's some weirdness in the middle. Because I was really distracted and I really was not thinking about it whatsoever. So, yeah. I don't know if that really has anything to do with how I initially felt. But I mean, I gained a lot of confidence as time went on. So, I'm even more excited about it. (Chuckling)

INTERVIEWER: What made you apply in the first place?

RESPONDENT: It was the – what that – I forgot who told me. I feel like it was like a professor, told me that a learning assistant was a learning assistant.

INTERVIEWER: Got you.

RESPONDENT: Right? You were helping students learn. Right? You were learning, yourself. Kind of. In a way. You weren't – you didn't go to school for however long, tie (ph) – however long to get your Ph.D. in physics. You didn't go through four years of majoring in physics to be a graduate student who's studying something related to physics. Right? So, your understanding was a learning assistant's understanding. [00:54:00]

But a learning assistant is expected to help students learn based on being in their position a semester or two ago. You know what I mean?

INTERVIEWER: Yeah.

RESPONDENT: So that's what – someone really explicitly explained that to me. Really has made me apply, to be completely honest with you. Because I was not going to apply.

INTERVIEWER: (Chuckling)

RESPONDENT: I was not going to apply.

INTERVIEWER: How fell (ph) has this L.A. position affected how you see physics in the real world or your own life?

RESPONDENT: That's affected a lot of different things, right? And I just said, like, in my physical chemistry class, I'm thinking about all this stuff. Like, with respect to how – when I first learned it. Right?

INTERVIEWER: Yeah.

RESPONDENT: Because that's – when I first learned it was this class. And that's where – I always think of knowledge as kind of like a coat – a coat rack. Like, you build your coat rack and you start to hang little things on it. Right?

INTERVIEWER: Mm-hmm.

RESPONDENT: So, I had this little coat rack coming into physical chemistry that I added more things to, built a little stronger. [00:55:05]

Things like that. At the same time, I'm reinforcing what was initially there by looking at when I first built my coat rack. And reviewing the blueprints of why –

INTERVIEWER: (Chuckling)

RESPONDENT: – I did this, why I did that. So I think that has all the difference when it comes to what I've learned and how I see physics in my daily life now. I mean, yeah. I think it's awesome.

INTERVIEWER: That's great.

RESPONDENT: I do. Yeah.

INTERVIEWER: I've never heard the coat rack analogy, but I love it.

RESPONDENT: Really? Oh, good.

INTERVIEWER: I think I'm going to start using it.

RESPONDENT: Good. You should.

(Chuckling)

RESPONDENT: It’s exciting.

(Chuckling)

INTERVIEWER: Yeah. Can you describe the L.A. team this semester and your role in it?

RESPONDENT: Hm. That’s an interesting question.

INTERVIEWER: (Chuckling)

RESPONDENT: I didn’t think of that. Hm.

INTERVIEWER: I like how you were trying to predict or –

RESPONDENT: Yeah.

INTERVIEWER: – think about the –

RESPONDENT: I was –

INTERVIEWER: – questions –

RESPONDENT: Yeah. I was anticip (ph) –

INTERVIEWER: What is that rush (ph), man?

RESPONDENT: I was anticipating some questions. Gosh. The roll (ph) on the – so, I don’t – maybe if I just, like, start babbling a little bit. [00:56:04]

I think it’s interesting how different everyone’s style is of teaching. The L.A.s, specifically. I think that is the most interesting thing I’ve been observing. I’m not sure how all of our different styles – I mean, the overall goal, right, is that your section learns physics. Or learns what that activity is supposed to be for that day. So I guess my ro (ph) – okay. Maybe this is good. I like to think of my role as an L.A. – the way I personally see it is that the L.A.s should be like the mortar in between the bricks.

INTERVIEWER: Mm.

RESPONDENT: Right? So we’re supposed to fill in some of the cracks that students have that, like, between the bricks – that Vashti, Dan, Bri (sp?). Whoever. The other team. Everyone put – it’s starting to build. Or even previous knowledge of physics. Right? So, the instructors put the bricks down. [00:57:00]

So, I think L.A.s are supposed to be in between. Right? And we're supposed to be, like – and the way that I teach is that I like to be very – not "very." But I like to be more personable with students so that they feel more comfortable and open to your ideas or opinions and things like that. So, I found it really important the way that – the teaching style that I find most important is that you get on a very – the si (ph) – like, a similar level as them. You know what I mean? But I'm not sure every L.A. does – I actually know for a fact that every L.A. does that. So I don't know if exactly my perspective of an L.A. is necessarily true, or like, someone else's is better, or something. But I think the way that I see it is the way I described it. If that makes sense or if that answers the question.

INTERVIEWER: Yeah.

RESPONDENT: Okay.

INTERVIEWER: Yeah.

(Pause from 00:57:48 to 00:57:53)

INTERVIEWER: Okay. I think I asked you this one. Was there anything you did for the first time as a physics L.A.?

RESPONDENT: With regards to like, teaching? [00:58:02]

INTERVIEWER: Yeah.

RESPONDENT: Hm.

(Pause from 00:58:05 to 00:58:11)

RESPONDENT: I think – it was probably like thinking on the fly. Because when I would tutor biochem. and stuff like that. I mean, I was very comfortable with the content. Right? But I've – had seen all of the stuff that they're working on. Because I did it before. So – and I mean, the same holds true in this class. Right? Because I have seen most of the activities we've done. I've done them. So, the same holds true. But people ask more questions in physics than they did in biochem. Like, they didn't ask why, for instance, a phosphate was tra (ph) – transferred to, like, this amino acid versus this amino acid. Right? So, in physics, people ask, "Well, so if – what if this was in the system? What if this was outside of the system?" [00:59:01]

So it's – I think physics – and as an L.A., th (ph) – what I'm practicing for the first time – and I think I described it a little bit before, too – is being able to think on the fly. And just not really be prepared for what someone's going to ask. And trying to – because physics is hard. Right? So you sometimes have to think about something. You think.

Sometimes you have to walk away and then come back to a table and say, "Actually, what I said might not be truly colle (ph) – correct." And you have to be able to – humility has been a huge part of this experience. Right? Like, if you describe something wrong, or you just don't think about something the right way, you have to fix it. That takes some courage. It takes some, like I said, humility to be able to do that and realize that you made a mistake, and you potentially affected someone. [00:59:57]

So I think that has been, like, the – a very real example of some of the, these first things I've done as a physics-specific tutor-type person.

INTERVIEWER: Got you.

RESPONDENT: Yeah.

(Pause from 01:00:09 to 01:00:14)

INTERVIEWER: If you can go back in time and talk to your former self as they are getting ready to start 273, what would you tell them?

RESPONDENT: I knew you were going to ask this question.

INTERVIEWER: (Chuckling)

RESPONDENT: Oh, man. I don't know. I really don't know. Looking back, this class is not hard. Right? Like, it's not hard. But it is hard – the content isn't hard. Right? It is hard because of building your physics thinking. Like, building the way you think about these problems. Right? So I think that is the most difficult thing in this class. So, I think I would have maybe – I – no. [01:00:59]

No. I wish I could go back and at least explain the objective of why we're learning physics. Or the objective of why physics is different from the other sciences. What makes it different. What makes it similar to math. What makes it similar to all these other sciences that I'm comfortable with. And I talked about that at the beginning of this with – like, I – with, I said I wished the class was a little bit more, like – explicitly put that "Yes, you can model these things that you're comfortable with, with physics. We're just going to do it this way right now." So, I think maybe I wish I could have done that. Because I think I wouldn't have been as afraid of it.

INTERVIEWER: Got you.

RESPONDENT: Truly. Because physics is like – I feel like a lot of people have an innate understanding of physics before even looking at an equation. Right? Everything's physics. Gravity's phys (ph) – it's everyday things. So I just – it's – there's no reason to be afraid of it. You can be afraid of the thinking. That's fine. But you have to overcome it, too. [01:02:00]

INTERVIEWER: So, throughout this – I think you called it, in the beginning of the interview, a transformative experience.

RESPONDENT: Yes.

INTERVIEWER: Have you had discussions with people about this? Like, with family and friends?

RESPONDENT: No. I haven't. So, what my family – sometimes – I mean, I love them. They're, like, the craziest people you'll find –

INTERVIEWER: (Chuckling)

RESPONDENT: – but the best people you'll find. But they just – I'm a first-generation college student, so like, they just don't get it. I wish they did. I wish I could talk to them about it. But they just don't understand it. Probably like, the person in my family who wa (ph) – who has as much of passion as me for learning and understanding our world and stuff. It's probably my brother. But like, me and my brother don't – we're not the closest of close. So, that doesn't always work. And my friends? I really don't see as many people who are as passionate about learning, either. A lot of my friends are very worried about grades and making money in their jobs, and blah, blah, blah, blah, blah. [01:03:06]

And especially, like, my best friend. She – because she, like – she would understand some of this stuff that I do. I'm – actually, one of my other best friends. She's probably my best best friend. She's two years older than me. She think (ph) – she's so proud of me for doing this and just everything I do. Because we – I think we truly understand one another. And we're both similar enough but different enough to really appreciate how different and similar we are.

So, she's been, like – if I've talked about this outside of class – or outside of the work environment, class environment, whatever – it would probably be most to her. Just because she – she's curious about my life. She's curious about what I'm doing, and things like that. So, probably her. She – I talked about it with her, and she's, like I said, proud. Proud of me. Heard (inaudible at 01:03:54)

INTERVIEWER: How did that make you feel?

RESPONDENT: Great. Very great. [01:03:56]

I'm realizing a lot of things about myself, but also my friendships and relationships with other people. And I think that's just – this experience has been very great. That's why I don't want to give it up. But unfortunately, I have to. Like, to study and stuff. But I really don't want to. I really don't want to. I've really liked this experience.

INTERVIEWER: And looking back on everything you've accomplished – how do you feel about your ability? Mm, can you ref (ph) – I mean, so, you've used a lot of phrases, like "transformative experience." Like, you're not afraid of physics anymore. You understand it more, at least the first semester. That you didn't think this was possible. That you wouldn't believe it if you told your previous self. What do you think about all that?

RESPONDENT: I think it's f (ph) – amazing. Right? I think I have exponentially gained so much power in, like, a scientific community or something in the future. [01:05:05]

Right? So I – if I'm collaborating on something in the future, I can look back on this. Stuff that I'm learning now, like, concepts that I'm learning now. And really analyze that I'm – makes these strong arguments that either support my case or refutes someone else's case. Right? That's power. That's such an empowering thing to be able to do. And Karl's (sp?) saying that he is one of my favorite – I – yeah. I think it was him.

He's one of my favorite scientists. He's an astronaut. I love him, and he said the quote that, like, "Once you underst (ph) – " "Once you're scientifically literate, your understanding of the world is completely different," or something like that. So that's, like, my favorite quote of all time, and so I live by that quote. Because it just resonates with me so much. So, for me, it all has to do with gaining the power to be like a credible source in a scientific community. [01:06:02]

In politi (ph) – any, anything. Right? That's why I love science. Because science is – like, "It is or it isn't. You have evidence to support that it is. Evidence to support that it's not."

INTERVIEWER: Mm-hmm.

RESPONDENT: Right? And once you have that evidence, you can stick it in someone's face and say, "You're crazy, because look." Right? I feel like a lot of the other disciplines are all just like, this theory-based stuff. Right? I mean, physics – I mean, science in general has some theory behind it. Right? But it's theory for a reason. It's been tested. It's been proven that there's no evidence to not support it. Right?

INTERVIEWER: Yeah.

RESPONDENT: So, but in my opinion – like, politics, for instance, I – people are studying what happened in the past and how it didn't work. None of that is interesting to me. Like, none of it. Right? So, you could find exceptions in almost anything, except science. Right? Like, science is such a powerful tool to understand the world. [01:06:58]

To unlock these crazy ideas that Einstein was like, thought crazy of back in the day. That Leonardo da Vinci, when he built – or, he drew all of his, like, models of airplanes and helicopters, he was thought crazy for. Or even Galileo. The Sun, and the Sun not being the center of the – all of that stuff. Right? That's all – it – I don't know. Science is the best. The best, like, empowering tool ever. And I think I've gained a lot of power through this experience. Which I love.

INTERVIEWER: Through the physics experience?

RESPONDENT: Yes.

INTERVIEWER: Wow.

RESPONDENT: Yes. I really believe that. And, like, while taking this class. Right?

INTERVIEWER: Yeah.

RESPONDENT: Like, (inaudible at 01:07:37). My physical chem. I keep, like – it's like – it's like –

INTERVIEWER: Yeah, I know.

RESPONDENT: It's like chem –

INTERVIEWER: (Chuckling)

RESPONDENT: It's because I'm such a visual –

INTERVIEWER: Yeah.

RESPONDENT: – way of –

INTERVIEWER: Is this – oh, I keep thinking you're going to talk about the chair in some way.

RESPONDENT: Yeah.

INTERVIEWER: (Chuckling)

RESPONDENT: And like, when I was talking about activities, I was like, looking over here, and I was like, referencing. Yeah.

INTERVIEWER: "But this has been consistently P. Chem." Yeah.

RESPONDENT: Yeah. "This is consistently P. Chem." It's like it sits next to me. I don't want to leave it. I want to hold (ph) – it's here with us. Right?

INTERVIEWER: You can have the chair.

RESPONDENT: (Chuckling) Thank you. So, yeah. [01:08:00]

I – yeah. I just – yeah. It's been really – all of that combined, this past semester, has been very remarkable, in my opinion. Yeah.

INTERVIEWER: Well, Paulo (sp?), another wonderful chat.

RESPONDENT: Thank you.

INTERVIEWER: Let me check in on the time here, because I'm sure. Yeah. We're over and up. (Chuckling)

RESPONDENT: That's all right.

INTERVIEWER: (Chuckling)

RESPONDENT: I love this stuff. I truly like doing this stuff, because you guys need this data, right?

INTERVIEWER: Yeah.

RESPONDENT: You need to prove that people should be learning physics this way. Right?

INTERVIEWER: Yeah.

RESPONDENT: This is the way to learn physic (ph) – and I true (ph) – I'm starting to really believe that, too. I really am. Just with all the experiences I've had. So.

INTERVIEWER: Well, I love this chat.

RESPONDENT: Yeah. Of course.

INTERVIEWER: And anything else you want to share about you? About the course? I mean, anything at all?

RESPONDENT: I don't think so. I mean, I think I laid it all out.

INTERVIEWER: Okay.

RESPONDENT: (Chuckling)

INTERVIEWER: And before you graduate, maybe I'll ask you to sit down again. As you get closer to the next journey.

RESPONDENT: Yeah. For sure. I think – like I said. [01:09:00]

So, after – I'm going to plan to maybe e-mail Vashti or something to ask her if I could just come and talk to her about –

INTERVIEWER: Absolutely.

RESPONDENT: – next semester. Because I'm really on the fence about not doing.

INTERVIEWER: And you've got to do what's best for you.

RESPONDENT: Right. Yeah. And I know she would understand that. I know Katie (sp?) would understand that. I know Edd (ph) – anybody would understand that.

INTERVIEWER: Absolutely.

RESPONDENT: And any – L.A.s, I think they're only hired per semester anyway. So, technically. So, I mean, yeah. But yeah. I –

INTERVIEWER: It's ideal if people can stick on, but –

RESPONDENT: Right. I mean, it's convenient.

INTERVIEWER: Yeah.

RESPONDENT: Right? Like, that's the most – that's the best part of it. So.

INTERVIEWER: But yeah. Absolutely.

RESPONDENT: But yeah. We'll see. I mean, maybe I'll be around. Maybe I won't be as around, but I'll be around.

INTERVIEWER: Yeah. So.

RESPONDENT: I'll be more than willing.

INTERVIEWER: And I just want to say thank you for giving me access into your experiences.

RESPONDENT: Of course.

INTERVIEWER: This has been an amazing journey we've had together.

RESPONDENT: I'm very glad to share. I'm very glad to share, right? You guys have laid this foundation for me to do whatever I want with it. Right? Like, I had – you've given me s (ph) – everybody. Vashti. Katie (sp?). You. Like, the people who have made this at MSU in Lyman Briggs have laid this path for me to just explore. [01:10:04]

That's been most – I'm gaining stuff that I'm going to use the rest of my life by just doing this stupid, simple stuff. It's not stupid. But little, stupe (ph) – little, simple things now, right?

INTERVIEWER: Yeah.

RESPONDENT: So, thank you. I mean –

INTERVIEWER: (Chuckling)

RESPONDENT: – thank you guys. Not –

INTERVIEWER: No.

RESPONDENT: Yeah. Seriously. No. Serious.

INTERVIEWER: (Chuckling)

RESPONDENT: Truly.

INTERVIEWER: What do you have the rest of the day?

RESPONDENT: Well, so I'm probably going to go visit my – because I'm a hospice volunteer.

INTERVIEWER: Oh, yeah.

RESPONDENT: So – yeah. So, I go visit my residents usually on Friday afternoons. So I'll probably do that.

INTERVIEWER: I think they love you.

RESPONDENT: They do.

INTERVIEWER: (Chuckling)

RESPONDENT: But I mean, they – they're like – they're most –

INTERVIEWER: Do you get, like, dressed up for you to come over at all?

RESPONDENT: Well, they mostly forget about our visits because they're all, like, memory care people.

INTERVIEWER: Got you.

RESPONDENT: So, yeah. But I mean, may (ph) – when they see me. More often than not, they remember me. My first patient that I ever had, he actually lived for, like, two years after.

INTERVIEWER: Who –

RESPONDENT: He was put on hospice because I – right when he was put on is when I got assigned to him. Then I was there, like, until the end, for him. [01:11:03]

In that – two years. Like, that's a long time.

INTERVIEWER: That's a long time.

RESPONDENT: So, he would look forward to our visits.

INTERVIEWER: Oh.

RESPONDENT: He actually remembered. That was the most – that's been one of the most interesting things for me in that experience. Right? So. But yeah. I mean, I love them. And, like –

INTERVIEWER: It’s incredible.

RESPONDENT: – I treat them like I wouldn’t treat any – anybody else. I wouldn’t treat anybody else. Right?

INTERVIEWER: Yeah.

RESPONDENT: So. I love it.

INTERVIEWER: Awesome.

RESPONDENT: It’s a great experience. Yeah.

INTERVIEWER: Awesome. I’ll see you next week. Thanks.

RESPONDENT: Stop my watch. See you later.

(Pause from 01:11:28 to 01:11:49)

**END TRANSCRIPT**

## APPENDIX T

## TRANSCRIPT: NICOLE INTERVIEW 1

INTERVIEWER: And do you have anything after this?

RESPONDENT: No, I don't.

INTERVIEWER: Okay. And I don't imagine it'll take long. Do you mind if I close the door?

RESPONDENT: No, that's fine.

INTERVIEWER: (door shutting) Awesome. Alright. So, last time this thing wasn't working. So, now we're recording—

RESPONDENT: (laughs)

INTERVIEWER: —in case the video camera fails. And it has.

RESPONDENT: (laughs)

INTERVIEWER: Alright. Hopefully [it'll record it]. (ph) [00:00:23] Alright. How's it going?

RESPONDENT: Good.

INTERVIEWER: Yeah. So—physics, huh? Um—so, this interview is pretty casual. I just have a page here with some questions that I'd like your thoughts on. For the most part, there's no—I mean, there's no wrong answer at all. I'm not going to ask you to do any physics. And I just want your thoughts on things.

RESPONDENT: Okay.

INTERVIEWER: Does that make sense? Um—so first, a very general question: Can you tell me a little bit about yourself?

RESPONDENT: Um, I'm a junior. So this is my third year here.

INTERVIEWER: Okay.

RESPONDENT: I'm a Genetics major. [00:00:58]

INTERVIEWER: Okay.

RESPONDENT: And I'm interested in going into health informatics. So I'm taking—like this semester, I'm actually taking a CMSE class.

INTERVIEWER: Oh, okay.

RESPONDENT: CMSE 201. So—

INTERVIEWER: Which one is that?

RESPONDENT:  It's like brand—it's brand new.  It's like Intro to Computational Modeling.

INTERVIEWER:  Wow.

RESPONDENT:  Yeah.  So I'm learning Python.  Yeah.  I really like it so far.  It's hard—

INTERVIEWER:  Yeah.  (overlapping talking)

RESPONDENT:  (overlapping talking) —but I like it.  So, I'm hoping to go in like a data science direction and do stuff with health data and—

INTERVIEWER:  Wow!

RESPONDENT:  Yeah.

INTERVIEWER:  That seems really cool.

RESPONDENT:  Yeah.  Amazing.

INTERVIEWER:  A lot of data science jobs, right?  Like it seems like the new hot thing.

RESPONDENT:  Yeah.  Actually, I went to a meeting for the Data Science Club the other day, and it was really—(overlapping talking)

INTERVIEWER:  (overlapping talking) There's a club?

RESPONDENT:  There is.

INTERVIEWER:  (laughs)

RESPONDENT:  It's also brand new.  It like just started last year.

INTERVIEWER:  Okay.

RESPONDENT:  So, yeah.  I'm excited about that.

INTERVIEWER:  Awesome!  (overlapping talking)

RESPONDENT:  (overlapping talking) And you might like—coming here, I didn't want to do pre-med because I have like a really week stomach.  But I still was interested in the health field, so.

INTERVIEWER:  I see.

RESPONDENT:  Found out about this last year and though it would be interesting.

INTERVIEWER:  That's cool.  So you're a junior?

RESPONDENT:  Mm hmm.

INTERVIEWER: Okay, how many more semesters do you think you have left?

RESPONDENT: Uh, three after this one. [00:02:00]

INTERVIEWER: Okay. So it's not two years. (overlapping talking)

RESPONDENT: (overlapping talking) So the full four years.

INTERVIEWER: Yeah. Even after—so you got to kind of find out about this informatics—(overlapping talking)

RESPONDENT: (overlapping talking) Yeah. I came in with a lot of credits. I came in with like—

INTERVIEWER: (laughs)

RESPONDENT: —25 or 28 credits or something like that. (overlapping talking)

INTERVIEWER: (overlapping talking) No, really?

RESPONDENT: Yeah. I dual-enrolled in high school, so I took a lot of— (overlapping talking)

INTERVIEWER: (overlapping talking) Oh, I see.

RESPONDENT: —community college classes.

INTERVIEWER: I see.

RESPONDENT: So that gave me a lot of room to just kind of like mess around and take some classes, do some things.

INTERVIEWER: Gotcha. Um—and so you're a genetics major?

RESPONDENT: Mm hmm.

INTERVIEWER: Okay. And, genetics and the informatics go together?

RESPONDENT: Yeah. I mean, like with the genetics, it was basically more or less I kind of realized like the end of last spring that I didn't really want to go into like a lab bench job.

INTERVIEWER: Yeah. (overlapping talking)

RESPONDENT: (overlapping talking) Didn't really want to get my Ph.D. So, I was kind of looking for option—I was like—because credit-wise, I'm like well-past a junior after this semester. (overlapping talking)

INTERVIEWER: (overlapping talking) Mm hmm.

RESPONDENT:  Like I'm almost—I'm gonna, yeah.  It's weird.  (overlapping talking)

INTERVIEWER:  (overlapping talking) Yeah.

RESPONDENT:  Um—so, I was kind of just looking for other options that I could like not abandon like the first two years of school I did but still have like some applicable skills.

INTERVIEWER:  (laughs) Yeah, yeah.

RESPONDENT:  And so, with a genetics major, I could take some computer programming classes that would count towards my major.

INTERVIEWER:  Yeah, yeah.  Right.  (overlapping talking)

RESPONDENT:  (overlapping talking) So that kind of gave me more than just like—a little bit of a wider skill set.  [00:03:07]

INTERVIEWER:  Gotcha.  Is this your first dive into computer programming?

RESPONDENT:  Mm hmm.

INTERVIEWER:  Okay.

RESPONDENT:  My mom actually like—that's like what she does for a living.  She actually works for— (overlapping talking)

INTERVIEWER:  (overlapping talking) Oh.

RESPONDENT:  —MSU.

INTERVIEWER:  Oh, wow!

RESPONDENT:  Yeah.  She— (overlapping talking)

INTERVIEWER:  (overlapping talking) That's pretty neat.  I don't know if that's a good thing or a bad thing having your parent work on the campus?

RESPONDENT:  Oh, I love it.  It's so great.

INTERVIEWER:  (laughs)

RESPONDENT:  Free rides home.  She buys me food all the time!  It's great.

INTERVIEWER:  Now when you say it like that, yeah.

RESPONDENT:  Yeah.

INTERVIEWER:  Yeah, I do miss getting food bought for me.  (laughs)

RESPONDENT: Oh, it's like—

INTERVIEWER: (laughs) Um—so, what got you interested in science?

RESPONDENT: In high school, it was just like always—I mean, I 'm like—I'm pretty good at it, I think. And it was always like the class that like most interested me. Like, I like to read, but I knew I didn't want to do that for a living and like— Math on its own was just too much for me. And so I just kind of knew. And like I had a really good science teacher who really like pushed me to do things and was one of those people who— "Oh, I don't know what I want to do or I don't want to do?" And he's like—it actually was to the point where I was like valedictorian in my high school, and so they had to—

INTERVIEWER: Wow.

RESPONDENT: —send in a whole bunch of stuff like to the newspaper like, "Oh, what are you majoring in?" I'm like—I was telling the teacher like, "I don't even know what to put!" And he goes, "Well you seem like the type of person who would like Biocab or Microbiology. Just put something like that even if you don't want to." So I did that and looked into it more and kind of— [00:04:20]

INTERVIEWER: So there's a newspaper article somewhere saying that—(laughs)

RESPONDENT: It's not like an article. But it's like a little questionnaire. (overlapping talking)

INTERVIEWER: (overlapping talking) —your favorite. (laughs)

RESPONDENT: Yeah.

INTERVIEWER: That's awesome. Tell me more about this science class? What made this teacher great?

RESPONDENT: He was just like—he really knew what he was doing. He actually like told us he had an offer to go up on a ship in Alaska and do research there, and he turned it down because he wanted to teach like that bad.

INTERVIEWER: Wow.

RESPONDENT: And so, I don't know—I kind of thought that said a lot about him that he'd turn down making six figures because he just wanted to teach.

INTERVIEWER: Yeah.

RESPONDENT: And he's just—I don't know—I learned a lot. I would say, because I took his class my sophomore year in high school. And then, my junior year, I dual-enrolled and took a bio class at my community college. And I would say that I learned more from him than I did from—(overlapping talking)

INTERVIEWER: (overlapping talking) So he also taught biology? [00:05:06]

RESPONDENT: Yeah.

INTERVIEWER: Okay.

RESPONDENT: Yep.

INTERVIEWER: What science classes did you take in high school?

RESPONDENT: I took bio, chem. What else did I take?

INTERVIEWER: Bio and chem, right?

RESPONDENT: Bio—no, no, no. Not biochem. (overlapping talking)

INTERVIEWER: (overlapping talking) Not biochem—oh. I was like, “That’s advanced.” (chuckles)

RESPONDENT: Bio, chem, earth science—did not take physics—and then I took bio at the community college.

INTERVIEWER: Oh, okay. So this was your first physics experience? (overlapping talking)

RESPONDENT: (overlapping talking) This is my first—yeah.

INTERVIEWER: Okay. Cool. So, you said health informatics. Do you have any ideas? Like take me into the future of what you’ll be doing for a little bit?

RESPONDENT: I’m not like totally sure because I haven’t really been able to like see in-depth with the kind of jobs they have. Like one thing I’m really looking into is like I sent my resume to MiHIN, which is a company here in East Lansing that like—

INTERVIEWER: What’s the company called?

RESPONDENT: MiHIN? It’s like—it’s an acronym. It’s like Michigan Health Information Network System—something like that. [00:06:01]

INTERVIEWER: Okay. Okay.

RESPONDENT: But like basically what they do is they’re taking data and—they’re like the hub for all the health data in Michigan. Like the government sends them stuff and like a whole bunch of different companies—and like they go through that data and—

INTERVIEWER: Wow.

RESPONDENT: Yeah. I’m just really interested in being able to like take the data we get from a hospital and like improve the patient experience because—(overlapping talking)

INTERVIEWER: (overlapping talking) Wow.

RESPONDENT: —I mean, I went down there to talk to the admissions rep at the University of Michigan because that’s where I want to go.

INTERVIEWER: Mm hmm.

RESPONDENT: And she talked about how like one of their students set up a program that allowed for rather than waiting for someone to like pass away and to donate their kidneys, they could actually set something up or someone with two good kidneys could donate theirs to someone else.

INTERVIEWER: Ohhhh.

RESPONDENT: So like someone from Idaho could donate their kidney to someone in Texas. And rather than like having to wait for like a time if someone were to pass—and have like that limited time to get it there. They could set up like, “Oh, you’re going to come give your kidney to this person on this date.” And I just thought that was really cool to like—(overlapping talking)

INTERVIEWER: (overlapping talking) Wow.

RESPONDENT: —be able to do something like that. [00:07:04]

INTERVIEWER: Sounds great.

RESPONDENT: Yeah. Yeah.

INTERVIEWER: (laughs)

RESPONDENT: So that’s why I’m really interested in seeing the kind of stuff that I could do.

INTERVIEWER: So do you think you’ll be using this data to kind of—do you think you’ll be like writing computer code to like get the data and find the right mix of data that—

RESPONDENT: Yeah.

INTERVIEWER: —answers the question you’re interested in?

RESPONDENT: Mm hmm.

INTERVIEWER: Okay. Cool. So, I’m going to ask you a couple of questions about the course. So I know that Lyman Briggs’ students often have like a choice. They either take the Briggs’ version of physics or they take the natural sciences version of physics. So why did you decide to enroll in this one?

RESPONDENT: Um, I actually—like I was really on a fence because I've heard like, "Oh, Briggs physics is so hard." But— (overlapping talking)

INTERVIEWER: (overlapping talking) Yeah.

RESPONDENT: —my roommate too the University of Natural Science physics and a few other of my friends took it, and they're like, "Oh, it's like terrible. Like, I feel like it was so hard." And then my friend Hannah, who's actually an ally for like—

INTERVIEWER: Oh!

RESPONDENT: —she's one of my allies.

INTERVIEWER: Okay.

RESPONDENT: She was like, "Yeah, like I took Briggs with Vashti and like I really enjoyed it. And I don't think it was as bad as people thought. Like, yeah, it was hard—it wasn't as bad as people made it out to be." And so, I heard nothing but bad things about university and had her and then one of my coworkers say like, "Oh, Briggs isn't that bad." So I was like I might as well do the one that's not that bad compared to the one that terrible. (chuckles) [00:08:20]

INTERVIEWER: (laughs) Yeah, the one that you—yeah, yeah. What did you expect this course to be like?

RESPONDENT: I wasn't really sure coming in. I knew it'd be a lot of group work from what Hannah had told me. And I was interested to see how, since there's not a separate lab—which was—actually that was the other reason that I chose this one is because the lab in the course was integrated.

INTERVIEWER: Okay.

RESPONDENT: How they would integrate that.

INTERVIEWER: Can you take me through like a typical day in the physics class?

RESPONDENT: So, normally we'll come in and like Vashti will give us some sort of warm-up activity like—just like a short worksheet that kind of like refreshes what we learned in the previous class—so like the previous week. So, we'll fill that out for the first like 10-15 minutes like within our groups. And then, she might lecture for a little bit, but usually not more than like 10 minutes at a time. (overlapping talking) [00:09:13]

INTERVIEWER: (overlapping talking) Mm hmm.

RESPONDENT: And then, the past few classes, we've just done some sort of like lab-related activity where we'll—like we use the motion sensors a couple of times, and then we'll break off and kind of do another worksheet or—yeah, usually do another worksheet. And then we'll do the whiteboards. So like we'll do the whiteboard discussion, [and that's kind of more of rather lecture.] (ph) [00:09:32] Rather than her lecturing, she does little whiteboards to lecture. So, we'll do the whiteboards. And then, this past one, we did coding at the end, which I enjoyed because I kind of had a knowledge of what I was doing, which was nice.

INTERVIEWER: Awesome. Um—so, can you tell me why you picked a course that's structured this way?

RESPONDENT: I think with like a subject like physics, it's kind of like abstract almost. It's easier if you can bounce your ideas off of other people rather than like sitting there and having someone lecture off you. It's a lot better to be able to ask questions, I feel like, in this environment. [00:10:13]

INTERVIEWER: Okay. So, walk me through like a week. You meet twice a week, right? Tuesday and Thursday? (overlapping talking)

RESPONDENT: (overlapping talking) Mm hmm.

INTERVIEWER: Are there certain things you do on certain days?

RESPONDENT: Not really sure because we've only had one full week of class.

INTERVIEWER: Oh, that's right. Memorial Day, right?

RESPONDENT: Yeah. Yeah, so—last week was the only full week we had. And she did mention—like we did labs on both days, and she mentioned that's not usually the norm.

INTERVIEWER: I see.

RESPONDENT: But I guess like with the kinematics, you know, like things go quicker from what she said. So I think it's like Tuesdays we do labs and Thursdays we do more of like a group discussion thing. But I'm not totally sure. (overlapping talking)

INTERVIEWER: (overlapping talking) Okay. Where do you think learning happens? In a class?

RESPONDENT: Um—for me, I feel like it's the whiteboards because before that, like, I usually feel very confused because—I mean, like I'm not going to lie, I'm struggling a little bit in there because I haven't taken calculus since fall semester of freshman year. So like all those concepts are still very rusty, and that's really what we're focusing on right now. [00:11:12]

INTERVIEWER: Mm hmm.

RESPONDENT: So like going through the worksheets and stuff is a little over my head. And like the girl—we're supposed to be in groups of three, but our third group member dropped the class, I think. So it's just me and another girl. (overlapping talking)

INTERVIEWER: (overlapping talking) Ohhhh.

RESPONDENT: And she like—she's like really good at math. So she's kind of carries us through the worksheets. And I'm kind of just like, "Ahhh." So when we do the whiteboards and like I really get it explained to me is when I start to understand it a lot more.

INTERVIEWER: Okay. What about the whiteboard—so is it—can you describe to me what happens in a whiteboard meeting?

RESPONDENT: So, we usually take five or ten minutes and on our whiteboard we'll do vocab and rules. So like vocab is like—like the other day, we did—talked about acceleration and a lot. So like words that have to do with acceleration, that help to describe acceleration.

INTERVIEWER: Mm hmm.

RESPONDENT: And then rules and like the things we're observing, like for acceleration—like when this happens, this is why. So like we'll write those down, and then we'll meet as a group and discuss and like talk about why is it this way or like what kind of equations could you use for this. [00:12:10]

INTERVIEWER: Are there ever like disagreements? How do you know what's right?

RESPONDENT: Yeah. So, there—people will disagree on like what's what or like a specific point of something. And usually, Vashti will let that discussion go for a little bit, and then once she thinks like—to me, it feels like once she thinks it's getting a little out of hand and we might be getting a little too far to one way or another, she'll run back in—kind of like set us straight again, like if we start to go off.

INTERVIEWER: I see. And, have you had any disagreements?

RESPONDENT: I—uh, actually, I don't remember exactly what it was, but I do remember there was one thing that—it was something to do with slopes that someone said that me and my group member, we were both like, "Oh, wait. That's not right." But, I think before we got the chance to say something like it was cleared up, but— [00:13:04]

INTERVIEWER: Okay. Okay. And how do you feel about that kind of—someone saying something that you think is wrong?

RESPONDENT: I—that's the one part about the whiteboard that I don't really like because it's such like a hard concept to wrap my mind around sometimes. I don't like how we—like it's allowed to like—[a wrong idea] (ph) [00:13:28] can persist for like for like five minutes at a time. Because then I kind of get lost. That happened the other—I think last Thursday. I kind of got lost because they were going on about something and then kind of backtracked. And then I just couldn't get caught back up.

INTERVIEWER: Gotcha. (pause) Yeah, how do you feel about that?

RESPONDENT: I—not a huge fan or that. I'm still trying to figure out like the best way to go about how I should like—should I just like tune out the conversation when things are like—until it gets brought back in? I'm planning on going to office hours this week to kind of like—(overlapping talking)

INTERVIEWER: (overlapping talking) Okay.

RESPONDENT: —talk to her about how I can like better understand if like I'm starting to lose track of the conversation. [00:14:11]

INTERVIEWER: Gotcha. (pause) How do you think knowledge is constructed in the course?

RESPONDENT: Like what do you mean by like—

INTERVIEWER: That's a good question.

RESPONDENT: (laughs)

INTERVIEWER: Um—what do I mean? I think I want to know—(pause) How do you think, um—hmmm—yeah, like how is knowledge constructed. I get—what am I trying to say? So, you said you make rules.

RESPONDENT: Mm hmm.

INTERVIEWER: That seems very definitive. So how do you make rules?

RESPONDENT: So it's like—like for example, velocity is the derivative of the position graph.

INTERVIEWER: Mm hmm.

RESPONDENT: That's the type of rule we make. It's something that like we will consistently observe in every problem on a worksheet or like—if we're using the motion sensors, like every time we walk away, we will see "this" happening. So those are like what the rules are. [00:15:08]

INTERVIEWER: So, do the students make the rules? Does the teacher make the rules? Or is it something that you just know?

RESPONDENT: Uh, the students come up with the rules. And then— (overlapping talking)

INTERVIEWER: (overlapping talking) Okay.

RESPONDENT: —so we'll like propose the rules to her and she'll write them down. Like we have a consensus whiteboard at the end. So like each group has their own whiteboard. And then, when we meet together, she'll put together a consensus whiteboard. And that will list like all the vocab and all the rules. And she'll post that on [D2L]. (ph) [00:15:33] And she says like, "There will never be anything wrong on a consensus whiteboard," which is one thing I like. If I get lost, I can go back to that consensus whiteboard and I'll see like, "Here are the rules—like this is definitive—this is right."

INTERVIEWER: Gotcha. And how do you arrive at a consensus?

RESPONDENT: Um—I think it's just letting the discussion play out, and once everyone's kind of like made their side to something, we kind of as a class like all agree. Once there's no one else objecting to something, (chuckles) basically. [00:16:05]

INTERVIEWER: Has there been any—(overlapping talking)

RESPONDENT: (overlapping talking) Or like their objection has kind of been shot down by others' objections.

INTERVIEWER: (laughs) Do you remember any instances of objections?

RESPONDENT: Off the top of my head, I can't think—like I remember it happening, but I can't remember specifically what it was about. (overlapping talking)

INTERVIEWER: (overlapping talking) Okay. That's fine. Um—have you encountered biology in this course, so far?

RESPONDENT: Not, yet. But I know tomorrow we are.

INTERVIEWER: (laughs)

RESPONDENT: Because we're (laughs)—we didn't have time to get to it on Tuesday, but we're doing something with like the motion of listeria bacteria and—

INTERVIEWER: I see. Okay. (overlapping talking)

RESPONDENT: (overlapping talking) So.

INTERVIEWER: And, have you encountered physics in any of your other courses?

RESPONDENT: In Calc-1, I remember doing—like there was a specific problem about someone like jumping off a cliff or something. And then, in my CMSE class—actually yesterday—we had to come up with like—we ended up coming up with our own models for dropping a ball off of Beaumont Tower. And then a skydiver—so. (overlapping talking)

INTERVIEWER: (overlapping talking) Oh, okay. Okay. [00:17:03]

RESPONDENT: And then I have homework to do for that class this weekend about a bungee jumper. So—

INTERVIEWER: (laughs)

RESPONDENT: —yeah! I am seeing physics a lot right now, actually. (overlapping talking) [00:17:09]

INTERVIEWER: (overlapping talking) Yeah. So, what makes those examples physics to you.

RESPONDENT: For me, it's like whenever there's something involving motion, like I immediately think physics.

INTERVIEWER: Okay.

RESPONDENT: So—all those things that like—with that CMSE class, they're all involving some sort of motion—like actually they're all falling motions. But, that is physics—like first thing that comes to mind.

INTERVIEWER: Gotcha. Who's teaching the class?

RESPONDENT: Devon Sylvia?

INTERVIEWER: Oh, okay, okay. I think he was in the Astronomy department beforehand? (overlapping talking)

RESPONDENT: (overlapping talking) Yeah, he is.

INTERVIEWER: So, what do you see as the similarities between like the different disciplines—bio, chemistry, and physics?

RESPONDENT: I think they all—like I actually was like on Kahn Academy earlier today watching—

INTERVIEWER: (laughs)

RESPONDENT: —some physics videos. And like one thing he talked about was how like physics is kind of one of the more peer sciences, like math is considered peer, and then like physics is like—it's like math, then physics, then chemistry, then biology—and they all kind of like build on each other. Like a lot of biology is like— Like I'm taking biochem right now, too, so I'm really seeing how a lot of biology is based on chemical reactions. And a lot of chemical reactions are based on like the physics of the molecules, and physics is all a lot of math, so. [00:18:23]

INTERVIEWER: Mm.

RESPONDENT:  It all like builds on each other.

INTERVIEWER:  Um—if you were going to draw the three disciplines, what kind of a diagram would show the relationship?  Because you said you saw a video on Kahn Academy where they talked about—(overlapping talking)

RESPONDENT:  (overlapping talking) Yeah.

INTERVIEWER:  —something (inaudible at 00:18:36).  Yeah.  Feel free to like—(overlapping talking)

RESPONDENT:  (overlapping talking) I would be like—I don't know.

INTERVIEWER:  (laughs)

RESPONDENT:  Like it's like a triangle.

INTERVIEWER:  Like a triangle?

RESPONDENT:  Physics is on the bottom.

INTERVIEWER:  Oh, okay.

RESPONDENT:  And then chemistry and then bio.

INTERVIEWER:  Okay.  (overlapping talking)

RESPONDENT:  (overlapping talking)  It's like you can't have these without like this physics foundation.

INTERVIEWER:  And you think that that's pretty true with what you were seeing?

RESPONDENT:  Yeah.

INTERVIEWER:  Okay.  And were you doing the Kahn Academy just to kind of review physics?  Or just for fun?  (overlapping talking)

RESPONDENT:  (overlapping talking) Yeah.

INTERVIEWER:  Or—

RESPONDENT:  Just to review physics.

INTERVIEWER:  Okay.  Uh, is it for like the—who you're covering right now? [00:19:05]

RESPONDENT:  Yeah.

INTERVIEWER: Okay. Cool. And so, what do you see as the differences between the disciplines?

RESPONDENT: Um—I feel like with physics especially, it's all very like cut and dry—like this is going to happen, and like everything's very sure. Whereas if you like compare that to bio—like in a lot of my bio lectures, it'll be like, "Well this happens and we don't really know why, but it does happen. But sometimes this'll happen." Whereas I haven't really encountered that really with physics.

INTERVIEWER: Okay. So what would you say the difference is? So wouldn't bio—they say "sometimes it happens; sometimes it doesn't. We don't know why." Um—

RESPONDENT: I feel like—(sigh) with bio like there's a lot more variables that can like come in and mess things up. Whereas with physics like there's always going to be—like gravity will always act on stuff and like— Whereas with bio like if you're in a dry environment—if you're in a wet environment—like there's just a lot more things that can vary. [00:20:08]

INTERVIEWER: Mm hmm.

RESPONDENT: And I think that's kind of like the same thing with this pyramid, like the smaller it is, the more variables there are that can affect how something's happening.

INTERVIEWER: I see. Um—how do you see bio, chemistry, and physics as related to each other?

RESPONDENT: Well, I guess it really, really—in bio, there's a lot of chemical reactions occurring. Those chemical reactions are brought on because of like physics within the atoms and the molecules and how they interact with each other.

INTERVIEWER: Um, so in this connection, I see you chaining from bio to chemistry—and then the chemistry to the physics.

RESPONDENT: Mm hmm.

INTERVIEWER: How about the physics to the biology? Are they connected?

RESPONDENT: (pause) Yeah. Like the first thing I think of when I think of physics to biology is like exercising—like motion. I remember when I was in like sophomore year at high school, we went to Pittsburgh and we went to—they have like a museum there that—I think—it's not like a sports museum, but it's like a— They do a lot of things where like you can track your motion and stuff, and that's like the first thing I think of if I thinks physics to bio like— [00:21:22]

INTERVIEWER: I see.

RESPONDENT:  —kin classes and—which I actually find like really cool.

INTERVIEWER:  Yeah?

RESPONDENT:  Yeah.

INTERVIEWER:  Kin means kinesiology.

RESPONDENT:  Mm hmm.

INTERVIEWER:  Okay.  Have you taken any?

RESPONDENT:  I haven't.

INTERVIEWER:  Okay.  Are you going to?

RESPONDENT:  I'm probably not at this point, but—

INTERVIEWER:  Yeah, because you're almost at the finish line, right?

RESPONDENT:  Yeah.

INTERVIEWER:  (laughs) And so—I think you told me already what you see yourself doing in the future.

RESPONDENT:  Mm hmm.

INTERVIEWER:  And I think I have a pretty picture about that.  I'm curious how you, yourself, using physics in that future, of the health informatics and—?

RESPONDENT:  Um—I could see it coming in as like if I'm trying to write a program for—like, say I like working for a hospital and they want something for patients in the stroke unit, or something, and they need me to like write some sort of program.  I could see it coming in where like I need to know something about the patient's movement or something?  I could see where I'd need to know like some basic physics stuff.  [00:22:22]

INTERVIEWER:  Okay.  Um—okay.  So you think—again, like the things about the movement of the patients, you're thinking you might be able to use physics?

RESPONDENT:  Mm hmm.

INTERVIEWER:  Okay.  (pause) Do you think of or you use physics in your like daily life?

RESPONDENT:  Outside of class thoughts, I really don't like think to myself, "Oh, that car is accelerating—

INTERVIEWER:  (chuckles)

RESPONDENT: —like in the positive direction." I wouldn't say like really outside of class I think about physics all that much.

INTERVIEWER: Okay. Do you ever talk about physics?

RESPONDENT: Outside of like talking about classes and homework and stuff? Not really, no. (o)

INTERVIEWER: (overlapping talking) Yeah. And, who do you talk about the class with? [00:23:03]

RESPONDENT: My roommate and my boyfriend.

INTERVIEWER: Okay.

RESPONDENT: And then also like my friend Hannah because she's an ally for the class.

INTERVIEWER: Doesn't that make sense? Um—and so, in the health informatics and, you know, genetics major, how do you think—or in what ways do you think physics plays a role?

RESPONDENT: Um.

INTERVIEWER: You've already told me the motion of the patients.

RESPONDENT: I think with like genetics, one thing that like I think kind of has to do with physics is talking about like protein structure and mutations and stuff, which actually like—that's what I'm— I work in a research lab and we're looking at a specific gene and how mutations in that gene affect the function of it.

INTERVIEWER: Mm hmm.

RESPONDENT: So I feel like that has a lot to do with physics because that has a lot to do with like the bonding and like how the amino acids are related to each other and stuff. [00:24:03]

INTERVIEWER: Mm hmm.

RESPONDENT: So I could see how physics we're like playing with that because I'm doing a lot of stuff with predictive algorithms that can like predict what will happen to protein function based on those mutations, so. [00:24:14]

INTERVIEWER: Okay. Why were you doing that?

RESPONDENT: Um, I work with [Brian Shooney] (ph) [00:24:18]. He is— (overlapping talking)

INTERVIEWER: (overlapping talking) Okay.

RESPONDENT: —in BPS. He's an internist right now. (overlapping talking)

INTERVIEWER: (overlapping talking) Okay. Okay. So that's the research you do?

RESPONDENT: Mm hmm.

INTERVIEWER: Oh, okay. Cool. So, I'm trying to unpack all the lingo. So—kind of a novice in bio and chemistry. So, you were saying the physics might come into play in how the proteins kind of—

RESPONDENT: Can like fold together and stuff.

INTERVIEWER: Okay.

RESPONDENT: So—

INTERVIEWER: Okay.

RESPONDENT: Yeah.

INTERVIEWER: And you're seeing that with like the attraction and repulsion of—

RESPONDENT: Yeah.

INTERVIEWER: Okay.

RESPONDENT: Yeah. Because like if you substitute one amino acid—like a polar amino acid for a non-polar one, it's going to affect the way that the protein can fold. And if it can't fold correctly, then it's not going to function correctly. (overlapping talking)

INTERVIEWER: (overlapping talking) I see. I see. Okay. Yeah, thanks for being patient with my lack of knowledge. [00:25:07]

RESPONDENT: (laughs)

INTERVIEWER: (laughs) How do you think physics will help you in your other courses, or help you get your degree?

RESPONDENT: I've already seen it help me with like my CMSE class just yesterday, actually. Like, it was nice because I went from coding in physics' lecture. And then I went to that, and we were doing like a similar type of thing. So that was kind of nice to like—it's nice to have those connected. I'm actually like watching videos in physics that are like directly for—like, literally, the video tag is CMSE 201. So that's—(overlapping talking)

INTERVIEWER: (overlapping talking) Oh, really?

RESPONDENT: —kind of cool. Yeah.

INTERVIEWER: Wow. Can you tell me about some of these examples of—so like take me into the perspective of you—like when you walk into class, and after doing physics and now you're going to CMSE, when did you realize the basic connections? (overlapping talking)

RESPONDENT: (overlapping talking) Um, we were trying to like write some code, and I was like, "Well, hey? Like I did this in physics today—well, I'll be looking to see if there's any similarities—anything I could take from that." And there was actually like one little point that I realized like, "Oh, I need to put this in my loop and—" [00:26:04]

INTERVIEWER: Do you know what that point was?

RESPONDENT: Um, it was something with the velocity. I don't remember exactly what it was, but— (overlapping talking)

INTERVIEWER: (overlapping talking) Okay. Okay. And, are you using Python in both—

RESPONDENT: Yep.

INTERVIEWER: —places. Okay, cool. Um—that's great! So it's already helping you?

RESPONDENT: Yeah.

INTERVIEWER: That's awesome. And what's this video tag that says CMSE 201?

RESPONDENT: It was like their—like the YouTube channel was the CMSE 201.

INTERVIEWER: Oh, really?

RESPONDENT: Yeah.

INTERVIEWER: Oh, wow. Okay. And that was connected to physics?

RESPONDENT: Yeah, like the video that was posted on the Physics D2L page was the one that I had to watch for my homework last week.

INTERVIEWER: No?

RESPONDENT: Yeah. And I told—(overlapping talking)

INTERVIEWER: (overlapping talking) Oh, so that's why I was kind of—I was like, "Okay, wait. The video from the CMSE 201—I was wondering if the physics—

RESPONDENT: Yeah. Like it was my lecture video that I had to watch.

INTERVIEWER: I see.

RESPONDENT:  I like turned it on and I'm like, "Oh, I don't need to watch this because I did last week."

INTERVIEWER:  (laughs) That's incredible.  That's efficient.

RESPONDENT:  Yeah.

INTERVIEWER:  You know?  Yeah.  (laughs) Is there any part of chemistry, bio, or physics that you find particularly engaging or like satisfying to think about?  [00:27:09]

RESPONDENT:  I think anything like—I think tomorrow in physics, I'm actually like excited to go because we're talking about like how it relates to the human body.  So like I think that's the stuff that really interests me.

INTERVIEWER:  Mm hmm.

RESPONDENT:  So.

INTERVIEWER:  Is that a new feeling?

RESPONDENT:  Um, I've always been interested in like health and like the human body and like how stuff works there—so, not super new.

INTERVIEWER:  How about the feeling of being (inaudible at 00:27:32) a class?

RESPONDENT:  That's—that's newer.

INTERVIEWER:  (laughs)

RESPONDENT:  That doesn't happen often.

INTERVIEWER:  (laughs) Okay.  That's awesome!  What are you hoping to get out of it—um, is it tomorrow's activity?

RESPONDENT:  I want like—I'm interested to see like—because I think it's pretty clear that when I think of physics, I think of all math and like movement.  I want to see how it can relate to like other things.

INTERVIEWER:  Gotcha.  (pause) And so, you know, you're a genetics major and then the health informatics.  What do you see as important things to take away from a course that's not your major—or in your major area?  [00:28:09]

RESPONDENT:  I think like being—like with something like physics, it's going to teach me good problem-solving skills.  So I think problem solving skills and how to work around like your—because I think I will struggle with physics more than the average—like other classes I've taken.  Just from the first couple of weeks I've noticed that.  So I think being able to like troubleshoot more and get through—because I'm not really used to struggling through my classes? (overlapping talking)

INTERVIEWER: (overlapping talking) Mm hmm.

RESPONDENT: So I think that's going to like help me in the future when I struggle with something at work, or struggle with something in grad school.

INTERVIEWER: What do you think is about physics that makes it about problem-solving and troubleshooting?

RESPONDENT: I think it's because the ideas are just like sometimes more abstract than the other—like they're just kind of different to wrap your brain around. Like thinking about acceleration and the positive or negative direction—you think of acceleration, always think of, "Oh, you're speeding up." [00:29:04]

INTERVIEWER: Mm hmm.

RESPONDENT: But, it doesn't necessarily have to mean that. And so that's—like there's just concepts that like kind of go against everything you've been taught naturally. (overlapping talking)

INTERVIEWER: (overlapping talking) Mm hmm. Um—okay. And, other than the troubleshooting and problem-solving, do you think you're going to take away other things from this specific physics class?

RESPONDENT: I'm not really sure. I guess—like how physics can relate to like biology is something I haven't put too much thought into. And I do think I'll get more of that out of this class.

INTERVIEWER: Okay. Are you enjoying yourself in the class?

RESPONDENT: Um—not—it's a very different class for me, and because I've never taken a physics class and I am struggling, like it's not my favorite class to go to at the moment. But I feel like as I get more comfortable and like figure out how I can learn this stuff better, I think it'll— It's not boring. Like I don't—it's a three-hour class that doesn't feel like a three-hour class. So I do think that's a good thing. [00:30:06]

INTERVIEWER: Okay. Yeah, because it's a bit of a marathon, right?

RESPONDENT: Yeah. Three hours—9 to 12. So—

INTERVIEWER: Yeah. That's—yeah. Um, how has it been working with the other people in the classroom?

RESPONDENT: I really like—so, me—I said my group was supposed to be three, but one girl, I think, dropped her class—so it's me and one girl. And then, actually the group that sits at our same table also didn't have a third group member, so we all kind of like bounced ideas off each other. So it's kind of nice. (overlapping talking)

INTERVIEWER: (overlapping talking) Okay.

RESPONDENT: Because even though my group itself is only just me and one girl, like we kind of bounce ideas off the other two, too. So that's nice. (overlapping talking)

INTERVIEWER: (overlapping talking) Gotcha. Okay. Now you told me a little bit that you're struggling. How would you say you're doing in the class, so far?

RESPONDENT: Um—I'm kind of—I'm understanding like the basic concepts, but as we elaborate on them more like and I—I'm struggling to apply them to different situations. So, I'm going to office hours on Friday because like I'm getting the answers kind of with help, but I'm still not completely understanding them the way I would like to. [00:31:09]

INTERVIEWER: Gotcha. And, what is your metric for knowing if you're getting well or not?

RESPONDENT: For me, it's when I can like get through a set a problems and not have to spend like more than 10 minutes at a time thinking about something, or not getting super frustrated when I'm thinking about something.

INTERVIEWER: I see. I see. And you said that you're not used to struggling through a class like this. In your other science courses, did you—

RESPONDENT: No. I mean—I think the closest feeling I had to this was like the first month of chemistry—fall semester/freshman year.

INTERVIEWER: Yeah.

RESPONDENT: And then I kind of figured out how to learn best in that class, and I'm kind of hoping that physics is the same way. I just haven't figured out how I should be taking notes or like what I should be paying attention to most.

INTERVIEWER: I see. So what was the best strategy for chemistry?

RESPONDENT: For me, in chemistry, it was just doing as many problems as I possibly could. [00:32:01]

INTERVIEWER: So I'm thinking that's probably what it'll be for physics is maybe like going to office hours and then like getting the theory behind it and then being able to apply it as much as I possibly can. (overlapping talking)

INTERVIEWER:  (overlapping talking) Gotcha.  How about in biology?  Would you (inaudible) succeed there?  [00:32:14]

RESPONDENT:  With bio, it’s—I just like—I’m not—I don’t like to study in groups.  I know a lot of people like say they’ll learn better when they’re in groups.  But I’m the type of person that like—I like to lock myself in the library and just like review slides over and over again.  I like to make flashcards.  I make a lot of quizlets and—

INTERVIEWER:  Mm hmm.  Is that—that’s the card program?  I’m not—yeah. (overlapping talking)

RESPONDENT:  (overlapping talking) Yeah.  They make—yeah.

INTERVIEWER:  I see.  Yeah, yeah, yeah.  I think I’ve used it for a class once.  Great.  Yeah, so I think I’m at the end of everything I have for you.  The last question is like:  Are there other things you think I should know about the course?  About you?  Anything you want to share?

RESPONDENT:  No.

INTERVIEWER:  Yeah?

RESPONDENT:  No.

INTERVIEWER:  Yeah?

RESPONDENT:  Covered a lot.

INTERVIEWER:  Yeah.

RESPONDENT:  So.

INTERVIEWER:  Covered—I mean, you’re efficient.  You—

RESPONDENT:  (laughs)

INTERVIEWER:  —ran through all the things.  Yeah, that’s all I have.  Are you okay with me contacting you again to catch up maybe midway through the course?  [00:33:08]

RESPONDENT:  Yeah.

INTERVIEWER:  And we’ll do another one of these interviews—

RESPONDENT:  Yep.

INTERVIEWER:  —and then you’ll get another $10 (inaudible at 00:33:12) gift card.

RESPONDENT:  Sounds good to me.

INTERVIEWER:  Keep stacking it up—

RESPONDENT:  (laughs)

INTERVIEWER:  —and it'll buy something.  Well, thank you so much, Nicole.

RESPONDENT:  Yeah, thank you!  (overlapping talking)

INTERVIEWER:  (overlapping talking) I appreciate it.  Yeah, absolutely!  Um—you're doing nothing after this.

RESPONDENT:  Nope.  I'm going to go eat dinner actually.  (overlapping talking)

INTERVIEWER:  (overlapping talking) Well that's—well, yeah yeah.  That's probably a good idea.  Some people had me—how many thing are you doing right now?  You have research?  Do you work?

RESPONDENT:  I—yeah, I work two jobs actually.  Like I'm an ally for like the bio lab here.

INTERVIEWER:  Yeah.

RESPONDENT:  Like the organismal bio lab.  And then, I worked in a job at a lab in the entomology department over the summer, so I go in there for a few hours on Friday morning just to make some extra money and like—

INTERVIEWER:  Yeah.

RESPONDENT:  —I really like my coworkers.  So we just like go and hang out.  (overlapping talking)

INTERVIEWER:  (overlapping talking) Is that like bugs?

RESPONDENT:  Yeah.

INTERVIEWER:  Yeah?

RESPONDENT:  I dissect beetles all morning.  But like I really like my coworkers, and we all come in on Friday morning and like dissect bugs together and like just listen to music—(overlapping talking)

INTERVIEWER:  (overlapping talking) That's fun.

RESPONDENT:  —and hang out.  [00:34:05]

INTERVIEWER:  Yeah.

RESPONDENT:  Yeah.  It's an easy way—(overlapping talking)

INTERVIEWER:  (overlapping talking) (inaudible at 00:34:07) bugs and music and friends.

RESPONDENT:  Yeah, exactly.  (overlapping talking)

INTERVIEWER:  (overlapping talking) Well, what else do you need?

RESPONDENT:  Nothing. That's all you need in life.

INTERVIEWER:  (laughs) Thanks again.

RESPONDENT:  Yeah.  (background noises)

[00:34:28]

## APPENDIX U

## TRANSCRIPT: NICOLE INTERVIEW 2

# TRANSCRIPT OF AUDIO FILE:

# LB273-11.15.17-NICOLE-INTERVIEW2

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*The text below represents a professional transcriptionist's understanding of the words spoken. No guarantee of complete accuracy is expressed or implied, particularly regarding spellings of names and other unfamiliar or hard-to-hear words and phrases. (ph) or (sp?) indicate phonetics or best guesses. To verify important quotes, we recommend listening to the corresponding audio. Timestamps throughout the transcript facilitate locating the desired quote.*

**BEGIN TRANSCRIPT:**

INTERVIEWER: Doing anything fun for Thanksgiving?

RESPONDENT: Just hanging out with family.

INTERVIEWER: (Laughing) Is that good or bad?

RESPONDENT: That’s good.

INTERVIEWER: All right, because sometimes hanging out with family could be the source of stress. But I forgot my audio recorder, so I’m just going to use my phone.

And I mean the same things that we talked about before, your instructors don’t know you’re here. They won’t be able to see this until after they’re done, you know, being in charge of anything on you. Yeah, do you have any questions?

RESPONDENT: No.

INTERVIEWER: Cool. So this interview’s going to be a little different from what we did last time. So I have a stack of activities that you worked on in class. And then I’m hoping you can just give me your thoughts on them. Then I’ll ask you some questions, and we’ll go from there.

Yeah. So first one is this. (inaudible). So first, just your thoughts. [0:01:02]

RESPONDENT: I like actually really enjoyed this activity because it was like easy to see the connection from like something really like biologically-relevant. Like I’m not personally pre-med, but like I know a lot of people in there are. So it was like interesting to see like the background behind like why you might need to treat someone with antibiotics and like this kind of like all ties it all together. So I thought that was really interesting. It wasn’t like super-easy to do, but it was like easy enough like once you got started, to like understand, like once you got going, how to do it, and like it all made sense. So I thought that was cool.

I thought the one thing about it was like it kind of… like it took a while. And a lot of people, like the data was just so variable that like you could see a general trend, but there wasn't anything like concrete. So I wish we would have had like a way to like… like I think Dan was the one who went over this with us. Like have him do it before and like show us his results and see like the difference between like what he got and what we all got, to kind of get a baseline. But, yeah. [0:02:08]

INTERVIEWER: So you said that this did a good job of connecting the bio and the physics. Can you say more words around that? Is that something that you value? Is it important to you? Let's check the camera; make sure it's going? I get paranoid because that one interview… yeah, it is going. One interview that I thought I pressed it and I didn't. Go ahead.

RESPONDENT: Yeah, so I think it is important for me to have like a class like physics be able to connect to other classes because like I sometimes wonder like, "Oh, when will I ever use physics?" But like this kind of shows that, "Oh, it is relevant". Like it does mean something to like what I might be wanting to do in the future.

And that's another thing that like with another class I'm taking, I'm taking like that computational modeling. And sometimes I can kind of see how like physics would fit into that where at least like those concepts you use in physics that kind of seem to be applicable in that class, too. [0:03:00]

And we've done a lot of stuff with like modeling like the spread of disease and stuff. So that's been really interesting to kind of see how like even though it's not directly physics, it's like concepts that we've used in physics are also being used there.

INTERVIEWER: Gotcha. Do you have any specific examples of when you made those connections with the computational modeling class?

RESPONDENT: When we talked about yet (ph) in class yesterday, like the Lennard-Jones potential, like we ran a model like including like that specific equation.

INTERVIEWER: Really?

RESPONDENT: Yeah. So it was modeling like… it was a lot like the one we did in class where we were modeling like the collisions. It was similar to that. And then like he used the Lennard-Jones potential.

INTERVIEWER: So take me to that moment. You're sitting in your computational modeling class, and they say that you're going to do this –

RESPONDENT: It was actually the opposite. So I was sitting in physics yesterday, and I like turned to my (inaudible), like, "Oh, hey, like we modeled this. I like have this equation on my computer right now that we used". So I thought that was cool.

INTERVIEWER: That's really cool. Did those moments happen a lot this semester? [0:04:02]

RESPONDENT: Not a ton. But I have seen connections between like physics and that class which makes sense because like the professor who teaches it like was actually almost a breaks (ph) physics professor, he told me. Yeah. Yeah, so that was real interesting.

INTERVIEWER: Gotcha. And did you tell anybody about these classes being –

RESPONDENT: Yeah, I have. A lot of times, like with my groups in physics, like I'll talk about how like, "Oh, like this is applicable. We did this in class". Like one time, like our very first homework assignment for that class was like modeling a bungee jumper, so it was like (inaudible). So like I struggled hard because like at that point, it was like two weeks into physics, and we had not learned any of those concepts. And I was like right over my head. But like looking back now, I understand it like so much better. It'd be so easy. Yeah.

INTERVIEWER: Were you using like similar software and stuff?

RESPONDENT: Yeah, it's like the exact same thing. Like the videos that Dr. Celtel (sp?) has posted are like straight from my class. Like I've watched the same videos. [0:05:06]

INTERVIEWER: No way. That's really cool. Wow, it's like two worlds (inaudible). Yeah.

RESPONDENT: Yeah. It really is.

INTERVIEWER: Did you expect this to happen?

RESPONDENT: No. Not at all. Like the first week of classes, I like looked at all like the python programming stuff she had posted. And like the YouTube channel on the bottom was like… I am literally in that class right now. And then I found that like some weeks, like the stuff would match up. So that was cool.

INTERVIEWER: That's really cool. That is really cool. So this wound-healing activity, why do you think they have you do this? Why do you think the instructors have you do this?

RESPONDENT: I think it's just to kind of like show… because I know there's like this like stigma with physics that like, "Oh, you just take physics to get it out of the way. Like you're never going to use it". But I think this kind of stuff kind of helps show that like you might not directly use physics, but like the concepts of physics are directing what you're going to do. And so like it's important to be aware of that and understand why. And I think this really backs that up a lot. [0:06:07]

INTERVIEWER: So you said the physics is directing what you do?

RESPONDENT: It's like the things you're doing, you might not be directly working with the physics. Like you're not like doing like problems and stuff. But in the background, like the things that are happening that you're trying to figure out are due to physics. Like there're physics concepts behind that.

So like you might not directly be dealing with the physics side of it, but like part of the reason there's a problem is because of the differences in the physics.

INTERVIEWER: Gotcha. And do you think knowing the physics behind these kinds of phenomena that you worked with in the wound-healing kind of helped you understand it better?

RESPONDENT: I think it did, yeah, because like I thought this one was interesting because like you always do kind of wonder like if our immune system is supposed to be like so robust and so great… and that's something like I've taken classes on it, and like that they tell you that. Like why do we ever need antibiotics? But this kind of like shows why. [0:07:11]

INTERVIEWER: Awesome. Did you ever end up talking to anybody about this activity?

RESPONDENT: Outside of class, I don't think so. I might have mentioned something to my boyfriend about it, but it was like just in passing.

INTERVIEWER: Yeah. Are people usually surprised when you bring up these stories, and do they align with what they think a physics class is?

RESPONDENT: Yeah, I'll talk about this class to like my boyfriend and he took like the university, and he's like, "Like we never did anything like that". And it's like, "Yeah, this class is like a lot different from what you took".

INTERVIEWER: Is he jealous?

RESPONDENT: He is jealous. He does seem pretty jealous.

INTERVIEWER: Yeah. You should just rub it in. (Laughing) And so… let's see. Do you think doing this wound-healing activity has equipped you to answer questions outside of class? [0:08:05]

RESPONDENT: Right now, like the classes I'm in, it's not super-applicable. But I was originally going to take an immunology class. Like this is definitely something that would come up in an immunology type of class.

I mean I'm a genetics major, so I could see it making sense in genetics because maybe like there's some sort of gene that like with like your neutrophils and stuff, like maybe there's something that like the physics can affect. I can see there being a link there, too.

INTERVIEWER: Okay. And so when you're thinking about your future career, after you get your genetics degree, do you think activities like the wound-healing one will help you?

RESPONDENT: I'm not sure if it'll help me particularly just because like I'm kind of going in a different direction than like supers… it's more of like a mix of computer science and science stuff. And it's more like a professional type of program. [0:09:08]

So like I'm not really sure like the physics is going to help me. But knowing that a lot of my friends are like pre-med or pre-vet, like I can see this helping them a lot.

INTERVIEWER: Gotcha. Great. The next thing I have… it's actually two things. And one is paramecium and the other one is this protein unfolding with an optical tweezer. So you'll see me cycle through the same questions for all these activities. So just first, just like your general thoughts.

RESPONDENT: Yeah. I don't think we ever got to this one in class, but I kind of glanced over it last weekend when I was studying. (Laughter) Kind of.

INTERVIEWER: It's like, "Wait, this is the one we never got to".

RESPONDENT: Yep. But like glancing through this one, like I think had I done it in class at the time, it would've really confused me. But now that I understand these concepts a lot more, like I think I got through like D, and then like I didn't have my calculator on me, so like it was kind of hard to really do a lot of it. [0:10:08]

But it made sense to me. So that was interesting like to know that like three or four weeks ago, I probably wouldn't have understood this. But like now, like it comes to me a lot easier. And that's like one thing I've noticed a lot with this class is like things won't make a drop of sense to me in class. And then I'll go back like a couple weeks later, I'm like, "Why did I not understand this?" Like I'll do that with the in-class activities. Like I'll get points marked off. I'm like, "This is just dumb". So yeah, that's that one. I haven't really looked at it that much since we never really got to in class.

This one, I remember not totally understanding, and I don't totally understand it still. Like I understand some of the questions. Like there was one about… just like I understood like the force type of stuff and like how like there're two different areas going on here. Like one where it's like one linear part and one other linear part. [0:11:10]

But the thing I didn't understand is like the region in the middle they were asking questions about. So I never really understood that, and I still don't really understand that. But again, I thought this one was pretty interesting because I'm taking biochem right now. So like we talk a lot about like protein unfolding and stuff and like the consequences it has.

So like basically every lecture or so, she'll talk about like what happens with certain like mutations in genes and stuff. And a lot of it has to do with like messing with the protein structure. So I thought that was kind of interesting because it applied back to biochem and kind of gave like an additional layer to what I had already learned in that class as to why stuff like that was happening. So that was interesting. [0:12:00]

INTERVIEWER: So did knowing that like physics is involved in those processes help kind of…

RESPONDENT: It did actually kind of help like because like I understood the chemical background of it. But like seeing an actual like more of a physical reason for it rather than just, "Oh, like this amino acid is in the wrong place". Like it kind of like helped like connect; like bridge that gap between like, "Oh, this is in the wrong place. Because it's in the wrong place, this is happening".

INTERVIEWER: Gotcha. Gotcha. And you mentioned with the paramecium that there're often activities where they don't make a lick of sense when you do them, but then looking back on it… so can you give me some examples of when this happened?

RESPONDENT: Like I said, with the in-class activities, it happens a lot where like I'll go back and see the points I got marked off for, and I'll just be like, "This is dumb".

Another one is we did like a box-on-a-wall one. And like at the time, I just like didn't really like process it. And now looking back, I'm like, "Oh, it makes like perfectly clear sense". And I don't know if it's just because like I don't like working much in group settings. [0:13:09]

Like working in that group setting like makes me like overthink things and like be too afraid to say like, "Oh, this is why I think what it is". But I've noticed that a lot with this class is I'll go back and look at stuff and understand it a lot more than beforehand.

INTERVIEWER: Gotcha. Is that a new feeling that you've had in this class, or is that just how you learn?

RESPONDENT: No, like that's definitely a new feeling for this class. And I think it goes back to that like group setting thing is I don't really enjoy working like in groups on stuff I'm learning. I'm fine working in groups on like projects and stuff, but like when I'm learning something, I prefer to just like sit down and have it like explained to me once and then go along with my business.

INTERVIEWER: So you've worked in how many different groups now? Two or three?

RESPONDENT: Three.

INTERVIEWER: Yeah. How has that been? Has that been a struggle?

RESPONDENT: Like my first group was just me and one other girl, and I thought we worked pretty well together. My second year, we worked very well together. Like we want to work on the next lab together. [0:14:09]

And then like this last group, like it's been okay. But like I don't know. Like everyone always seems to want to like tell each other that, "Oh, that's not right. That's not right". So that one's been a little harder because I feel like I'm starting to understand stuff in this class a little more. So like I'll try to say like, "I think this is how we do it". And like one of the other girls was saying, "No, I don't think that's it". And then like I'll know I'm right, but I just don't feel like arguing with her. So that's been a little bit of an issue. But that's the only time I've really run into a problem. There's only been one person that's kind of done that.

INTERVIEWER: Gotcha. And you say the second group was just great.

RESPONDENT: Yeah, we worked really well together, I feel like.

INTERVIEWER: What do you think was the magic ingredient there?

RESPONDENT: I think like one of the girls had a lot of good background knowledge in physics, so she was able to like help us along. And we were all just like really willing to help each other. And like we weren't afraid to like ask questions; like ask the TA's or ask like anyone in class like what was going on. So I think that helped a lot is that like we just were able to understand like when the other person needed help, like we didn't just move on and… [0:15:14]

INTERVIEWER: That makes sense. So why do you think the professors have you do activities like this where there's kind of like a bio application on a worksheet?

RESPONDENT: I think it helps put things like into perspective because like it's one thing to just like go and like explain a concept and use like stock (ph), fake, boring numbers. Like, "Oh, like this box is dropping off a building or something".

And like, yeah, you can kind of learn it, but you don't understand why it's happening really. And this kind of puts it in a perspective where you can like see it in real life and be able to like explain a concept because like it's not perfect all the time. So like this kind of shows that. Like this really does happen in real life. These aren't just like problems out of a textbook. [0:16:01]

INTERVIEWER: Did you think that before coming to class that the physics that you were going to learn had applications in the real world?

RESPONDENT: I mean I knew physics had an application in the real world, but I didn't think about like the biological side of it like whatsoever. I knew like chemistry had a lot of physics involved, but I didn't really think that with biology, there was so much that you could like look at really.

INTERVIEWER: Yeah. Is this stuff interesting for you?

RESPONDENT: Yeah, I find this stuff interesting. It's just good to have. Like with this one, being able to connect it to biochem like so easily, or like when I was able to connect like yesterday with my CMSE, it's nice to be able to make those connections.

INTERVIEWER: Great. Do you think these activities are valuable to you?

RESPONDENT: I think they are because like it makes it so that physics is like less boring and like you get something that makes like sense as like a bio type of person. Like seeing stuff like this, it like, oh, it like makes things click. [0:17:09]

Because a lot of times with like physics problems, they'll just seem kind of like not abstract to me, but like I just won't see how they're like applicable. But like something like this, like this like directly involves like what I'm learning, and like it makes sense with like my degree.

INTERVIEWER: And are you seeing this kind of connection between courses in other courses?

RESPONDENT: Yeah, actually. All three of them, I could see being applicable to like what I want to do in the future. Like CMSE, obviously. Like that's kind of what I want to do after I graduate. But like with biochem, like I can kind of see how… like I want to kind of go in like a genetics-based type of informatics thing and like work on like bridging that gap between like genetics and like the clinicians and how to help them. [0:18:00]

So like biochem has helped with that because it's like shown me like different types of mutations and diseases and stuff and like why they're caused. And then the physics kind of goes with that because like biochem shows why it's caused, and physics shows why the biochem kind of happens. So yeah, I do think everything is kind of connecting.

INTERVIEWER: When did you first start thinking that the physics explains why the biochem is happening?

RESPONDENT: It was these types of activities. I think there was another like similar protein type of one. And it was like that was when I kind of realized like, "Oh, like a month ago, we did this in biochem, and now we're doing it in physics. It like makes sense".

INTERVIEWER: So do you think these activities have helped you answer questions outside of the class?

RESPONDENT: Not necessarily just because like learning this was like after we went over the material in biochem. But like I do think that like other students would be able to use it because like from talking with my group, I was like, "Oh, we talked about this in biochem". They're like, "Oh, we haven't taken biochem". I'm like, "Well, like we literally like learn this". So I can see how like someone who hasn't taken like biochem would use this. [0:19:12]

This kind of like thing would be important in like I took a microbio (ph) class. So it's kind of applicable there because we talk a lot about like different pathogens and like this involves like how the pathogen can get like where it needs to go and stuff.

INTERVIEWER: Gotcha. Okay. When you first saw these kind of biological-related physics problems, what were you thinking?

RESPONDENT: My first thought was just kind of like, "How do you even model physics in biology because like these are like living things. They're so unpredictable. Like how can you even show that?" So that was like my first thought.

INTERVIEWER: Yeah. And now that you're seeing kind of activities where you look back on them and then you realize that you know how to do it, do you feel proud? [0:20:09]

RESPONDENT: I do. Yeah. It's cool to be able to like look at something like this and like it's biologically relevant. And you can like use that to just… like it gives you just more of like depth in your knowledge. So if someone wants to like know like, "Well, why is this pathogen like so much more virulent than another?" And like you can like give a background and say like, "This is why".

Or like, "Why did this mutation cause this to happen?" And you can like say like, "This is why", along with like your explanations from other classes.

INTERVIEWER: Right. Do you often get into those kinds of conversations? (Laughter)

RESPONDENT: No. But if I were.

INTERVIEWER: If you were.

RESPONDENT: If I were.

INTERVIEWER: The next thing I have is actually a series of three things. I think this was the computational series of activities? [0:21:00]

RESPONDENT: Mm-hm.

INTERVIEWER: The first one is a (inaudible). Then put them in a box. And then tracking (inaudible). Yeah. Some of your thoughts on those?

RESPONDENT: These ones, I'm actually probably going to be going to office hours to get a little help with because like I understand like the coding part of it just because like I have that background knowledge a little bit. But I guess like I don't still really super-understand how it's like simulating diffusion.

I get the collision parts and like the momentum issues. Like these ones, I get pretty well. But like I just don't really understand the diffusion concept of it quite as well. So that's like still something I'm trying to work through.

But like this is another one where like I went back and looked at these actually last night, and like I was reading through like some of the stuff and like saying, "Well, what does this code mean?", and like now that makes a lot more sense.

So I feel like when I plan on going and sitting down and going through them again, I'll probably understand them more than I did at the time just because that seems to be a pretty common trend. But it still kind of confused me how like that was modeling diffusion. [0:22:13]

INTERVIEWER: I see. Can you say some more words? You said you understood the collision part, but you didn't understand the diffusion part.

RESPONDENT: Yeah. So basically, like I understood the concept of like when we're modeling a collision, like you're going to exchange the momentum. And when you're doing it in a box, like you have to like make sure you account for the change in momentum when you hit a box and all of that stuff.

But I struggle to understand like… I guess maybe it's just because I don't really like… I understand what diffusion is, but I don't understand like the physics of diffusion. And I know we did a lab on it, and it still kind of went over my head a little bit. So I guess I just don't understand how diffusion and physics really go together really well because I understand this part, and I think I'm just struggling to bridge the gap between this part and the diffusion part.

INTERVIEWER: Gotcha. Gotcha. So how did the collisions lead to the diffusion part that you know? [0:23:03]

RESPONDENT: Yeah. That's what I can't really like formulate very well because like I can understand what diffusion is, and I can understand how like when two particles collide, like what's going on. But I can't understand how two particles colliding leads to diffusion.

INTERVIEWER: Gotcha. And this was a pretty heavy coding week. How did you feel about that?

RESPONDENT: I felt okay about it just because like I had that background knowledge from like CMSE. And I think going back, even now I'd really understand it well because we actually did that simulation in my CMSE class a couple of weeks ago that was very, very similar to this.

INTERVIEWER: Gotcha. Gotcha. Did you end up leading the group? Was this the second group or the third group?

RESPONDENT: This was the second group.

INTERVIEWER: So were you like the…

RESPONDENT: I would say that like with both like big computational days we've had so far, I was able to like kind of talk people through it. And while I may not have been like the first one to come to an answer, I was like saying like, "This is where we need to look. This is what we need to do". And… yeah. [0:24:03]

INTERVIEWER: Does that make you proud?

RESPONDENT: Yeah, actually, like I think we're doing computational stuff like tomorrow, I think. And so like I'm excited for that because like I know that like I have that background knowledge to help me build a… and I don't feel like I lead stuff a lot in physics, so being able to like take charge on something, it's like fun. Like because it's like my personality. I like to do it.

INTERVIEWER: (Laughing) That's great. Were your group mates… did they say anything about you knowing all this coding stuff and –

RESPONDENT: It was more just like, "Oh, you're like taking this class, and you probably understand this a lot more than we do. Like can you explain it?"

INTERVIEWER: I see. I see. Did you expect to do this much coding in a physics class?

RESPONDENT: I knew coming in, we did coding just because like I was friends with someone who took the class before.

INTERVIEWER: Gotcha. Cool. So tell me, do you think these activities are valuable to you?

RESPONDENT: Well, I mean I guess they could be, yeah, because like what I want to do is… like health informatics, it's a lot of computer programming stuff. So like any experience I can get, even if it's not something I might necessarily do in the future, like I feel like it's valuable to be able to work on that stuff. [0:25:17]

So I can see how this is like good for me personally, like career-wise, just because it's like giving me exposure to another like type of thing I could do.

INTERVIEWER: Gotcha. Yeah. I think those are all the ones I have for that. The next thing I have is actually a big stack (laughing) [feel free] (ph) to put through. I think this is what the professor actually wrote on the ELMO document camera. So yeah.

RESPONDENT: These help a lot. I think one thing that I really do that has helped me study is like after she posts them, I'll like go back and write them out on my computer because like I have a touchscreen, so it's like fun because I can write. [0:26:08]

So like I'll write them out and color-code them exactly as she did. And I think that helps me a lot. Like being able to color-code them myself and like go through everything the like same way that she did has helped me like understand the investigations very well because I know she mentioned in class like, "People need to study the investigations more".

And I feel like that's one thing that I do understand like very well. For the last exam, I felt really prepared for the investigation side of things and like understanding that. And like it's again going back to like at the time, I didn't quite understand it like going back. Like now I understand this stuff super-well.

And like she's lately been going over like problems from the in-class activities, and I really like when she does that because I think the way I learn best personally is just do like one example and then go do it. [0:27:04]

It's like to see her do an example like really makes it a lot easier for me to go do more because even if it's not the same exact problem or like the same type of problem, like to see like the thought process behind how to do one specific type of problem makes the rest like easy for me just because like me, personally, I pick that stuff up really quickly and like how to apply different concepts. So when she's able to show like the application of different concepts, I like really appreciate it a lot.

INTERVIEWER: So why do you think the professor does this?

RESPONDENT: Does like these as a whole?

INTERVIEWER: Yeah.

RESPONDENT: I think it's just a good way to like kind of synthesize everything we talk about in class because like I know for me, personally, like at the beginning of the semester, like for the first month, for the first exam, I tried to like write down everything as we were going through the whiteboard meetings. And then I realized that like that doesn't help me as much as just sitting and listening to the conversation and then going back and looking at these. And I can like remember like, "Oh, like we talked about this with this specific example". [0:28:02]

And so I think this helps a lot because like when she posts them, like it means that like I don't have to worry about getting all these notes down. They're going to be there. And I can focus more on like observing what's going on in class.

INTERVIEWER: And I think there're like different sections of these handwritten things. And so like your section has this (crosstalk), and the other section has (inaudible).

RESPONDENT: Oh, yeah. Yeah.

INTERVIEWER: Can you tell me a little bit about that?

RESPONDENT: Sometimes she posts like this stuff from both sections, and I actually wish she'd post them from both all the time just because I like having that like different perspective because maybe like the other section found like one little thing that was different. Or like they did an experiment a different way that kind of like showed the like relationship. So like I do think like just getting as much different information as you could would be super-useful. So like being able to look at both sections would be nice.

And that's another thing that like she'll post to the whiteboards, and like I haven't really gotten a chance to look for this exam yet. But for the last exam like on some of them, she'd post both sections, and on some of them, she wouldn't. And I found that when she posted both sections, I really understood those even better just because it like gave me like double the amount of information that I could like learn about the investigation. [0:29:14]

INTERVIEWER: Gotcha. And these were from what students say, right?

RESPONDENT: Yeah.

INTERVIEWER: And so were there any moments in any of the whiteboard meetings… or these consensus boards where you've gotten your piece of information on the consensus board?

RESPONDENT: Yeah, I'm sure there've been times. I can't think of a specific example right now, but… actually, yes, I can. (Laughter) When we did like the force experiment, like that was a work experiment. And like we tried to model like how direction of the force matters and stuff. So like she talked to our group specifically, and we talked about our experiment. And I feel like that one actually helped me a ton because I like really, really thoroughly understood it. Like I think out of my group members, I probably like felt like I understood it like the most and was best able to explain it. [0:30:06]

INTERVIEWER: How did that feel?

RESPONDENT: That felt good because like I don't understand physics a lot, but when I do, it's just a great feeling. It's a great feeling.

INTERVIEWER: That's awesome. Were you proud that your group was able to share the (crosstalk)?

RESPONDENT: Yeah. Yeah, I was proud like that what we had worked on like actually made sense because the girl in my group like originally suggested our project as a joke. And Polo (sp?) was like, "No, I think you should do it. Just like modify it a little", because like she was like, "We'll put two cars together and pull them in opposite directions". And Polo (sp?) was like, "No, like actually do this experiment". And we're like, "Oh. Okay".

INTERVIEWER: What was going on through your head when this kind of seemingly comical idea was actually like, "Oh, yeah".

RESPONDENT: My first thought was like, honestly, like, "Oh, physics". Like you truly never know what is going to happen in this class because it was like a completely 100-percent joke idea, and it like ended up actually like working out really well and showing like something really important. [0:31:03]

INTERVIEWER: That's great. Is that what you expected when you came into this class?

RESPONDENT: No. Not at all.

INTERVIEWER: Let's see. So you've actually rewritten these in your own handwriting on a digital touchscreen.

RESPONDENT: Yeah.

INTERVIEWER: So do you think that process has equipped you to do stuff outside of class? Like has that given you skills or abilities?

RESPONDENT: I don't know if it's necessarily like given me like skills or abilities. But it's helped me to kind of like just make sure that all my thoughts are on the same page as all of this because for me, like just reading through this, it's like all back-and-forth, back-and-forth. So like being able to like organize it in a way that makes sense to me helps a lot.

INTERVIEWER: Is it something you've done before, or was that like a challenge because of how this is laid out?

RESPONDENT: I usually… like I do it for biochem, too. I like to like handwrite out my notes in a way that makes sense to me and put them in an order that makes sense to me. [0:32:04]

INTERVIEWER: Gotcha. And then the last one I've got here. Oh, this is the last (inaudible) is this one.

RESPONDENT: Oh, this one's a while ago. (Laughter)

INTERVIEWER: Yeah. I think that was like a force, like a collision, SUV, car –

RESPONDENT: Yeah.

INTERVIEWER: – something. Yeah.

RESPONDENT: Yeah. I'm trying to remember what experiment we… I think this was with the second group. I think this might have been like Newton's second law one where we were like trying to show that force equals ma. And our group was just a disaster. Like a just absolute disaster. We were changing like too many variables at once, so we couldn't actually show what we wanted to do.

So this one was frustrating for me because everyone else in the class seemed to like already have all this background knowledge about it, but like I had never taken a physics course. So like this is like a really fundamental concept, and I see that now. [0:33:10]

But like this was like the very first time we got introduced to forces. So like with no physics background, it didn't really make any sense to me. So this is another one where looking back, I'll be like, "Oh, duh". But yeah, this one I remember like our group, I think we changed like both mass and acceleration. So like everything was just a complete train wreck. And like when I say zero data, we had absolutely like zero like data that could actually work. It was just like random numbers thrown on our whiteboard.

But we like recognized that it was wrong because we knew what the relationship should've been. So like we kind of like talked it through with Dr. Celtel (sp?), and we're like, "Why is this happening?" And she's like, "Well, you're just changing too many things at once". So that was like good to be able to have her help us talk through it. [0:34:01]

INTERVIEWER: Was it frustrating?

RESPONDENT: It was frustrating because like we knew something was wrong, but it was kind of like we just didn't know what to do about it because we didn't want to rerun the whole experiment because like we were kind of pressed for time. Like we were worried like would we not get our participation points for the day because like we tried, but like it just didn't work.

INTERVIEWER: Did it end up working out?

RESPONDENT: Yeah, it did end up working out because we actually were able to kind of use it as like, "This is why it was wrong, and this kind of like shows that like it's important to like, yeah, figure things out before you start doing them".

INTERVIEWER: (Laughing) So how do you think this activity is valuable to you?

RESPONDENT: It was valuable in showing that like if you're confused about something, ask questions, because I think that was kind of part of our problem is like we thought we knew what we were doing, and then like as soon as problems came up, rather than just like calling like Dr. Celtel (sp?) over or like Polo (sp?) over or Brandon over or something, just being like… like we didn't call them over, and instead, we kind of just sat there like, "Oh, this is wrong. Ha, ha. Well, it's wrong". And we should have just called someone over and been like, "Like why is this wrong? Like what could we have done differently?" [0:35:14]

INTERVIEWER: Gotcha. So I know like when I was taking chemistry… I think it was organic chemistry lab. I sucked. Every time I would have to get a precipitate – I think that's the word – it would go through my vacuum, and it would all dissolve, then I would have nothing. So like you're supposed to weigh it out, and you're supposed to get like some –

RESPONDENT: Purity (ph)?

INTERVIEWER: Yeah, something. But yeah, I never would do well. And I'd be like, "Yeah, that's what I got". So I recognize that now as like my old self.

So you said that in this lab when you got the wrong numbers, you're like, "Yeah. We got the wrong numbers. All right. Done". And then it seems like later on, these investigations – like the work one – you were able to really understand it. It started with a comical idea, it actually extracts some meaning out of it. So tell me about that transition. Like what's different now? [0:36:08]

RESPONDENT: I think this has actually been like something that's like been going on for me this whole semester is like I've never really been one to ask questions because things usually just come easily to me. Just like that's how school's always been for me. So like I think I could count on one hand the number of times I had to go to office hours for all of my classes the last two years. And then like this semester, it's like triple that for like I've gone to office hours for like physics and my CMSE class like all the time.

So I think like just in general, this semester has like forced me to understand that like you're not going to know everything, so you have to ask questions. So I think like as this semester has gone on, I've gotten better at doing that in like everything. So it's like gotten better at doing it in physics with like the labs and stuff.

INTERVIEWER: Do you think that that's a valuable skill to have?

RESPONDENT: Oh, definitely. Yeah, I think getting over that like fear of asking people for help has like been really important for me. [0:37:02]

INTERVIEWER: Gotcha. Would you say that this course has affected your confidence?

RESPONDENT: I think it has made me like less… not really scared, but I'm not as like uneasy about going to office hours and stuff. Like I know like I need the help, I have to go.

INTERVIEWER: Yeah. How did the first exam go for you?

RESPONDENT: I did okay on it. Like I did better than the average. So like it was lower than like the type of exam scores I usually get. But like going into this class, I was like, "Like this is like a very different type of class for you. Like you don't need to stress yourself out if you're not doing as well". It was really just like I understood 90 percent of the exam, but like the very last question, it was this stuff that I just didn't fully understand that I had gone to office hours for and still just didn't really fully understand it. I was like hoping it wouldn't come up on the exam that much, but it did. [0:37:55]

And that was something that like I knew going into the exam, like I had done everything I could to try and understand it, and it just was one of those concepts that just wasn't clicking with me. It's like looking at it like now, it's like I couldn't have really done anything differently to do better on that because I went to help room like multiple times for like that specific issue, and just like it never was something that made sense to me.

INTERVIEWER: Gotcha. When do you know that a concept or a topic has clicked?

RESPONDENT: When I'm able to just kind of like look at a problem and not really have to think. It just kind of like comes second nature to me. Like for example, like the incline problems, I was struggling through those. And then like a couple nights ago, I was like working through them, and like it all just kind of like started to go. I'm like, "Oh, first I have to do this, and then this, and then this". And it just like was like seamless. Like didn't even have to like think about like what the next step was because like I had gotten so used to doing like stuff in that order.

INTERVIEWER: Do you work on the homework with people, or do you just –

RESPONDENT: No, I usually just do it alone.

INTERVIEWER: Okay. Okay. So this problem kind of has the context of a person talking about an SUV and a car. Do you think that was like an authentic connection? [0:39:15]

RESPONDENT: I think it was because like, I don't know, it just makes me think of like my dad drives an SUV. And so like I've actually grown up and like going in larger vehicles all the time. And I've always thought to myself like, "Oh, like I would not want to be in like a small car". I've always been like adamant. Like, "I am not getting a small car when I get a car". So like it's relevant because like those are like the type of decisions that I'm going to have to make in a few years like when I decide to get a new car.

INTERVIEWER: Gotcha. Do you think you'll be thinking about the physics when you… like when you think about the SUV and car?

RESPONDENT: I think I'm not going to think like exactly like, "Oh, physics. Like this force is going to do this". But my knowledge of like why I think one might be better than the other is going to be based in physics concepts, if that makes sense. [0:40:01]

INTERVIEWER: Okay. So how do you think you're doing in the class so far?

RESPONDENT: I think I'm doing pretty well. I'm like hovering right on the border between a 3.5 and a 4 point.

INTERVIEWER: Congrats.

RESPONDENT: Thanks. So it's like I would be really happy with a 3.5 because like I know a lot of people like taking university physics, like they struggled to like 3.0 it. And so like I'm like, "Oh, a 3.5 would be great". But at the same time, like I'm a perfectionist. I'm like, "I really want a 4 point".

So like I'm trying not to let myself be disappointed if something doesn't go well or if I like miss it by like five points or something. So it's like it's a very different feeling for me because like that doesn't happen to me very often where I'm like right on the border. I'm usually like easily one way or another.

INTERVIEWER: Gotcha. Would you say this has been the most challenging class?

RESPONDENT: One of… yeah, I would say this and my CMSE class are the most challenging classes I've been in.

INTERVIEWER: Gotcha. So this semester's been –

RESPONDENT: This semester's, yeah, been brutal. But it's fine. (Laughter)

INTERVIEWER: Well, clearly, you're succeeding. If you're between a 3.5 and a 4, you're doing pretty well. And how do you know when you're doing well and when you're not doing well? [0:41:08]

RESPONDENT: For me, like my definition of "well" is like well beyond what most people's definition of "well" is because like usually, I… like, yeah, I like to 4 point classes. So like when I'm not 4-pointing, it's like, "Oh, you're not doing well".

But like with this semester, it's like kind of involved like taking a step back and realizing like these are like really tough classes. Like most people don't 4 point them, so you don't need to be perfect. And so like normally, doing well involves a 4 point. Right now, doing well involves like actually just understanding the material and like not wanting to rip my hair out over it.

INTERVIEWER: (Laughing) So going from a focus on the grade, like getting a 4 point, to understanding, when did that happen for you?

RESPONDENT: I think it happened like probably early October, mid-October, when like it was like to the point where I was like just like going absolutely nuts trying to get everything done. Like super-long nights, and like my mom like took me out to dinner and she's like, "Look, you need to like stop doing this to yourself. Like you don't have to 4 point every class. Like as long as you're like understanding stuff and not completely lost, you're going to do fine". [0:42:19]

So that was when I focused more on just like making sure I understood what I was doing rather than getting it 100 percent perfectly right.

INTERVIEWER: Awesome. And who do you talk about this course with?

RESPONDENT: I talk about it with my boyfriend sometimes and one of my roommates because like she took like university physics. Like I'll talk to her about like how different it is. And actually, they both took university physics.

INTERVIEWER: Yeah. What does your mom think of you kind of mastering the concepts recently of the work and –

RESPONDENT: Yeah, she's very glad that I'm understanding things a whole lot better because I stress her out a lot less. But she's like glad that I've like put myself like so that I'm not so like stressed out over like, "Oh, you have to be perfect all the time". [0:43:06]

INTERVIEWER: Yeah. Do you ever tell her stories from physics class?

RESPONDENT: Not really just because like I don't see her a whole lot.

INTERVIEWER: Gotcha. And so, Nicole (sp?), you're always my fastest interview. I think you know exactly what you want to say. Are there any other things you think I should know about you or the course?

RESPONDENT: I don't think so. I think I'm good.

INTERVIEWER: We're all done.

RESPONDENT: Awesome. Thank you.

INTERVIEWER: Thank you so much. Appreciate it.

RESPONDENT: Stay dry.

INTERVIEWER: Yeah. Yeah. Hopefully, the ten dollars will go towards, I don't know, some holiday gifts or something.

RESPONDENT: That's exactly what the plan is actually.

INTERVIEWER: Thanksgiving food. (Laughing)

RESPONDENT: Talk to you later.

INTERVIEWER: Have a good one.

RESPONDENT: You too. [0:43:48]

**END TRANSCRIPT**

## APPENDIX V

## TRANSCRIPT: NICOLE INTERVIEW 3

[00:00:00.00]

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CMSE PHYSICS CONNECTION
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[00:08:04.21] Gotcha, gotcha. Um. And I know that last semester we talked a lot about your CMSE course.

[00:08:12.09] Hm. mmm. [nods in agreement]

[00:08:12.09] Did more kind of syngergy happen between the physics class and...

[00:08:17.08] With that class it kind of, it more or less ended for me before thanksgiving break because like we gave project presentations for the rest of the semester and I presented mine before Thanksgiving, but the CMSE class did help, we did have a programming project in physics this semester and it helped a lot with that like, everyone else really struggled through it and I pretty much had the code almost done before he showed us literally the entire code in class. [Whoa]. So that was kind of frustrating 'cause I spent a couple of hours on it the night before 'cause I wanted to have it done, and he's like "I'm just going to show you how to do it today in class." I was like "Oh."

[00:08:48.12] So tell m--unpack that for me, tell me about that.

[00:08:50.12] Um... bascially like what we had to do was we made, a [air quotes] "gun" that shot off charges at a wall, and we had 4 like random charges placed everywhere else and I had pretty much everything was right, we had to use Coulomb's law to like make it like inter--make the charge we're shooting off with the other ones and I had everything right like I had the charges randomly generated, and it was shooting stuff off. Except, I couldn't figure out how to do the distance, that was literally the only thing that I had wrong, so.

[00:09:18.22] Gotcha, how did that feel?

[00:09:20.19] It was good, I felt like the class I'd like--I don't know it kind of all came together and it was nice to feel like while everyone else was struggling, I had a really good grasp of what was going on.

[00:09:29.18] Um...what do you think helped you do that so quickly?

[00:09:32.20] I think um, a big focus of it was understanding like how to use random numbers and like how to set things up in space. Um like in the space of the program, um and since I had a really good background knowledge of like what, how to do that, I think it like put me ahead of everyone else.

[00:09:48.15] Gotcha, where did that background knowledge come from?

[00:09:50.06] From CMSE

[00:09:51.01] From CMSE, Gotcha. Um, were you proud?

[00:09:54.23] Yeah I was

[00:09:55.17] Yeah? Did you tell people that like you were done?

[00:09:57.29] Yeah like the two girls that I'm in a group with in that class, they were like, "oh like can you show us how to do this, can you explain it, i have no idea what's going on" so that was nice.

[00:10:05.27] Gotcha, um and this isn't the first time that you've kind of had something figured out on your computer, I think I remember from the first semester you had a, I think you were presenting to the class...

[00:10:18.15] Yeah I had like um it was about random walk, and we bascial--we more or less did like the exactly what we were doing in class and we wrote a program for it, so that was really cool.

[00:10:28.13] Yeah, I mean-how was that interacting with your groupmates.

[00:10:31.02] Um I liked it because I think it really helped them to understand it better because the activity we were doing like it was just a little bit harder to see because you were doing it manually wheras when I could show them on the computer they could see within like 5 seconds what was going on.

[00:10:44.14] Gotcha

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MEMORABLE MOMENTS IN 273
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[00:13:59.12] Tell me some memorable moments from the first semester.

[00:14:02.05] Um I think one memorable moment was like towards the end when we were talking about like the water molecules and stuff, I really liked that because I felt like it related really well to Biochem, so I thought that like those two concepts like together like really gave me a really strong idea of why polar and nonpolar molecules don't interact basically. So.

[00:14:26.17] Oh, ok, so take me to the phys-which parts were they when you talked about water.

[00:14:31.12] Um that was the very end of the semester we basically just did-we didn't really do any like experimentation or anything we just kind of talked through a lot of it and made like giant whiteboards and drew a lot of pictures and stuff. Um but I remember like there was one specific question where I was like we literally had an entire slide in my biochem lecture that is this word for word [Really?] So I like showed them and I'm like this is what's going on and this is like how the physics would work behind it so.

[00:14:55.19] Whoa, so you were showing your groupmates?

[00:14:57.21]Yeah

[00:14:58.08] In physics?

[00:14:58.18] Hm.mmm. [nods in agreement]

[00:14:59.22] Um it seems like a lot of times you're bringing in outside of class materials into the class, how did that feel?

[00:15:05.12] It was nice, it was nice to make that connection between the two, because it kind of like reinforces the idea that science is super interconnected so.

[00:15:12.14] Gotcha, um do you find yourself doing that in other classes?

[00:15:15.22] Um sometimes like I said about the Eukaryotic Cell Biology, in my HPS not so much 'cause that class is about maps so [laughs]

[00:15:22.05] [laughing] it's about maps?

[00:15:23.14] Maps, yeah.

[00:15:26.05] Ok um awesome, so what were some of the high points?

[00:15:29.18] Um. I think, doing well like really well on the second exam like was a really big like, it boosted my confidence a ton, it made me feel like wow, like I didn't have any physics knowledge coming into this. I can finish this semester out strong and 4-point and I think that was a really rewarding feeling knowing like I was able to like push through like--'cause I know in the very beginning of this semester I was like really confused, I didn't much, and then like kinda like learned how to best learn, and so seeing that pay off felt really good.

[00:16:00.09] Take me through the process of you learning how to best learn.

[00:16:03.20] Um. So when the semester started I just, I like didn't really know what I should be focusing on, when I should be taking notes, should I just be taking notes all the time? And then I kind of realized that like I got a lot more out of it when I wasn't taking notes and when I was just paying attention to what people were saying so I found that like listening in class rather than taking notes and just going back and looking back at like the stuff that doctor S wrote and stuff, that seemed to help me the most and like going through Kahn Academy videos and doing example problems helped me lot.

[00:16:34.10] Gotcha, um. take me to some moments where you felt just amazing in the class.

[00:16:40.15] Um. The time that I showed like the program I wrote that was probably one of the best ones just because I felt like it related so well to the class and I think it really helped a lot of people so that was pretty rewarding. Um like I said after that second exam, I felt pretty good and then there was a lab but I can't remember which one it was where we had like this totally random off-the-wall idea and we were like--oh like that's--like we threw it out as a joke and Miles was like no like you guys should really do that, you need to do that. so that was like, that was cool that an idea that we thought was just a joke turned out to actually be like important and like needed for the discussion.

[00:17:17.19] Do you remember what kind of lab it was?

[00:17:19.03] Um. it was definitely something with the IOLab and I think it had to do with, it had to do with work, I don't remember exactly what it was that we did.

[00:17:27.23] Um. Awesome, and how about now in like 274, what are some high points?

[00:17:35.14] Um...

<<tells story of G's video game>>

# APPENDIX W

## TRANSCRIPT: SAM INTERVIEW 1

# TRANSCRIPT OF AUDIO FILE:

# LB273-09.22.17-SAM-INTERVIEW1

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*The text below represents a professional transcriptionist's understanding of the words spoken. No guarantee of complete accuracy is expressed or implied, particularly regarding spellings of names and other unfamiliar or hard-to-hear words and phrases. (ph) or (sp?) indicate phonetics or best guesses. To verify important quotes, we recommend listening to the corresponding audio. Timestamps throughout the transcript facilitate locating the desired quote.*

**BEGIN TRANSCRIPT:**

Starts at 00:00:12

INTERVIEWER: That should work.

STUDENT: Hello (laughter).

INTERVIEWER: Yeah I think this works. Alright. Some of the ground rules. You can't give me a wrong answer on anything. I would want to know your experiences, your thoughts on things. You can be as brutally honest as you want. None of the instructors will know. In fact, Vashti doesn't know you're here. Vashti doesn't know that you've consented. She doesn't know that you're participating, neither do any of the LA's or TA's. And they won't until they have no control over your grades and your future or anything like that. Let's see I'm not going to ask you to do any hard physics problems. That isn't the purpose. I'm just trying to get your experiences and your thoughts. [00:01:01]

In this sheet I've got just some questions that I will run through that I'd like your thoughts on. That's about it. There's an audio recorder just so in case something dies, at least we have some record of it. (chuckles) First question. Do you have any questions?

STUDENT: No. Not really, no.

INTERVIEWER: Cool. I thought I saw you with a Harry Potter themed shirt. Was that true?

STUDENT: Yes.

INTERVIEWER: What was that?

STUDENT: I played quidditch or I did last year and I—we haven't got a practice this year but like I've continue—I plan to continue.

INTERVIEWER: Alright. So tell me some of the things that clearly you're not flying.

STUDENT: No.

INTERVIEWER: Okay. So I'm a huge Harry Potter fan what position do you play?

STUDENT: Chaser.

INTERVIEWER: Okay. Wow. It's pretty good.

STUDENT: It's a full contact sport too?

INTERVIEWER: Really?

STUDENT: Yeah.

INTERVIEWER: So describe like one of the adaptations you've had to make to make it (inaudible at 00:01:59).

STUDENT: I don't know. If you've ever played soccer, basketball, football it's all that combined. Your goal is to get the quaffle through the hoops. But you also have beaters coming at you, so you have to coordinate to where your team's beaters are getting the other team's beaters and their chasers if they're trying to score. And your beaters take you up to their hoops and help you score by—because once you get hit by a bludger you have to go back to your hoops, touch your hoops because you're dismounting your broom.

INTERVIEWER: I see. So what are the bludgers?

STUDENT: They're dodge balls.

INTERVIEWER: Really?

STUDENT: The quaffle's a volleyball.

INTERVIEWER: Does it hurt? People get crazy?

STUDENT: Yes. I actually saw some guy with a seizure once because he got hit so hard (chuckles). Because it's full contact, you could check people. Yeah. And he got hit so hard by our keeper and he had a seizure. That was in Pennsylvania.

INTERVIEWER: That sounds intense.

STUDENT: Yeah.

INTERVIEWER: (Laughs). Wow. Yeah so that was cool to see. Do you guys customize your brooms? [00:03:02]

STUDENT: No. Not really. We had brooms that say Michigan State on them but that's about it.

INTERVIEWER: Does Michigan State have an official team?

STUDENT: Yeah.

INTERVIEWER: Sweet. That's awesome Does Anne Arbor?

STUDENT: I think so. We played them in regionals I think.

INTERVIEWER: Are you guys better than the Anne Arbor team?

STUDENT: I don't know. Last year we weren't [laughter).

INTERVIEWER: My wife goes Anne Arbor so yeah. Just a friendly rivalry I guess. So the first question is very broad. Can you tell me a little bit about yourself?

STUDENT: Well I'm a college student. My interests are mostly like sports related. I enjoy most of my time exercising. I have one sister, two parents. I live in the Flint area Flushing if you ever heard of that? My sister is in high school. She's a senior. And yeah that's pretty much it about me.

INTERVIEWER: How about your experience with school so far? [00:04:00]

STUDENT: Throughout school, through high school, I've been a really good student like straight A's every time. And now I'm in college I'm just like—

INTERVIEWER: Why do you think that's happening?

STUDENT: Harder classes.

INTERVIEWER: Harder classes.

STUDENT: I think that's pretty much it. I was in Chemistry last year and chemistry and I don't mix well. (Laughter). So yeah it was a struggle but this year has been easier.

INTERVIEWER: Okay. And what's your major.

STUDENT: I have a dual major. Nutritional sciences and kinesiology.

INTERVIEWER: Wow, okay. And what got you interested in that?

STUDENT: About two years ago I just decided to get into nutrition and I was just like wow. I really like this stuff and that's how I got into weightlifting and all this stuff. It's how I decided I wanted to do something with that. I'm getting my personal trainer certification now. Yeah.

INTERVIEWER: Wow. That's a lot of stuff.

STUDENT: I know.

INTERVIEWER: What got you into nutrition? [00:04:54]

STUDENT: I don't know. I just like—I like living a healthy lifestyle because you have so much more energy lifting like that. You get—you have so many more benefits than if you were to eat processed food and stuff. And then we don't know really what we're putting in our bodies with all that food. I just thought it was really interesting.

INTERVIEWER: Cool. And what got you interested in science to begin with?

STUDENT: My parents are both in the medical field. My mom's a doctor; my dad's a physical therapist. And I always told myself that I wanted to go in the medical field because I hated what they had to do and then I was like—well I honestly don't see myself doing anything else. I can't be an engineer because me and calc don't mix either. But biology is my forte. I really enjoy different sciences. I've really enjoyed anatomy and how the body works.

INTERVIEWER: So how did you get interested even though there was resistance? You were like I don't want to do what they do. But then now there's some alignment. [00:05:56]

STUDENT: I actually was first interested in the body by the brain because I took a psychology class in high school and I found it very interesting. There's this one organ inside of us that determines who we are. So I got more interested—because the brain controls everything you do basically. So that's just kind of spiraled off into like—oh I really like anatomy, I really like muscles and how they move and how they work.

INTERVIEWER: Awesome. And so take me to the picture of Sam working. What are you doing? What's day in your life (inaudible at 00:06:30) future career like?

STUDENT: My future career? I'm trying to decide between two things. I want to become a psychiatrist because I want—I want to be a doctor of some sort. So I really like the brain and I've had experienced with helping people who have been depressed and have anxiety and stuff. And so that's really where I want to go to because I want to help people like that. But then there's also a part of me that wants to be an orthopedic doctor because I want to help rehabilitate people and do—because you see those inspirational posts about people who lost a leg but they're still doing triathlons. And I want to be part of that as well. [00:07:09]

INTERVIEWER: What got you interested in wanting to help people?

STUDENT: I just like to help people. I like—my biggest goal in life is to inspire somebody. Like someone to say I did this because of Sam. You inspired me to do this. That's my biggest goal in life.

INTERVIEWER: I see. So I'm going to ask you a couple questions about class. So I know that (inaudible at 00:07:33) grade students have a choice in the flavor of physics they take, university physics or (inaudible at 00:07:37) physics. Can you tell me why you enrolled in this one?

STUDENT: My advisor talked to me about it. I asked her which one I should take. And she was like well, if you want to go to medical school (inaudible at 00:07:49) physics would probably be something you'll lean more towards because it's integrated lab and you would have more experience with biological studies within that class other than university physics. I didn't like the fact that it's called base though because like I said I don't like calculus. But I also didn't want to split into four different classes. [00:08:08]

INTERVIEWER: Oh yeah. Two for the fall because lab is separate. I see.

STUDENT: And so it just fit easier into my schedule.

INTERVIEWER: Okay. What did you expect the course to be like?

STUDENT: Not like it is, honestly. I expected it to be like high school physics. You get all these equations, kinematics, stuff like that. And now we're looking at how wounds heal and I'm like that's pretty cool. Yeah I actually really enjoyed that.

INTERVIEWER: Yeah. Can you tell me more?

STUDENT: I don't know. I really liked how she—how Vashti related it to biology because I find it really interesting about the human body and how you find the rate of how a wound heals like that was really cool. And you can determine whether a patient needs antibiotics or not because of that and I thought that was interesting.

INTERVIEWER: Take me through a typical day in your physics class. What do you do? [00:09:02]

STUDENT: Well sit down. (Laughs).

INTERVIEWER: That's a good first step.

STUDENT: Dread the three hours. But usually there's a warm-up. During the warm-up we discuss and then we have—sometimes we'll do a work sheet, do a board meeting and present boards and stuff. Then we'll have a different investigation to do and do another work sheet. And then we'll collaborate together, take some notes. And depending on the day it'll have a lab where we take the computers out and do something with it and then investigate that.

INTERVIEWER: Okay. Can you tell me why you think the course is structured this way?

STUDENT: I think it is this way to like bring kids more toward acting with physics and not just learning it—like learning the equations, how you plug (inaudible at 00:09:59) and stuff. But like actively being present within physics because I mean, if you think about physics is everywhere around us. You can basically take anything and put it into an equation I guess, or relate it to something in some way in some sort of way in physics. And I like how you can relate or how this class relates everything to what this world is I guess.

INTERVIEWER: Can you give me more words on this, putting things in the world into equations?

STUDENT: I guess—you can take a person and—determine whether or not they're going to get to somewhere on time or not. You can take a person—you can take a wound healing, determine how fast that will heal. You can take a building and be like well will the wind on tuis on some sort of day will it cause this building to sway. You can apply physics to pretty much everything. [00:11:03]

INTERVIEWER: Got you. And when did you start thinking that physics can be applied to everything?

STUDENT: I have some friends who are engineers and so they're pretty much into physics I guess. When I hear them talk about, how this works in this way, that makes me think. I have a friend who's an engineer right now or who's schooling in engineering right now and he just got into weightlifting. I'm helping him out and stuff. And he's like I find it really interesting how the body is a bunch of levers and pulleys. I've never thought of it that way. And in my course for personal training, there's a whole chapter about how the body is a bunch of machines.

INTERVIEWER: Oh wow.

STUDENT: Like simple machines. I was like that's actually very interesting. And so that's how I started to get—like how biology and physics could relate. [00:11:59]

INTERVIEWER: Walk me through a typical week in the class. Are there certain things you do on certain days?

STUDENT: Kind of like how we—how Vashti structured the class is do an investigation in the lab and then the next time we come back, you'll take those and apply that to a real-world situation, kind of like the wound healing. Then see how you could use that in the future. And then I guess move on to another chapter.

INTERVIEWER: Got you. How do you think—let me rephrase. Where do you think learning happens in the course?

STUDENT: I want to say just learning happens inside of a person because—you could sit there and not absorb anything and not learn it. I would think you'd have to be interested. [00:13:01] You have to show some sort of interest in what you're learning in order to pay attention and to grasp the concept. Because if you're not present in class—even if you're sitting there but you don't have attention towards the class, I don't think that you could learn it. You could probably pick up a few things you could remember, but in my experience you don't really learn anything without being interested in some way.

INTERVIEWER: Got you. And then you mentioned several different kind of activities that you do in class. Is there a certain type of activity in class that you think that's where the learning's happening?

STUDENT: The labs I think.

INTERVIEWER: The labs

STUDENT: I'm an on-hands learner and so when I get to do something that's where I see most of—where I learn. Like in the labs when we dropped the ball or when we did the motion-sensing thing, that's when I learn the most because I can see it happening and I'm participating in what we're recording as data. [00:14:04]

INTERVIEWER: Okay. So for you doing that stuff is helping?

STUDENT: Yes.

INTERVIEWER: How is knowledge (inaudible at 00:14:17)?

STUDENT: What do you mean by that?

INTERVIEWER: Okay. So to make it more specific. So I think last week or this week, you covered momentum. How did you all construct that idea?

STUDENT: I think since a lot of us had previous—I don't want to say physics courses but relatable to physics in high school, where we kind of understood the definition of momentum. And so we kind of built on that with new concepts brought from our instructor to learn more about the topic I guess. Yeah. [00:15:05]

INTERVIEWER: And did you have previous experiences in physics?

STUDENT: Yes. I took physics in my senior year in high school.

INTERVIEWER: Can you tell me a little bit more about that?

STUDENT: It was basically kinematics, forces and stuff, all the basic physics things. We got equations, worksheets, figured out problems. Actually our semester project was to build a catapult. That was pretty cool and I think my team won. We shot toilet paper rolls and it was really cool.

INTERVIEWER: It seems dangerous to teach students how to build a toilet paper launching near Halloween.

STUDENT: It was pretty awesome.

INTERVIEWER: It was pretty awesome. Okay. How do you determine who's right? Or how to you settle on an answer in class? [00:15:51]

STUDENT: Well I mean I guess like everything majority rules. That's like a philosoph—philosophical—there we go—question because we never really know what is right or who is right. I guess it's all opinion-based. But I mean if there is a fact saying that this is correct then I would base it off the fact. But also if you're in a class with a bunch of smart people like Briggs, the majority would rule I guess.

INTERVIEWER: I see. Have you—I think you told me, a little bit about this but one, I still want to ask you a question. Have you encountered biology in this course?

STUDENT: Yes. The wound healing. Yeah that was very interesting.

INTERVIEWER: Walk me through that day. What were you thinking when you—? [00:16:48]

STUDENT: I forgot what the one that my group did. We did all three of them but I think we did have the wound one. There were three different videos: neutrophils, E. coli and the wound healing. And so my group had the wound healing and it was actually really cool to see the video of the wound closing. I mean I don't get really squeamish when it comes to blood or anything. And I had this severe cut on my arm, so I got to watch over time how the wound healed and how it's still healing right now.

INTERVIEWER: Wow. That's pretty impressive.

STUDENT: (Crosstalk) stitches but—And so watching that on video was really cool to me. To see how the body can reform itself and produce scar tissue when it's been completely sliced.

INTERVIEWER: Did it feel real that you had this kind of experience with this cut healing over time?

STUDENT: Kind of because I remember seeing it like—I watched it get stitched up and it was like—it was actually really cool (laughs). And so they just basically pulled the skin together and it was just two edges and I was like how is that even going to—look like thread that they used. [00:18:01] But seeing—it just kind of come together after a while. And my mom was a doctor and she pulled them out. There were three internal ones and ten external ones and so when they started to heal they started to get annoying. So my mom cut them and pulled them out and the skin was still attached. And so I found that very cool how the body can just reform itself. Not necessarily regenerate but just combine I guess back together.

INTERVIEWER: Can I ask how you got that cut?

STUDENT: Thanksgiving. I was doing dishes. (Laughs).

INTERVIEWER: Was it a knife?

STUDENT: Yes.

INTERVIEWER: Oh wow.

STUDENT: It was a big knife.

INTERVIEWER: My wife and I got a one of those food processors and it comes with these discs for slicing. And we're washing it and I was moving the sponge too quickly and I ended up cutting my thumb and my other finger. She told me, it's really sharp. Yeah. I got blood everywhere. It was just a mess. Have you encountered any other biology in this course (inaudible at 00:19:05)?

STUDENT: From what I can recollect now, not really. I can understand how different things we've learned can be applied to biology but nothing super specific.

INTERVIEWER: Then have you encountered physics in any of you other courses?

STUDENT: Yes. My kinesiology course actually. Our first third of the class is about physics so we started with kinematics. We're moving on to impulse momentum right now actually. So we've already covered that in this class. Because like I mean obviously that's an intro class but how the body moves in a physics standpoint, I guess. It's actually really cool.

INTERVIEWER: Are you feeling that there's a cross over?

STUDENT: Yes definitely. That's a little more simpler because the farthest in math we're going is trig. But here we're doing calculus and using integrals and stuff. [00:20:00]

INTERVIEWER: Got you. And what do you see as the similarities between the different since disciplines. Like bio, chemistry and physics?

STUDENT: I would say they're all relatable to our world and surroundings. I mean in the body you can find physics. You find chemistry and biology. You can probably find physics, chemistry within a building, even biology as well, maybe with like different bacteria around places. I think those three major sciences are important to understand because that's where we're living is in science. I mean yes we're living in math and we're living with English and stuff, but everything we do everything we are everything we have is science-based in some sort of way. [00:20:57]

INTERVIEWER: That was a really great phrase. I feel like that should be on a poster somewhere (laughter). What do you see as the differences between the three?

STUDENT: Really not a major difference because all of them relate in some way. I mean you can find different molecules and how they interact with each other using physics. You can find wound healing with physics. You can find the chemicals that make up your body with biology. So I really don't think there's a huge difference. I think the overall topics, kind of like biology is mostly organisms, chemistry is mostly elements and physics is math.

INTERVIEWER: I see.

STUDENT: But nothing really big difference.

INTERVIEWER: Now I'm going to ask you questions—and you started answering this. How you see the disciplines as related to each other? When I ask this sometimes students have an image in their head and I have no idea what they're talking about so usually I have them draw it. But if you feel like drawing something to make it clear. So how do you see biology, physics and chemistry relating to each other? [00:22:06]

STUDENT: Like I said in the world, everything we do is all sciences. I mean even if you walk into a bio lecture, you can probably find something physics related. I'm in biology as well right now and we're learning about mitosis and meiosis. And you can use physics to find how fast that happened. How fast cells can duplicate, cells can split in half or how chromosomes can duplicate themselves, or sex cells can become present in offspring. You could also find like different chemical imbalances in your brain. Like for someone who suppressed serotonin. It's something they would take like a serotonin supplement to chemically balance their brain in order to help them function regularly I guess. Normally. [00:23:11] And so I think those are all relatable within—especially humans because we're made up of all of them. And it's very interesting to understand that. I was in chemistry, I'm now in biology and physics and there is all relations together within the human body.

INTERVIEWER: I see. So you think all three exist in all places?

STUDENT: Yes.

INTERVIEWER: Okay. In your future career, how do you see yourself using physics?

STUDENT: If I were an orthopedic doctor, I could definitely see myself using physics. Like how fast a patient can recover with this sort of treatment. What are the angles at which—if they were to get a synthetic limb, what are the angles they can move? What is the machinery I guess needed and how can you implement that in everyday movement. If they were to get a prosthetic leg, how would you (inaudible at 00:24:26) that leg? Or how could they use that leg to move or function like a bipedal human instead of having them in a wheel chair all the time. If I were to be a psychiatrist, I really don't know how I would use physics. I guess finding how fast a patient can recover, or how long they would need a drug or antibiotic—not antibiotic, a drug to not need it anymore, not become dependent upon it. And so I guess it would be with upping the dosage or lowering the dosage and so on. [00:25:08]

INTERVIEWER: Okay. Do you ever find yourself thinking of doing physics in your daily life?

STUDENT: Yes. Now actually. When I go to the gym and I lift weights I see all of the levers and I see how they work at certain angles. It's fascinating. And how fast or how slow can the muscles work before they get hypertrophied or very sore. When blood rushes to your muscles they look bigger. It's called a pump and so how fast the pump can happen. How long you can work out before you start to really feel fatigued and stuff like that. [00:25:57]

INTERVIEWER: Are there any other places that you find yourself thinking of physics outside the gym?

STUDENT: Yes. When riding my long board or a bike, hills and stuff. Like how hard am I going to have to pedal? How much power do I need to get up the hill? Or how much power do I not need to go down the hill.

INTERVIEWER: Got you. And in the areas of science that you're interested in, how do you think physics plays a role?

STUDENT: I would say more so the topics I would say I'm more interested are like power and strength and energy as well as speed. Because if you take an Olympic athlete and calculate how fast they run 100 meter sprint you can find—if you were to videotape it, you can find that their stride length, you can find where they can tweak this if they need to pump their arms longer to get faster. And that's where I would like to take physics if I were to be an orthopedic doctor. [00:27:20]

INTERVIEWER: I see. It seems like this kind of tracking video has been a touchdown for you. Was that the first time you'd done video tracking with you class?

STUDENT: Yes.

INTERVIEWER: Was it something that kind of changed your view on how you can apply physics?

STUDENT: Yes actually. I mean there's normal videotaping where you can find it and slow it down but actually tracking a certain point on the video, I found this very cool. I played softball in high school and my coach—I worked with the coach at Anne Arbor and they have this machine or camera that can take a swing of a bat or—take it apart. And so being able to track that would be awesome. You could perfect the swing that way and hit a thousand feet. You probably couldn't but I mean— [00:28:13]

INTERVIEWER: Did that help?

STUDENT: Yes.

INTERVIEWER: I did not think (inaudible at 00:28:16) works.

STUDENT: If I were to take that into a lab and dissect a runner or dissect a hitter that would be amazing to see and how you could tweak their performance in order to make it better.

INTERVIEWER: Are you thinking about doing (inaudible at 00:28:34)?

STUDENT: I didn't even know that normal students could. I thought it was only for honors kids.

INTERVIEWER: Oh no. I think you could do—I think you could do it, right?

STUDENT: I didn't know.

INTERVIEWER: Yeah. I just remember hearing about the project with the slow (inaudible at 00:28:49). But that was one of the categories of honors options.

STUDENT: If I could I would love to. That would be so cool.

INTERVIEWER: Take out some of your old footage?

STUDENT: Yeah. [00:29:00]

INTERVIEWER: That would be awesome. How do you think physics is going to help you with your other courses or to get your degree?

STUDENT: I think it would help me a lot with my kinesiology courses. Kinesiology the definition of that is the movement of the human body I guess. My dad's a physical therapist and he's an asset I can use. He knows the ins and outs I guess of the body. And physics just opens up a whole new realm of how to look at that body as a machine, as machines. As different machines that work together to produce life I guess. Also with biology, chemistry. But reaching for something is physics. There's an angle in your elbow. There's a speed that you're grabbing it with. There's a force that you're exerting and I think that's fascinating.

INTERVIEWER: Is there any part of chemistry, biology or physics that you find particularly engaging or satisfying when you think about it? [00:30:04]

STUDENT: The levers and pulleys of the body is probably my favorite thing. And the wound healing, that was really cool too. Anything related to how the body moves I guess is really interesting to me and really intriguing.

INTERVIEWER: Do you ever find yourself sitting and thinking about it like outside of the classroom setting?

STUDENT: Uh-huh. I go to the gym with my engineering friend a lot and doing a set either of us watching each other or just watching myself, I see how that works. You could also use physics to determine how to work a muscle better. Because if you were to—for a biceps curl for instance, if you were to go all the way down you would get most of the muscle and bring it all the way up. Whereas going down to 90 degrees is not going to work the entire muscle because there's different heads of the biceps. [00:30:59] But if you go all the way down you're working the shorter head down here. Whereas if you're just going to 90 degrees you're not—you don't get the full effect.

INTERVIEWER: I see. Is your friend also into thinking about the levers and stuff? Or is it something that you bring in?

STUDENT: Yeah he is. Yeah he is the one who brought the idea into my head. He's really into physics. He loves physics and so he'll find any way to relate back.

INTERVIEWER: I see. What do you see as the important things to take away for a course that's outside of your major?

STUDENT: Probably how to apply that to your major or to things you're interested in. I mean if I didn't have a medical school major and I didn't have to take physics I probably wouldn't. But if I did I would definitely find a way how that would benefit me. I mean right now in my major I have to take an agriculture course. I really don't like it. [00:32:00]

INTERVIEWER: What do you do in the agriculture course?

STUDENT: I don't know. It's basically online and you have to write a—

INTERVIEWER: It's an online agriculture course?

STUDENT: It's online. We meet once a week. And so everything we do is online. Our exams are online, our quizzes are online, our finals are online. We meet once a week and that's our attendance grade. And I'm not interested in agriculture but I can understand how I would need that for my major nutritional sciences. I mean if you don't know which soil you're harvesting crops from that could really harm your body.

INTERVIEWER: I see. That makes sense. What do you think you're going to take away from physics?

STUDENT: Well Briggs' physics, I think I'm going to be opened up to a whole new realm of math specifically because I've only been in algebra, calculus, but this is math applied to life. [00:32:58] And so with me, I find a lot of satisfaction figuring out a math problem. If I can't figure it out I'll be super frustrated. But if I can solve it and get the right answer—or one that makes sense at least, and apply that to something that would be amazing. If you could figure out how much your body has to hyper extend for you to get a severe injury that would be cool. Or how flexible you can be before you hurt this muscle. Like how far is too far type of thing.

INTERVIEWER: I see. Had there been moments in class—you said you found really—If you really like to figure things out and if you don't, it's very frustrating. Have you had any moments of frustration or moments of joy (inaudible at 00:33:54)?

STUDENT: Yes. (Crosstalk). Some problems that Vashti gives us—is it Vaashti or Vashti?

INTERVIEWER: I think it's Vashti. [00:34:03]

STUDENT: Okay.

INTERVIEWER: At least that's how she says it, yes

STUDENT: The last problem we did yesterday with the NASA, that was frustrating because – when you put things in a coordinate I can see it. But you screw up one line and you're done. You can't figure that problem out. And so when I was in physics we had these (inaudible at 00:34:24) problems. And my professor or teacher taught us how to break it up into different axis and find three different right angles and like figure it out like that. But then I was just told like last week that the physics class my friend took at Mott (phonetic at 00:34:43), all you have to do is just plug this equation in and you've got it.

INTERVIEWER: I see.

STUDENT: Why did I have to do it the long way because that just saves all the frustration? But when it comes to multiple variables that's when I struggle. If I get all these variables I know what they are and where they go into an equation and how to plot this graph, then I'll be okay. But when it's like—you need this one but not this one, but I'm going to tell it anyway because it's part of the problem. So that's when I start to struggle. [00:35:16]

INTERVIEWER: I see. Have you had any moments that you're proud of in class?

STUDENT: Yeah. The wound healing. I keep going back to that. Being able to track that certain point; I found very satisfying. I was very proud of myself to be able to find the rate at which that wound healed. And if I could do that on a real person that would be really cool. Tell this person, oh you need antibiotics because this wound is not healing fast enough because this travels faster.

INTERVIEWER: Were you the person of the group that was like, look you guys I have this huge wound (inaudible at 00:35:54) heal—?

STUDENT: No I wasn't but I—I'm the techie person in the group so I'm on the computer most on the time because (inaudible at 00:36:07) programs.

INTERVIEWER: Have you always been good at computers?

STUDENT: At Mac yes. And that's what we use in the classroom. So my family is a huge Apple family.

INTERVIEWER: I see. Everything's Apple?

STUDENT: Everything's Apple.

INTERVIEWER: And how would you say you're doing so far in the course?

STUDENT: Fairly well. We have not really had an exam yet or a quiz. Obviously I'm going to be nervous because there are those problems that I'm going to be struggling with. But with content that I'm understanding I think I'm doing fairly well. Also because I'm in another class that's doing the same thing.

INTERVIEWER: I see. And are you able to apply the things—you said you covered momentum in the physics class this past week and that now you're starting momentum and impulse in the other class. Are you able to apply the physics that you're learning into that class?

STUDENT: Yes. Especially in bodily terms being able to use momentum in a track race. [00:37:04] You need to build this much speed and acceleration in order to go this far. Or like momentum with the high jumper. That's what we went over with yesterday I think. We watched a video of a high jumper and where their center of mass is and how that can make or break your jump.

INTERVIEWER: I see. Who do you talk about this course with?

STUDENT: One of my—like my engineering friends. I have had a couple of problems on (inaudible at 00:37:35) that I need help with—so he's also in calc-based physics and so—his is a lot harder than ours right now because I think they're moving at a faster pace—he's in engineering so he's more the techie stuff and we're more like the sciencie stuff. And he also has a class online with it. I don't really know how you do physics online (laughter).

INTERVIEWER: So it's an online physics class? [00:38:03]

STUDENT: Yeah.

INTERVIEWER: So I'm at the end of m y questions here. My last one here is, are there other things you should know—other things you think I should know about the course, about you? Anything you want to share?

STUDENT: I think it's a great course. Yeah. It's not a typical physics course and I like that about that. When you think of physics people are like, you either like it or you hate it. And this one is not happy medium but it's more towards the liking side (laughter), to more like I don't really want to go to physics but what if we learn something cool?

INTERVIEWER: What are you looking forward to learning?

STUDENT: Different things about the body. If I can apply every lesson we learn to something biological or anatomically based I think I would do very well in the course because I find myself very interested and very knowledgeable about that. [00:38:56]

INTERVIEWER: And are you going to be taking the second semester as well?

STUDENT: Yes.

INTERVIEWER: Awesome. Well cool. Do you mind if I reach out for an interview in the middle of the semester sometime?

STUDENT: Yeah, sure.

INTERVIEWER: If I think of stuff I'll send you an e-mail. Yeah. And I'll see you Tuesday I guess in class.

STUDENT: Alright. Thank you.

INTERVIEWER: Absolutely. Thank you Sam. What do you have next?

STUDENT: I'm going to crossfit soon.

INTERVIEWER: (Laughs). How many days a week do you say you work out?

STUDENT: Every day except for one day. I take a rest day.

INTERVIEWER: You take a rest day okay.

STUDENT: (inaudible at 00:39:31).

INTERVIEWER: I have to get back to the gym one day (laughs).

STUDENT: Thank you very much.

INTERVIEWER: Thank you Sam.

[End of Audio 00:39:39]

**END TRANSCRIPT**

# APPENDIX X

## TRANSCRIPT: SAM INTERVIEW 2

# TRANSCRIPT OF AUDIO FILE:

# LB273-11.16.17-SAM-INTERVIEW2

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*The text below represents a professional transcriptionist's understanding of the words spoken. No guarantee of complete accuracy is expressed or implied, particularly regarding spellings of names and other unfamiliar or hard-to-hear words and phrases. (ph) or (sp?) indicate phonetics or best guesses. To verify important quotes, we recommend listening to the corresponding audio. Timestamps throughout the transcript facilitate locating the desired quote.*

**BEGIN TRANSCRIPT:**

(pause)

INTERVIEWER: First things first; I'd like to get you paid (background noise) for your time. Here's another Amazon gift card.

RESPONDENT: Thank you.

INTERVIEWER: And if you could fill this out, (pause) (background noise) I'll get myself organized over here. (pause) I'll use my cell phone as a backup. (pause)

RESPONDENT: What's the date today?

INTERVIEWER: Today is -

RESPONDENT: Sixteenth?

INTERVIEWER: Yep. (pause) (background noise) Cool. It's kind of like the same caveats as we've had previously; your instructors don't know you're here. They won't see any of this stuff until a little after they're not your instructor anymore. So you don't have to worry about any of that. [00:01:08] (background noise)

Do you have any questions before we start?

RESPONDENT: Mm-mm.

INTERVIEWER: You seem like you're ready to rock and roll.

RESPONDENT: (chuckle)

INTERVIEWER: You're here right on time, even early. This interview is going to be a little different from the first one. What I'm interested in; I have a stack of stuff from class that you've already worked on. Just like the blanks from (inaudible at 00:01:33). And I just want to get your thoughts on them. You'll see me cycle through similar questions for each. We'll give it a shot.

First one; (background noise) (pause) here is this. The first thing I want to know is just your thoughts (background noise) of it. You could describe it to me in -

RESPONDENT: Was this the wound healing?

INTERVIEWER: Mm-mm. [00:02:07]

RESPONDENT: This was probably my favorite whatever we did; investigation or (chuckle) something we did in this course, as of now. I liked watching these microscopes and being able to tell if we would give a patient antibiotics based on this information. I mean granted, it's not like 100 percent, but it still was really cool to me. (pause) I don't what else. (chuckle)

INTERVIEWER: When you say it's not 100 percent, (overlapping voices) what do you mean?

RESPONDENT: I mean in my experience with diagnosing people, you would need more information than just this, I guess. But that could be different; I don't know.

INTERVIEWER: Got ya. (overlapping voices) And what experience have you had?

RESPONDENT: Like if you go into a doctor's office, they ask you about symptoms, and whether or not you're experiencing this or this, because you could be diagnosed with something totally different.

INTERVIEWER: You said this was your favorite. Can you tell me more about that? [00:03:19]

RESPONDENT: Yeah. Around last year, I had an incident when I was doing dishes, and I accidentally sliced my arm.

INTERVIEWER: Oh no!

RESPONDENT: I still have that scar; I got 13 stitches on it.

INTERVIEWER: Wow.

RESPONDENT: And being able to experience that, and this is kind of correlational. Watching this heal over time, and looking at that, it just makes me wonder what my cells were doing. (chuckle)

INTERVIEWER: That's really interesting. You know what a weird thing is, that you've mentioned that? I was washing the dishes, and I sliced my finger open and my scab is still - I had to do only two stitches. That was an intense experience. I can't imagine, that seems -

RESPONDENT: Yeah, it was very gory. (chuckle)

INTERVIEWER: And blood everywhere?

RESPONDENT: Yes.

INTERVIEWER: You come into physics class, and you sit down, and they gave you this activity. Take me through what you were thinking. [00:04:24]

RESPONDENT: For this one?

INTERVIEWER: Yeah.

RESPONDENT: (pause) It was so long ago. I walked in, like I do every day, just not knowing what we're going to do. And Vashti was like "Okay, we're going to look at how a wound heals." I was like, that's pretty cool. Then she explained the whole scenario, and what we have to go through, to determine if this patient needed antibiotics or not.

I thought it was just super eye-opening in how many different ways you can test whether or not a patient needs something, or doesn't need something or it has something. So it was just another way that opened my eyes.

INTERVIEWER: Got ya. What were the different ways that kind of opened your eyes?

RESPONDENT: Kind of like using Tracker, for instance, or even just looking at symptoms, or being able to look at a bacteria, and how its cells move with it or against it.

INTERVIEWER: Awesome. Why do you think the instructors have you do an activity like this? [00:05:36]

RESPONDENT: Since we're in a residential college of science, I think this course in doing this just connects the different sciences that we have to do for our majors. And since I'm going into a biological aspect, I think this related 100 percent to what I want to do. And now we're going into energy with chemistry, and I don't like chemistry, so, (chuckle) -

INTERVIEWER: You said this is related to what you want to do. Do you think having done an activity like this is helpful for what you want to do?

RESPONDENT: Yeah. I mean specifically to what I want to do? Maybe; maybe not. I don't really know what I want to do yet. But being able to have these resources to look back on is something that I think is very valuable.

INTERVIEWER: Why do you think it's valuable?

RESPONDENT: Because if I can get into like a lab with microscopes, or something, I could potentially do this in my future application. So the knowledge to be able to have, I guess is valuable. [00:06:47]

INTERVIEWER: Got ya. (pause) That' a really interesting thing you said there. You said that "If I was in a lab with a microscope, that I could do something like this." (pause) Do you think this activity has equipped you to answer questions outside the classroom?

RESPONDENT: Yeah. With the resources available to me, I think so; yes.

INTERVIEWER: Can you elaborate a little bit?

RESPONDENT: (pause) I guess if one of my friends were to come and ask me, "Do you think I should get stitches or not?" Well, I could ask how deep it is, and how fast does it look like it's healing. And if it's not that fast, then I could think back to the different cells; how they're working, and the bacteria in there; if it's going to get infected, whether or not they could need stitches or not. [00:07:52]

INTERVIEWER: Do you see connections between this activity in any of your other courses?

RESPONDENT: No. (chuckle)

INTERVIEWER: Did you imagine, when you signed up for a physics class, that you'd be doing activities like this?

RESPONDENT: Nope, not at all. I was thinking it was all like projectiles, and forces and stuff like that.

INTERVIEWER: How do you feel about it, that you do things like this?

RESPONDENT: I think it's really cool.

INTERVIEWER: Yeah?

RESPONDENT: Yeah. I have friends who are physics majors, and their advisors told them to take university physics, because their major is in physics, and not Lyman Briggs, because this doesn't really have relevance to their major.

INTERVIEWER: I see.

RESPONDENT: So I kind of like that difference, because I don't really want to sit in a physics lecture and learn about forces and vectors. (chuckle) I would rather learn about this. [00:08:47]

INTERVIEWER: Got ya. That makes sense. The next thing I've got for you (background noise) are these two worksheets. (pause) Here's one of them. (pause) And then, if I could find it, (pause) (background noise) I think one of them. Let me see if I can find the other one. (pause) (background noise) (coughing) What comes to mind?

RESPONDENT: I don't even remember doing this one.

INTERVIEWER: (chuckle) You might not have. I heard from other students, that there were some sections that didn't get to all the things. And there were some sections where they did get to all the things. (pause) (background noise)

RESPONDENT: I don't even know if we did this one. [00:09:59]

INTERVIEWER: No? That's okay. We could skip that one, if we didn't do it. Oh, this is going to drive me nuts. Alright, I got another copy. (background noise) (coughing) (pause) Always print multiple copies is what I learned, (chuckle) because you never know when you'll lose something.

RESPONDENT: Very true.

INTERVIEWER: (chuckle) (pause) (background noise) There it is. Did you do that one?

RESPONDENT: (pause)

INTERVIEWER: It had to do with like conviscous forces and paramecium.

RESPONDENT: (pause) (background noise) I don't remember doing this one either. (chuckle)

INTERVIEWER: Okay, fair enough.

RESPONDENT: I mean I worked, like my lab was with viscous forces, but - [00:11:02]

INTERVIEWER: Well, let me ask you a general question. When you see activities like this, right? I'm sure you've seen other activities where you had biological applications on a worksheet. What do you think about those? You might not have done these specific ones, but the idea of kind of in the physics class, you're doing problems where it's like a paramecium, or it's a protein unfolding.

RESPONDENT: I would much rather do these than work with atoms. So I guess my preference would be to work with this. However, I don't have the prior knowledge to understand what a lot of these microorganisms are. But I understand in this course, we don't really need that. If I get some knowledge like in these paragraphs, then I think it's a little bit easier to understand. And I'd much rather work with these than other things. [00:12:09]

INTERVIEWER: You said you would rather work with these than atoms.

RESPONDENT: In chemistry. (chuckle)

INTERVIEWER: Oh, in chemistry. I see. Why is that?

RESPONDENT: I don't like chemistry. (chuckle) I really don't.

INTERVIEWER: When did you first start thinking that?

RESPONDENT: When I took chemistry. (chuckle)

INTERVIEWER: Was this last year?

RESPONDENT: Yeah.

INTERVIEWER: I see. (overlapping voices)

RESPONDENT: It just doesn't make sense to me.

INTERVIEWER: It doesn't make sense to you.

RESPONDENT: Mm-mm.

INTERVIEWER: And does this stuff make sense to you?

RESPONDENT: Yes.

INTERVIEWER: Yeah?

RESPONDENT: Yeah.

INTERVIEWER: Why do you think that is?

RESPONDENT: I don't know. I mean both my parents are in the medical field, so I've heard stuff like this be brought up nonchalantly. So I guess it all just connects.

INTERVIEWER: Got ya. So you hear these words?

RESPONDENT: Sometimes. My dad is a physical therapist; my mom is a family physician. So my dad will talk a lot about the muscular system, because he specializes in rehabilitation. When he talks about like how bones and muscles interact, then he also has a master's in biochem, so he'll bring it to a miniscule like level, and talk about how like different proteins do this, this and this. I've heard that stuff growing up too. [00:13:22]

INTERVIEWER: I see. (background noise) Why do you think the instructors have you do these kind of biological application worksheets?

RESPONDENT: Because a lot of us are going into the medical field, and a lot of us probably want to be doctors, dealing with patients who have a sickness and they need to be put on antibiotics. And we need to know what's going on inside the cells, and the bacteria within the cells, or within the body to know what's going on. So knowing how these little organisms move is pretty helpful.

INTERVIEWER: Do you think it's been valuable to you, doing these kind of worksheets?

RESPONDENT: Personally, not really, because I want to work on a more macroscopic level. I'm between like three different occupations, whereas it's like neurology, which is not really macroscopic. But psychiatry and then orthopedic doctor. [00:14:28] (overlapping voices)

So I don't really know, I know I will have to know some stuff in the microscopic level, but not a lot. So I don't really think it's that relevant to me, but it's interesting.

INTERVIEWER: Why neurology? It seems like neurology and psychiatry go together a little bit. One is like the physical side, maybe one's the mental side. And the other one is kind of orthopedics, which is like bones. So tell me about why those three?

RESPONDENT: Well, I've had a history of helping people with depression and I was diagnosed myself. So I was always interested in how the brain worked. In sophomore year of high school, I decided I wanted to go into that; go into psychiatry. Because I wanted to be a doctor, but I also wanted to talk to people. (chuckle) So I just wanted the letters in my last name. [00:15:33] (chuckle)

My mom and dad were like, "Well, why do you want to go into psychiatry? You deal with crazy people." And they're kind of against it. So my dad brought up neurology, and he's like, "That's where the money is, (chuckle) then you don't have to deal with the crazy people."

Then I kind of thought about it, because you also get to learn how the brain works. Then, since I got super into fitness, shortly after that, my parents were like, "Oh, why not be an orthopedic doctor? They're where the money is too." (chuckle) So now I've just been like cycling through all of those. That's what's (overlapping voices) up in the air.

INTERVIEWER: Cool; that sounds cool. And you got some time to (overlapping voices) figure it all out, right?

RESPONDENT: Yeah.

INTERVIEWER: It seems like whatever path, there's going to be some money. (chuckle) So I think you'll be fine. Let's see (background noise) what the next thing is. Let's do these. (pause) (background noise) I think this is like a series of three things. The first one is this ligand and enzyme, and then we've got keeping things in a box, and then here, it's tracking proteins. [00:16:49]

First, I'd just like your thoughts on it.

RESPONDENT: I hate Python. (laughter) I find it interesting that we can make a computer program do that. But it just baffles me on how we have courses at MSU that specialize in training people how to use Python. So I don't know why we would bring it up to people who have no idea how to use it. Like I have a friend who's in a CSC, and he's struggling with Python.

I know we don't have to write codes, but we have to understand them, and it's a totally different language; I don't like it. Anyway, (chuckle) when we looked at ligand and enzyme, I thought it was pretty cool, because I like the 3D representations with the codes, because it gives me a better understanding on how they move in reality. It's better than just 2D arrows and nothing moving. That helped me a lot. (pause) (sigh) I don't really know what else. [00:17:57]

I didn't like the codes. (chuckle) But I liked seeing them move.

INTERVIEWER: You said "I don't know why they make us do some things that we have no experience in." But when you did like wound closure, you used Tracker, you said. And most people probably haven't used Tracker before. So what differentiates these two things? These two tools that you're using; the Python and the Tracker.

RESPONDENT: Tracker, we had like instructions on how to set everything up. And it was easy to just shift and click. I mean, and then there's Python; Python can be used for so many different things; coding computer programs, coding so many different things. And there's courses here designed to help engineers do that.

So I understand how we have to know the language a little bit. But introducing it to like a physics course, I don't know; a physics course that's focused on medical school majors, I don't know. I guess the way we learn it doesn't really set well with me. Understanding a language, I can totally get. [00:19:16]

But how this line would do this, this and this, or giving us a code to look at representations of things, but being able to alter the code is just, I don't know, I don't really understand why, because we're not engineers. (chuckle) I don't want to deal with that stuff.

INTERVIEWER: Got ya. Why are they making you do this? Why do you think the instructors are having you work on these activities?

RESPONDENT: Probably to have us have a broader understanding of different areas of study, I guess. I mean I'm not saying like I wish we didn't, because it pretty cool. And sometimes I can help my engineer friend and sometimes he can help me. So I don't really have anything against it, nor do I have anything for it. I'm just neutral.

INTERVIEWER: I see. Take me into some of the conversations you've had with your engineering friend, where you've kind of described yourself as not having experience doing this, and they're learning in a course designed to teach Python and you're helping him work on it. [00:20:22]

RESPONDENT: Well, since now, I have knowledge in reading a code, I can find his errors. And there's this thing that engineers do, that he told me; there's this rubber ducky, and you're supposed to read the code to the rubber ducky to find your errors. Because once you tell someone out loud, you find your errors.

INTERVIEWER: Interesting.

RESPONDENT: So if his codes don't go through, then I can have some input like, "Hey, you're missing this here. This isn't indented; this should be in the loop." Stuff like that. So when we've had (inaudible at 00:20:55) problems as well, he's helped me do code, and when I can't get correct values, he'll tell me, "Oh, you need to indent here, or you need to finish this here."

INTERVIEWER: Got ya. How does it feel that you're able to find his mistakes?

RESPONDENT: Pretty cool. (chuckle) It's made me think, oh maybe I want to be an engineer. But I can't be an engineer; I don't like calculus. (chuckle)

INTERVIEWER: Were you proud? [00:21:24]

RESPONDENT: Kind of. Yeah, being able to have knowledge in different areas of study, other than my own.

INTERVIEWER: Is it something that's new to you, that you're able to help kind of troubleshoot someone else in a different discipline? Or is something that happened recently?

RESPONDENT: I wouldn't say it's new, but I wouldn't say it's old. Because I've had, right now, it's been about like maybe three and a half, almost four years that I've gotten into fitness, and health and stuff. And I've been putting this knowledge into people around me. So I wouldn't say it's relatively new, but it's not old. Because I've been asked questions about different fitness things, so I can instill more knowledge in other people.

INTERVIEWER: Would you say it's been valuable that you've done this activity? These coding kind of series of activities? [00:22:22]

RESPONDENT: Yeah, kind of. I mean if I'm ever brought in a situation, where the machine doesn't work, I can just pop on my head, hey it's probably something wrong with the coding. And then people can come after that. But, (chuckle) I mean, I really don't know when I'm going to use this for the rest of my life, but like having the knowledge could bring conclusions that I would never have prior.

INTERVIEWER: Do you that affects the confidence you have?

RESPONDENT: Yeah, a little bit. Because I have a few engineer friends. And so being able to understand the lingo is kind of confidence boosting.

INTERVIEWER: Is there an example of a moment where that's happened and you felt confident?

RESPONDENT: When (sigh) my friend was having trouble with an assignment, and he's like, "Well, I've put this in this loop, and Y loop, bla, bla, bla." And I'm like, "Hey, I understand that." (chuckle) [00:23:22]

INTERVIEWER: Were they surprised?

RESPONDENT: No, because they know I do Python.

INTERVIEWER: Got ya. You said that you don't think, or you're not sure if you'll ever need this in your future. Do you think when you're doing neurology, or psychiatry, or orthopedics, like coding is ever going to come into play?

RESPONDENT: Probably not.

INTERVIEWER: Probably not?

RESPONDENT: If anything, it might come into neurology, but I don't think so.

INTERVIEWER: What would it look like if it came into neurology?

RESPONDENT: I don't know, probably looking at how neurons fire. And we have a lot of machines to be able to see that. So I guess the coding within the machine, or even just looking at a visual representation of neurons firing, neurons not firing, to produce some mental disability; being able to visualize that within a code. [00:24:27]

INTERVIEWER: What did you think about the connection to diffusion? (pause) I think this was like a YouTube video.

RESPONDENT: I never really liked diffusion, (chuckle) so – I'm not a big microscopic person, even though I want to go into something involving the brain. Like with the rest of the body, I don't really care for microscopic stuff. (chuckle) So I didn't really have major like, oh my gosh moments. (chuckle)

INTERVIEWER: Do you think coding these things helped you understand diffusion more?

RESPONDENT: (pause) Yeah, because we had a lab on it, so being able to talk through it with my lab groups was kind of helpful.

INTERVIEWER: Take me into those conversations; what happened?

RESPONDENT: Well, my previous lab group, not the one I have now, but the one I had before, I really liked, because all of us I think, had knowledge in three different aspects. So when we came together, we were like super smart. Because I think one of them knew chemistry pretty well, and that's where I think diffusion has pretty big prevalence. [00:25:45]

I know biology fairly well, and so when we all came together, and just talked through the process of diffusion, and how it connected to whatever we were working on, it helped me have a greater understanding of it in a broader aspect, and not just in this one area of study.

INTERVIEWER: Are you taking any other courses where this coding thing might come up?

RESPONDENT: No, probably not. Or, no.

INTERVIEWER: Awesome. The next thing I have is actually a big pack. (background noise) (pause) I think I stole this from one of the sections. (pause) (background noise)

RESPONDENT: I really like these.

INTERVIEWER: (chuckle) [00:26:41]

RESPONDENT: Because they dumb everything down to something where I can understand. (chuckle) Because when I think, I think like this. I don't think in different colors, but I think this, and then I'm drawn here, and then I think this, and then, it's all my thoughts put onto paper. And I really like when we do these; I wish Vashti would go slower when doing this, because I can never write everything down. So I just don't write anything down, and then I just listen and then I look back and de-toil at these things.

Because if I keep writing, I'm not going to pay attention to what she says. So before exams, I'll look at the consensus boards, and I'll write all of them down in my notebook, just so I understand it. Because I learn best when I write it out. [00:27:39]

So when she does these, I really think it's very beneficial for me, because I don't like words; I like symbols. When everything gets put into symbols, I can read it better.

INTERVIEWER: I see. (pause) Why do you think Vashti does this?

RESPONDENT: For people like me, who don't learn well when they just have words on a paper, like this does this, and this does this. But when you put it in like an equation, or just in graphs, and diagrams, it simplifies the meaning down to the essentials.

INTERVIEWER: When did you first start thinking that you liked symbols more than words?

RESPONDENT: Probably when I took physics in high school. And even in calculus, because in some calculus problems, you have to find different areas. So I pick out the words that mean the most, and I'll draw them out. I met with Vashti after the first exam, to discuss my misconceptions. And we came to the conclusion that I'm a terrible (chuckle) test taker, and I make the stupidest math errors. I always have. [00:29:00]

So when I can take words from the question, and put them into diagrams, and pictures, that helps me understand it better. This, I think, helps me learn more than anything else in the course. Because the investigations I understand, are applications of how concepts work. But being able to visualize it in this sort of way is my favorite.

INTERVIEWER: So you'd say it's valuable to you?

RESPONDENT: Yes, very much so. I wish a lot of professors did this.

INTERVIEWER: Have you ever seen other professors do something like this?

RESPONDENT: Not really. I mean they'll do it on a whiteboard, but a lot of professors will just have words. Like when I took organic chemistry over the summer, that's all symbols. So being able to look at, I don't know, I do best with arrows; arrows show me what comes next. And that's what I like. [00:29:59] (pause) (background noise)

I guess with enforced (inaudible at 00:30:13) diagrams, I like these, because it takes the picture out of the aspect, and it puts arrows there. So I can see where everything is going. Because you can't really see where the forces are here, but I can see them here. So that helps me a lot.

INTERVIEWER: You said that this is basically how you think. When did you start developing this way of thinking?

RESPONDENT: Since my parents have been in the medical field, they've also had to take multiple math classes, and science classes. And everything in math and science, in my opinion, is all representations. So when I would ask help for like a math course, my dad would draw out equations, and would draw out graphs, just to visually represent what this question is asking. [00:31:09]

And I've found that throughout my schooling, I've been best at math, but I don't really like math, but I can do it. So putting everything in terms of like the mathematical language makes sense to me. I don't like writing paragraphs; I don't like writing sentences; I prefer just doing this equals this, and this is this, when you put it in this aspect.

INTERVIEWER: Got ya. It's my understanding that these are based on what students bring up in the section. So there might be like two different versions, one for each section. (pause) Have you ever gotten your information put on the board?

RESPONDENT: I think so. (pause) One of them; I think it was this one; this is I think, a different section than mine. But with this problem, my group, I think, had the most, the cleanest data. So I think she had our numbers in there. [00:32:22]

INTERVIEWER: Your group had the cleanest data; how did that feel?

RESPONDENT: Pretty good. (chuckle) (pause)

INTERVIEWER: What do you think the value is in having your group's data represented, and now the whole class is using that to study? (overlapping voices)

RESPONDENT: I think it's valuable because with my data, I'd know how I got there. Whereas if someone else, if she had someone else's data on here, I would probably have to crunch the numbers, to see how she got there. But I already know how it on there, and I can see the process better.

INTERVIEWER: Were you or your group members proud that “Wow, we got our data on there.”

RESPONDENT: (pause) Yeah, I guess so. (chuckle) I’m just kind of indifferent.

INTERVIEWER: Why are you indifferent? [00:33:17]

RESPONDENT: I don’t know. I mean it’s not like a huge feat for me, it’s just we do it and we move on, I guess, as long as I understand it, (overlapping voices) I’m pretty content.

INTERVIEWER: I see. Is it basically normal for you? You’re like, “Oh yeah.”

RESPONDENT: Yeah, my biggest concern is that I understand it, whether or not it’s my content or not. This course is pretty accelerated, so I want to be able to understand the material before we keep going.

INTERVIEWER: Got ya. Do you think writing things out like this is going to help you when you’re a neurologist, psychiatrist or (pause) (overlapping voices)

RESPONDENT: Orthopedic.

INTERVIEWER: Orthopedics. (chuckle)

RESPONDENT: Yes, because from my experience, doctors want it sweet and to the point. They don’t care about the paragraphs, and the letters and they just want, “Okay, what does this mean?” “This means this, this, this.” “Okay. I’ll take it.” But if I have to read a documentary about all of this stuff, when it could just be summed up in two lines, I don’t want to read all of that. (chuckle) I have better things to do. [00:34:33]

So being able to represent like in graphs, being able to represent a trend over time is way more valuable to me than saying, “Oh, this happened at this time and this happened at this time. So we can conclude that this happened all together.” I mean I can read it from a graph.

INTERVIEWER: That’s great. The last thing (background noise) is this investigation. (pause)

RESPONDENT: Was this momentum?

INTERVIEWER: This is the SUV/car collision one. I think it might’ve been the first one you did. Where there’s like statement that a friend makes. (pause)

RESPONDENT: Okey-dokey. I think this was like conservation of momentum, maybe.

INTERVIEWER: Mm-mm. Potentially. [00:35:36]

RESPONDENT: I don't like momentum either. (chuckle) I understand it's a very crucial concept to understand. But I just think it's so confusing, because you have to have the same momentum that you started with the same momentum that you finished with. And I get it through energy, sort of, but not momentum, because there's a large equation within the tiny equation.

INTERVIEWER: Can you explain that? (overlapping voices) Can you -

RESPONDENT: Like within the mv, there's just so much more. And you can't just have momentum and mv. From what this class has taught me, there's so much more between the two objects, and then how the momentum is going this way, and this way or this way. I don't know, it's just a mess for me. And a side note; I really like how professors make situations in real life, because I can visualize it better. [00:36:37]

And it kind of makes it fun, because my engineer friend is in calc III right now, and he has a professor who's pretty comical. In one of his questions, it was talking about like, "Oh your friend says this, this and this. How can you prove him wrong and tell him to shut up?" (chuckle) And that makes it funny, so then you kind of want to figure out what to do.

So the SUV and the car made it more real to me, to visualize how these things were working, where there's just a box and a box.

INTERVIEWER: What do you think it is about the SUV and a car versus a box and a box? I mean we see boxes (overlapping voices) every day.

RESPONDENT: Yeah, but we also see collisions between cars more often than boxes. And I guess if you were thinking in a broader aspect, you can figure out how to prevent that from happening, because that could hurt people. So finding these momentums could, I don't know, decrease the potential of these cars crashing. I don't know; if something were to change. [00:37:51]

INTERVIEWER: You said that you like when your classes have a connection to the real world. Were their other examples from this course where that's happened for you?

RESPONDENT: (pause) The wound healing. And then what else? The springs. I really wouldn't say that had a direct correlation to what happens in the real world. But when you look at toys, and like they have springs in them. I don't know, that's what I think of (chuckle) when we work with the springs and like the different forces. If you were to pull a slinky apart, like the different forces you have to apply on each side. It brings up different aspects of real life to me.

INTERVIEWER: Got ya. Now to flip it on you, when you're out in the real world, do you ever find yourself thinking about the physics you learned in physics class? [00:38:52]

RESPONDENT: Yes, actually today, I was thinking; I was on my way biking to my 8 am class, and I don't know why it just popped into my head. But I was on my highest gear, and I was like, what's the force I'm exerting on this peddle? Like what is it? (chuckle) And so it just kind of popped into my head, because it's not the force on the peddle, it's like the force in my muscles. And how do my muscles get energy to produce that amount of force? Well, when it's in the food that I eat, and then where does that energy come from? It's just cycles. So sometimes it pops into my head, yeah.

INTERVIEWER: Awesome. Were there any other examples that come to mind?

RESPONDENT: With my engineer friend, he brings it up a lot. And I forgot, oh, we were talking about how the wheels to wheels law, where you're supposed to be biking with the traffic. In my opinion, I think it should be opposite, because of safety. And so we had this debate, and he's like, "Well, you're more safe if both momentums are going the same direction, as opposed to a head-on collision." [00:40:10]

And then I brought up the point where you have time to react when you're going the opposite way, whereas, if they just come up and clip, you don't have time to react because you don't even see them. So he brought up a bunch of physics, and said, you know the amount of force exerted by this car, and the force you come will just go opposite, and the car wins because it's bigger.

Then he said, well on the other side, if you're going with it, your forces combine. So we just had the large debate and brought physics into it.

INTERVIEWER: (chuckle) Sounds like it got heated.

RESPONDENT: It did. (chuckle)

INTERVIEWER: Well, that's funny. Why do you think the professors have you do these investigations?

RESPONDENT: Probably to, instead of just saying this is a rule in physics that you have to follow, we are finding how this rule comes to play, and (background noise) what it represents and why it's a rule. So instead of just getting it and using it, it's implementing how it works. [00:41:29]

INTERVIEWER: So doing these investigations, I guess this one was with the ISLE labs, do you think that that's equipped you to like answer questions outside of class?

RESPONDENT: Not really. I'm not a fan of the investigations. I like the purpose of them, because it digs deeper into what we're learning. But I don't really feel like they help me with the concept of lab, because I'm a person who just looks at representations and knows them and then applies them.

I don't really care for the why, especially with what I'm going into, even though the why is pretty prevalent, this kind of like, I don't know. It's hard to explain, but I'm not a fan of knowing why over a long period of time. Because we take a little bit to do these investigations and talk about them. And I like their purpose, like I said; I just don't like spending a bunch of time doing it. I would just like to know why, that's all. [00:42:39]

INTERVIEWER: Tell me what's different about these investigations and then the wound healing. Because in the wound healing, I think you said that it was interesting to see, imagining this cut healing on your hand, and now you're thinking about what's happening there. It's seems to me that like a similar vein to like the why of why this happens. What's different about them, where you like one and the other one doesn't really kind of like jive with you?

RESPONDENT: I guess it must just be like the context and what these things are, because I don't care for ISLE labs. (chuckle) I mean I guess if it was like collisions between cells, I really think maybe it would be more interesting. But just having it objects doesn't really tickle my fancy. (chuckle)

INTERVIEWER: Got ya. [00:43:34]

RESPONDENT: That might be it; I don't really know.

INTERVIEWER: When you say objects, you mean like -

RESPONDENT: Like ISLE labs.

INTERVIEWER: Oh, okay. So you want things that are like cells, and not like the ISLE lab?

RESPONDENT: Yeah, I would say so, because then it like relates to something that I have interest in. Whereas I could relate this into something, but I would never like think about that. I would just be like, oh this is what happened. But when we look at it in a micro or macroscopic level within something I'm interested in, then I'll have a more understanding of it.

INTERVIEWER: (pause) Do you think you'll need to think about these kinds of investigations when you're doing your future career?

RESPONDENT: Probably; maybe not in my career. I mean collisions – well, maybe so, because I'm going to be an orthopedic doctor, and someone tore their ACL because they were playing soccer, and got hit, I mean then I would have to understand collisions and stuff. I wouldn't really have to go in-depth on the forces; I would just have to know like the direction in which it got hit, where it's torn, what actually happened. I wouldn't have to go super in-depth, but I think I would use them. [00:44:55]

INTERVIEWER: (pause) How do you think you're doing in the class so far?

RESPONDENT: I think I could do better, but I am taking 16 credits. (whispering) I know, and I have a job. (chuckle) And I'm trying to get my personal trainer certification, so that's another class on top of the five that I have. (sigh) So I'm a pretty busy bee. (pause) So I probably could spend more time on this course, but it will sacrifice my other courses. If I can just get an even good grade across the board, I'll be happy.

INTERVIEWER: I see. And how do you make that decision, that strategic decision of which course to pay attention to, and which course not to pay attention as much?

RESPONDENT: I talk to my mom. (chuckle) I actually brought this up to her the other day; she came up to have dinner with me. And I had this agriculture class that I just needed for my major, because my major is nutritional sciences; I really would never ever take that class if I had to; it's really boring; it's basically online; it's like two credits, and I could 4-point that class if I really, really, really tried. But that's sacrificing time that I could be spending on courses that actually apply to my future career. [00:46:16]

So I'm happy with a 3.5 in that class, as well as getting 3.5s across the board in my other classes. Rather than getting a 4-point in that class, and like 2.5s and 3.0s in my other classes. Because the time that I spend on something I don't even care about is time that I'm wasting for something that I do care about.

I asked my mom, and I was like "Would it be better to strive for the 4-points and let my other grades suffer? Or get even grades across the board?" And she said, "Even grades across the board." Because when are you going to use agriculture? (pause) I don't really, I mean, I care, but I don't really care. (chuckle)

INTERVIEWER: Can you give me some examples of courses that fit into the ones you care about and the bin of not caring about? [00:47:09]

RESPONDENT: Agriculture, I don't really care about; organic chemistry, I'm taking orgo lab right now. I don't think I'm going to really use that in my future, so I would throw that out too. But things like biology and physics, they're my two toughest courses right now, and I would probably use, this physics especially, I would use in my future, because it relates to biological aspects. I have a kinesiology course too, that I would use in my future, if I were to be an orthopedic doctor; especially as a personal trainer, being able to know how the body moves, which planes it moves in and what these movements are called is beneficial to me.

So out of my five courses, I'm really (sigh) cautious about three of them, whereas the two, I could or couldn't 4-point and do well in. But I don't want to focus too much on that, because I have other grades to uphold. [00:48:08]

INTERVIEWER: Got ya. Do you ever talk to your mom about this physics class?

RESPONDENT: Yeah actually, I told my parents about this wound healing thing, and they were pretty like, they're like, "Wow, I never did that in physics." (chuckle) And I was like "Yeah, this physics class is pretty cool." I would rather take this physics class than any other physics class.

INTERVIEWER: Really?

RESPONDENT: Yeah, because it has relevance to what I want to do.

INTERVIEWER: I see.

RESPONDENT: Whereas looking at vectors every day is not something I want to do.

INTERVIEWER: Were your parents excited that you were getting a chance to do this in the physics class?

RESPONDENT: I think so, because then it just brings my potential up for future things.

INTERVIEWER: Are there other people you talk about the course with?

RESPONDENT: Yeah. I talk about it with my friends, and like what we did. I also complain about how long it is. (chuckle)

INTERVIEWER: It is three hours now. [00:49:08]

RESPONDENT: It's very long. Although I had an orgo class in the summer that was four hours, so it was rough. But actually, those three hours goes by fairly fast. The first two hours go by faster than the last hour. But it goes by fairly fast, because I get involved in it. And like in this class, in my opinion, if you are not involved, you won't learn anything.

So for me at least, if you miss a day, (pause) I'm sorry, (chuckle) you're screwed. Because we do so much, and you have to be present, and you have to be active and listening to understand these concepts in full detail, to get a good grade in this course. (pause)

INTERVIEWER: That's a very sophisticated view on classes. When did you come to that conclusion?

RESPONDENT: When I came to college. (chuckle) Because in high school, I was that 4.0 student; I was number four in the class (overlapping voices) and I got like everything correct. And now it's just (pause) (sigh) now I have to pay attention, and I actually have to do stuff. (chuckle) Whereas, I can get away with it in high school, but I can't now. [00:50:26]

INTERVIEWER: I see. Well, Sam, it's been a great chat, as always. Are there any other things you think I should know about the course? About you? Anything you want to share?

RESPONDENT: Not that I know of, no.

INTERVIEWER: Okay, if not, you're free.

RESPONDENT: Awesome.

INTERVIEWER: You're released.

RESPONDENT: (chuckle) (overlapping voices) Thank you very much.

INTERVIEWER: Enjoy the gift card.

RESPONDENT: Oh I will. (chuckle)

INTERVIEWER: Spend it towards something fun. (background noise) (pause) Where are you off to next? Or were you just waiting for physics?

RESPONDENT: (pause) I'll probably go relax for a minute. (chuckle)

INTERVIEWER: Sounds like a plan.

RESPONDENT: Alrighty, see you later.

INTERVIEWER: Thanks again. (background noise) [00:51:06]

**END TRANSCRIPT**

**BIBLIOGRAPHY**

## BIBLIOGRAPHY


[1] AAMC-HHMI, *Scientific Foundations for Future Physicians*, 2009.

[2] N. R. Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, English, Washington, DC, 2012.

[3] H. Quinn, H. Schweingruber, and T. Keller, Eds., *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, Washington, D.C., 2011.

[4] E. F. Redish, J. M. Saul, and R. N. Steinberg, "Student expectations in introductory physics," *American Journal of Physics*, vol. 66, no. 3, pp. 212–224, 1998.

[5] A. Elby, J. Frederiksen, C. Schwarz, and B. White, *Epistemological Beliefs Assessment For Physical Sciences (EBAPS). Retrieved December 15, 2013*, 1998.

[6] E. Brewe, L. Kramer, and G. O'Brien, "Modeling instruction: Positive attitudinal shifts in introductory physics measured with CLASS," *Physical Review Special Topics - Physics Education Research*, vol. 5, no. 1, pp. 1–5, 2009.

[7] E. Brewe, A. Traxler, J. De La Garza, and L. H. Kramer, "Extending positive CLASS results across multiple instructors and multiple classes of Modeling Instruction," *Physical Review Special Topics - Physics Education Research*, vol. 9, no. 2, pp. 1–10, 2013.

[8] A. Madsen, S. B. McKagan, and E. C. Sayre, "How physics instruction impacts students' beliefs about learning physics: A meta-analysis of 24 studies," *Physical Review Special Topics - Physics Education Research*, vol. 11, no. 1, pp. 1–19, 2015.

[9] C. H. Crouch, P. Wisittanawat, M. Cai, and K. A. Renninger, "Life science students' attitudes, interest, and performance in introductory physics for life sciences : An exploratory study," *Physical Review Physics Education Research*, vol. 14, no. 1, 2018.

[10] B. D. Geller, C. Turpen, and C. H. Crouch, "Sources of student engagement in Introductory Physics for Life Sciences," *Physical Review Physics Education Research*, vol. 14, no. 1, 2018.

[11] P. Mulvey, E. Dodge, and S. Nicholson, *Enrollment and Degrees Report*, 1997.

[12] A. Nair, P. W. Irving, and V. Sawtelle, "Using disciplinary perspectives to refine conceptions of the "real world"," in *2017 Physics Education Research Conference Proceedings*, 2018, pp. 268–271.

[13] A. Nair and V. Sawtelle, "An uncommon case of relevance through everyday experiences," in *2018 Physics Education Research Conference Proceedings*, 2018, pp. 1–4.

[14] L. J. A. Elliott, *Intercontextuality, Framing, and Transfer*, 2017.

[15] A. Nair and V. Sawtelle, *Operationalizing relevance in physics education: using a systems view to expand our conception of making physics relevant*, 2018.

[16] A. Bookstein, "Relevance," *Journal of the American Society for Information Science*, vol. 30, no. 5, pp. 269–273, Sep. 2007.

[17] D. P. Newton, "Relevance and science education," *Educational Philosophy and Theory*, vol. 20, no. 2, pp. 7–12, 1988.

[18] M. Stuckey, A. Hofstein, R. Mamlok-Naaman, and I. Eilks, "The meaning of 'relevance' in science education and its implications for the science curriculum," *Studies in Science Education*, vol. 49, no. 1, pp. 1–34, 2013.

[19] W. K. Adams, K. K. Perkins, N. S. Podolefsky, M. Dubson, N. D. Finkelstein, and C. E. Wieman, "New instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey," *Physical Review Special Topics - Physics Education Research*, vol. 2, no. 1, pp. 1–14, 2006.

[20] I. Halloun and D. Hestenes, "Interpreting VASS Dimensions and Profiles for Physics Students," *Science & Education*, vol. 7, no. 6, pp. 553–577, 1998.

[21] M. Rokeach, *Beliefs, attitudes, and values: a theory of organization and change*, ser. The Jossey-Bass behavioral science series. Jossey-Bass, 1968.

[22] U. Bronfenbrenner, *The Ecology of Human Develpment. Experiments by nature and design*. Harvard University Press, 1979, p. 330.

[23] K. Cummings, "The Rensselaer studio model for learning and teaching: What have we learned," in *Proceedings of the National Research Council's Workshop Linking Evidence to Promising Practices in STEM Undergraduate Education*, 2008.

[24] *Modeling Instruction at Florida International University*, https://perg.fiu.edu/resources/modeling-instruction.

[25] *Studio Physics at Colorado School of Mines*, https://physics.mines.edu/undergraduate-program/education-development.

[26] *SCALE-UP at North Carolina State University*, http://scaleup.ncsu.edu.

[27] *TEAL at Massachusetts Institute of Technology*, http://icampus.mit.edu/projects/teal.

[28] R. Yin, *Case study research: Design and methods*, 2009.

[29] J. A. Maxwell, *Qualitative research: An interactive approach*. SAGE Publications, 2005, p. 220.

[30] P. Bell, "On the Theoretical Breadth of Design-Based Research in Education On the Theoretical Breadth of Design-Based Research in Education," *Educational Psychologist*, vol. 39, no. 4, pp. 37–41, 2010.

[31] A. Nair and V. Sawtelle, "Real-time Visualization of Equipotential Lines Using the IOLab," *The Physics Teacher*, vol. 56, no. 8, pp. 512–514, 2018.

[32] *MAXQDA: Qualitative Data Analysis Software*, https://www.maxqda.com.

[33] J. Saldana and J. Saldaña, *The Coding Manual for Qualitative Researchers*, 2009.

[34] *Diversity at MSU 2016-17 Student and Workforce Data Report*, 2016.

[35] E. F. Redish, C. Bauer, K. L. Carleton, T. J. Cooke, M. Cooper, C. H. Crouch, B. W. Dreyfus, B. D. Geller, J. Giannini, J. S. Gouvea, M. W. Klymkowsky, W. Losert, K. Moore, J. Presson, V. Sawtelle, K. V. Thompson, C. Turpen, and R. K. P. Zia, "NEXUS/Physics: An interdisciplinary repurposing of physics for biologists," *American Journal of Physics*, vol. 82, no. 5, pp. 368–377, 2014.

[36] V. Sawtelle and C. Turpen, "Leveraging a relationship with biology to expand a relationship with physics," *Physical Review Physics Education Research*, vol. 12, no. 1, pp. 1–19, 2016.

[37] C. Wieman and K. Perkins, "Transforming Physics Education," *Physics Today*, vol. 58, no. 11, p. 36, 2005.

[38] D. Bennett, L. Roberts, and C. Creagh, "Exploring possible selves in a first-year physics foundation class: Engaging students by establishing relevance," *Physical Review Physics Education Research*, vol. 12, no. 1, pp. 1–11, 2016.

[39] E. Brewe, V. Sawtelle, L. H. Kramer, G. E. O'Brien, I. Rodriguez, and P. Pamelá, "Toward equity through participation in Modeling Instruction in introductory university physics," *Physical Review Special Topics - Physics Education Research*, vol. 6, no. 1, pp. 1–12, 2010.

[40] E. Brewe, "Modeling theory applied: Modeling Instruction in introductory physics," *American Journal of Physics*, vol. 76, no. 12, pp. 1155–1160, 2008.

[41] K. Moore, J. Giannini, and W. Losert, "Toward better physics labs for future biologists," *American Journal of Physics*, vol. 82, no. 5, pp. 387–393, 2014.

[42] P. M. Sadler and R. H. Tai, "Success in college physics: The role of high school preparation," *Science Education*, vol. 85, pp. 111–136, 2001.

[43] G. Kortemeyer, "The Challenge of Teaching Introductory Physics to Premedical Students," *The Physics Teacher*, vol. 45, no. 9, p. 552, 2007.

[44] R. F. Moll and M. Milner-Bolotin, "The effect of interactive lecture experiments on student academic achievement and attitudes towards physics," *Canadian Journal of Physics*, vol. 87, no. 8, pp. 917–924, 2009.

[45] K. K. Perkins, M. M. Gratny, W. K. Adams, N. D. Finkelstein, and C. E. Wieman, "Towards characterizing the relationship between students' self-reported interest in and their surveyed beliefs about physics," *Physics*, vol. 818, pp. 137–140, 2006.

[46] M. J. Cahill, K. M. Hynes, R. Trousil, L. A. Brooks, M. A. McDaniel, M. Repice, J. Zhao, and R. F. Frey, "Multiyear, multi-instructor evaluation of a large-class interactive-engagement curriculum," *Physical Review Special Topics - Physics Education Research*, vol. 10, no. 2, pp. 1–19, 2014.

[47] K. A. Slaughter, S. P. Bates, and R. K. Galloway, "A longitudinal study of the development of attitudes and beliefs towards physics," *AIP Conference Proceedings*, vol. 1413, pp. 359–362, 2012.

[48] J. Marx, S. Mian, and V. Pagonis, "Attitudes of Undergraduate General Science Students Toward Learning Science and the Nature of Science," *Physics Education Research Conference Proceedings*, vol. 790, pp. 125–128, 2004.

[49] A. Elby, "Helping physics students learn how to learn," *American Journal of Physics*, vol. 69, no. S1, S54–S64, 2001.

[50] S. P. Harter, "Psychological relevance and information science," *Journal of the American Society for Information Science*, vol. 43, no. 9, pp. 602–615, Oct. 1992.

[51] E. Etkina and A. Van Heuvelen, "Investigative Science Learning Environment: Using the processes of science and cognitive strategies to learn physics," *Proceedings of the 2001 Physics Education Research Conference*, pp. 17–20, 2001.

[52] M. Şahin, "Exploring university students' expectations and beliefs about physics and physics learning in a problem-based learning context," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 5, no. 4, pp. 321–333, 2009.

[53] C. H. Crouch and E. Mazur, "Peer Instruction: Ten years of experience and results," *American Journal of Physics*, vol. 69, no. 9, pp. 970–977, 2001.

[54] J. van Aalst and T. Key, "Preprofessional students' beliefs about learning physics," *Canadian Journal of Physics*, vol. 78, no. 1, pp. 73–78, 2000.

[55] S. Sharma, P. K. Ahluwalia, and S. K. Sharma, "Students' epistemological beliefs, expectations, and learning physics: An international comparison," *Physical Review Special Topics - Physics Education Research*, vol. 9, no. 1, pp. 1–13, 2013.

[56] U. Wutchana and N. Emarat, "Student effort expectations and their learning in first-year introductory physics: A case study in Thailand," *Physical Review Special Topics - Physics Education Research*, vol. 7, no. 1, pp. 1–15, 2011.

[57] P. Zhang, L. Ding, and E. Mazur, "Peer Instruction in introductory physics: A method to bring about positive changes in students' attitudes and beliefs," *Physical Review Physics Education Research*, vol. 13, no. 1, pp. 1–9, 2017.

[58] J. de la Garza and H. Alarcon, "Assessing Students' Attitudes In A College Physics Course In Mexico," *AIP Conf. Proc.*, vol. 1289, pp. 129–132, 2010.

[59] K. E. Gray, W. K. Adams, C. E. Wieman, and K. K. Perkins, "Students know what physicists believe, but they don't agree: A study using the CLASS survey," *Physical Review Special Topics - Physics Education Research*, vol. 4, no. 2, pp. 1–10, 2008.

[60] J. L. Dienstag, "Relevance and Rigor in Premedical Education," *The New England Journal of Medicine*, vol. 359, no. 3, pp. 221–224, 2008.

[61] L. Eyal and R. Cohen, "Preparation for clinical practice: A survey of medical students' and graduates' perceptions of the effectiveness of their medical school curriculum," *Medical Teacher*, vol. 28, no. 6, 2006.

[62] R. Pabst and H. J. Rothkotter, "Retrospective evaluation of undergraduate medical education by doctors at the end of their residency time in hospitals: Consequences for the anatomical curriculum," *Anatomical Record*, vol. 249, no. 4, pp. 431–434, 1997.

[63] D. Muller and N. Kase, "Challenging traditional premedical requirements as predictors of success in medical school: The mount sinai school of medicine humanities and medicine program," *Academic Medicine*, vol. 85, no. 8, pp. 1378–1383, 2010.

[64] J. N. Hall, N. Woods, and M. D. Hanson, "Is social sciences and humanities (SSH) premedical education marginalized in the medical school admission process? A review and contextualization of the literature," *Academic Medicine*, vol. 89, no. 7, pp. 1075–1086, 2014.

[65] J. Leach and P. Scott, "Individual and Sociocultural Views of Learning in Science Education," *Science & Education*, vol. 12, no. 1, pp. 91–113, 2003.

[66] B. Rogoff, J. Baker-Sennett, P. Lacasa, and D. Goldsmith, "Development through participation in sociocultural activity," *New Directions for Child and Adolescent Development*, vol. 1995, no. 67, pp. 45–65, 1995.

[67] J. G. Greeno, A. M. Collins, and L. B. Resnick, "Cognition and learning.," in *Handbook of educational psychology.* London, England: Prentice Hall International, 1996, pp. 15–46.

[68] W. Sandoval, "Conjecture mapping: An approach to systematic educational design research," *Journal of the Learning Sciences*, vol. 23, no. August 2014, pp. 18–36, 2014.

[69] J. Watkins, J. E. Coffey, E. F. Redish, and T. J. Cooke, "Disciplinary authenticity: Enriching the reforms of introductory physics courses for life-science students," *Physical Review Special Topics - Physics Education Research*, vol. 8, no. 1, pp. 1–17, 2012.

[70] E. F. Redish and T. J. Cooke, "Learning each other's ropes: Negotiating interdisciplinary authenticity," *CBE Life Sciences Education*, vol. 12, no. 2, pp. 175–186, 2013.

[71] E. Brewe and V. Sawtelle, "Modeling Instruction for University Physics: Examining the Theory in Practice," *European Journal of Physics - Accepted*, vol. 39, no. 5, p. 054 001, 2018.

[72] S. Traweek, *Beamtimes and lifetimes*. Harvard University Press, 2009.

[73] J. S. Gouvea, V. Sawtelle, B. D. Geller, and C. Turpen, "A framework for analyzing interdisciplinary tasks: Implications for student learning and curricular design," *CBE Life Sciences Education*, vol. 12, no. 2, pp. 187–205, 2013.

[74] H. Gavaghan, "Physics grapples with its image problem," *Nature*, pp. 265–268, 1996.

[75] W. DeBuvitz, "The attraction (and fear) of a counterintuitive world," *The Physics Teacher*, vol. 52, no. 1, pp. 62–62, 2014.

[76] K. Williams, "Understanding, communication anxiety, and gender in physics: Taking the fear out of physics learning," *Journal of College Science Teaching*, vol. 30, no. 4, pp. 232–237, 2001.

[77] F. Ornek, W. R. Robinson, M. P. Haugan, and C. A. Email, "What makes physics difficult ?" *International Journal of Environmental and Science Education*, vol. 3, no. 1, pp. 30–34, 2008.

[78] H. B. Carlone, "Innovative Science Within and Against a Culture of "Achievement"," *Science Education*, vol. 87, no. 3, pp. 307–328, 2003.

[79] A. Gupta, A. Elby, and B. A. Danielak, "Exploring the entanglement of personal epistemologies and emotions in students' thinking," *Physical Review Physics Education Research*, vol. 14, no. 1, 2018.

[80] P. a. Schutz and R. Pekrun, "Emotions in Education," *Adult Learning*, vol. 18, no. 2, p. 19, 2007.

[81] P. Häussler and L. Hoffmann, "An intervention study to enhance girls' interest, self-concept, and achievement in physics classes," *Journal of Research in Science Teaching*, vol. 39, no. 9, pp. 870–888, 2002.

[82] *GlowScript IDE*, http://www.glowscript.org.

[83] M. D. Caballero, M. A. Kohlmyer, and M. F. Schatz, "Implementing and assessing computational modeling in introductory mechanics," *Physical Review Special Topics - Physics Education Research*, vol. 8, no. 2, pp. 1–15, 2012.

[84] S. Weatherford, "Student Use of Physics to Make Sense of Incomplete but Functional VPython Programs in a Lab Setting," PhD thesis, North Carolina State University, 2011.

[85] J. Skeet, *Short but complete programs*, http://yoda.arachsys.com/csharp/complete.html.

[86] A. Thompson, *SSCCE: Short, Self Contained, Correct Example*, http://www.sscce.org.

[87] *InqScribe: Simple Software for Transcription and Subtitling*, https://www.inqscribe.com.

[88] E. Cruz, B. O'Shea, W. Schaffenberger, S. Wolf, and G. Kortemeyer, "Tutorials in Introductory Physics: The Pain and the Gain," *The Physics Teacher*, vol. 48, no. 7, pp. 453–457, 2010.

[89] M. A. Albanese, M. H. Snow, S. E. Skochelak, K. N. Huggett, and P. M. Farrell, "Assessing personal qualities in medical school admissions," *Academic Medicine*, vol. 78, no. 3, pp. 313–321, 2003.

[90] S. Magleby, "The Care and Feeding of Pre-Meds," *APS April Meeting Abstracts*, Q6.003, May 2009.

[91] D. Weller, K. Hinko, and V. Sawtelle, "Investigating Complementary Computational and Empirical Activities for Students Learning Diffusion," in *PERC Proceedings*, 2018.

[92] E. F. Redish, "Evaluating Our Instruction : Surveys," *Teaching Physics with the physics suite*, pp. 91–114, 2001.

[93] D. Hemmingway, V. Sawtelle, and C. Turpen, "How an educator characterizes scientific domains and disciplinary relationships : A case of change," in *PERC Proceedings*, 2015, pp. 135–138.