JUST-IN-TIME TEACHING IN UNDERGRADUATE PHYSICS COURSES: IMPLEMENTATION, LEARNING, AND PERCEPTIONS

by

JESSICA HEWITT DYWER

B.S., Mary Washington College, 2004
M.S., Dartmouth College, 2009

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Curriculum and Instruction
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Abstract

Regardless of discipline, a decades-long battle has ensued within nearly every classroom in higher education: instructors getting students to come to class prepared to learn. In response to this clash between teacher expectations and frequent student neglect, a group of four physics education researchers developed a reformed instructional strategy called Just-in-Time Teaching (JiTT). This dissertation investigates the following three areas: 1) the fidelity with which undergraduate physics instructors implement JiTT, 2) whether student performance predicts student perception of their instructor's fidelity of JiTT implementation, and 3) whether student perception of their instructor's fidelity of JiTT implementation correlates with student views of their physics course. A blend of quantitative data (e.g., students grades, inventory scores, and questionnaire responses) are integrated with qualitative data (e.g., individual faculty interviews, student focus group discussions, and classroom observations). This study revealed no statistically significant relationship between instructors who spent time on a predefined JiTT critical component and their designation as a JiTT user or non-user. While JiTT users implemented the pedagogy in accordance with the creators' intended ideal vision, many also had trouble reconciling personal concerns about their role as a JiTT adopter and the anticipated demand of the innovation. I recommend that this population of faculty members can serve as a JiTT model for other courses, disciplines, and/or institutions. Student performance was not a predictor of student perception instructor fidelity of JiTT implementation. Additionally, the majority of students in this study reported they read their textbook prior to class and that JiTT assignments helped them prepare for in-class learning. I found evidence that exposure to the JiTT strategy may correlate with a more favorable student view of their physics course. Finally, according to students, favorable JiTT implementation occurred when instructors reviewed all questions contained within the JiTT assignment during class and when instructors clearly connected JiTT questions to the textbook reading, lesson discussion, and other assignments. The impact of this work rests in its possibility to set the stage for future education studies on the fidelity of implementation of other research-based instructional strategies in various disciplines and how they affect student performance and perceptions.

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Dedication

This dissertation is dedicated to my daughter, Gwendolyn Rose,
and to all of the young girls who think science is *cool*.
May you never fear failure, and may doing your best always satisfy you.

Chapter 1 - Introduction

The physics education research community dedicates a significant portion of its efforts to investigating innovative teaching strategies. In particular, interactive learning pedagogies, such as the Physics by Inquiry curriculum, Open Source Tutorials, and Investigative Science Learning Environments have gained attention among physics education research constituents (McDermott, 2001; Goertzen et al., 2011; Etkina & Van Heuvelen, 2007). Students exposed to research-based instructional strategies typically improve their abilities to choose a correct quantitative procedure to evaluate data as well as increase their conceptual understanding and qualitative reasoning skills (Etkina & Van Heuvelen, 2007; Shaffer & McDermott, 1992).

Another area of interest that pertains to research-based instructional strategies, or teaching innovations, in physics education includes the use of technology both inside and outside of the classroom. Multimedia Learning Modules, for example, entail an online pre-class component where students log onto a server and view a slide show containing animation, narration, and embedded assessments that relate to an upcoming physics topic (Stelzer et al., 2009). This pedagogy is discussed in greater detail in Section 2.5.1. Nakamura (2012) studied how to effectively implement an interactive Web-based physics tutorial system called the Pathway Active Learning Environment in high school and undergraduate physics courses. Educators and learners are tapping into other technological resources growing in popularity such as "clickers," the Khan Academy tutorials, and Massive Open Online Courses, widely known as MOOCs. How technology is used to augment classroom teaching is more thoroughly discussed in Section 2.2.2.

Additionally, McDermott (2001) reports that the majority of physics education research studies concentrate primarily on "the student as a learner, rather than on the instructor as a teacher." While comparing students across different learning environments (i.e., lecture versus active teaching environments) is of great value, this study highlights the importance of understanding teachers as maestros of innovative classroom engagement techniques. Effectively implementing research-based instructional strategies into a lesson is an acquired skill that may take practitioners several semesters to initially—and perhaps painstakingly—adapt to their classroom, content, and personality. An instructor must progressively learn, oftentimes by trial and error, how to execute classroom innovations in ways that enhances their students' learning.

Integrating teaching innovations into physics lessons requires patience on the part of both the instructor and her/his students. Many undergraduate physics students have been conditioned to learn in a static environment where they sit passively listening to their instructor. The same students tend to experience a certain level of shock when confronted with a reformed style of teaching that requires them to take more ownership of their learning by actively participating in their learning experiences (Enghag & Niedderer, 2008; Knight, 2004; McKeachie & Svinicki, 2006; Novak, 2011).

Throughout the physics education research literature, the universal definition of the traditionally taught physics course sparks visions of a purely lecture-based teaching method where the instructor works through problems and derivations at the board before a room full of sedentary students. Freire (2005) coined this traditional form of education the "banking" model where instructors merely deposit tokens of knowledge into student brains leaving them to register and make sense of the new information on their own. Research-based—or reformed—instructional strategies aim to combat this scenario. Reformed teaching methods strive to create a classroom environment that is more interactive, engaging, and dynamic for both instructors and students (Bain, 2004; Crouch & Mazur, 2001; Etkina & Van Heuvelen, 2007; Hake, 1998; Knight, 2004; Mazur, 1997; McKeachie & Svinicki; 2006; NRC Report, 2012).

Unfortunately, students commonly display resistance when they can no longer sit idly in class as they watch their instructor do all of the work for them. An interactive classroom calls for student participation, and this shifts some of the responsibility of learning from the instructor to the student (Novak & Patterson, 1998; Novak & Patterson, 2000). Encouraging students to take ownership of their learning experiences requires changes in both educational philosophy and classroom culture. Therefore, understanding the perceptions students *and* faculty have about particular teaching innovations, combined with students' general views about learning science, helps inform physics instructors as they make an effort to create a more accepting transition from the traditional to the reformed classroom.

One aspect that may affect how well the gap is bridged between physics education research and the physics education practice of using a new teaching strategy is evaluating how well physics instructors implement a reformed pedagogy into their daily lessons. In this dissertation, I present a research design to help answer the 2013 National Research Council's (NRC) report on undergraduate physics education call for increased investigation using research-based approaches to improve undergraduate physics education. While several studies investigate ways to increase learning and student engagement in physics and other disciplines (Crouch & Mazur, 2001; Goertzen et al., 2011; Hake, 1998; Herreid & Schiller, 2012; Knight, 2004; Mazur, 1997; McDermott, 2001; Redish et al., 1997, 1998), many within the field would agree that the vast majority of instructional approaches in undergraduate physics classrooms remain unchanged and of the traditional variety.

At the core of this research, I focus on how different instructors implement one specific teaching innvation called Just-in-Time Teaching (JiTT). I address how faculty members implement JiTT and whether they do so according to the intent of the literature set forth by Novak et al. (1999). This type of assessment is referred to as an evaluation of the *fidelity of implementation* of a teaching innovation. Additionally, I investigate faculty perceptions of JiTT as a method to prepare students for in-class learning.

A second focus area of this study assesses student performance and whether learners feel JiTT assignments prepare them for their physics lessons and other graded measures. Based on student views about how their instructors implement the pedagogy, I look at whether students consider JiTT a valuable tool that facilitates their in-class learning.

The final part of this project centers on student views about learning physics and how an instructor's JiTT implementation can impact student attitudes toward learning physics in general.

In the subsequent pages of this chapter, I provide an overview of JiTT and how it is currently used within the context of this research frame. I also explain the motivation behind this study, research questions, as well as the research approach. I conclude Chapter 1 with an outline of the remaining chapters of this dissertation.

1.1 Background: The Evolution of Just-in-Time Teaching

1.1.1 The Reading Memo: JiTT Predecessor

One might consider Edwin Taylor's practice of using reading memos a first edition version of Just-in-Time Teaching. His intent was to solicit feedback from students in his relativity course as it related to the content and organization of the textbook they used and that he co-authored. Here is an excerpt from his charge to students:

> STUDENTS!…At the end of each chapter, note down general difficulties you have and questions you would like answered…Turn in the notes on each chapter on the day the reading assignment is to be completed. The instructor will respond to each reading memo (Taylor, 1992).

Since the use of technology in the early 1990s was nowhere near the level of sophistication or ubiquity we see in today's curricula, Taylor reviewed handwritten feedback from his students and addressed their needs during class by in-turn responding to individual student's concerns. He reported that his students felt the reading memos encouraged them to complete readings on time and that the subsequent discussions during class were fruitful. He even cited a student who claimed the following:

> [B]y WRITING questions…one tends to have a clearer conception of what's going on. Typically, I start to write my question down, and by the time I've got it worded clearly enough I've solved it myself (Taylor, 1992).

Just as many reformed teaching methods encourage active participation during class, Taylor (1992) noted the way his students went from passive victims of the banking education system—as defined by Freire (2005) at the start of this chapter—to "active participants in improving their textbooks."

1.1.2 JiTT Emergence

In the mid-1990s, faculty members from three higher education institutions across the United States began working concurrently to develop the pedagogy that is called Just-in-Time Teaching. These institutions varied not only by enrollment size but also by their demographic composition. The first collaborating school, Indiana University-Purdue University at Indianapolis, was an urban institution with approximately 22,525 undergraduate and 8,165 graduate students (IUPUI, 2015). The second school was the United States Air Force Academy, a technical military institution with 3,993 undergraduate cadets (U.S. Air Force Academy, 2015). The final school to contribute to the development of JiTT was Davidson College, a liberal arts institution with 1,850 undergraduate students (Davidson College, 2015). The diversity of these academic institutions exemplifies the many classroom environments for which JiTT is suited and why it can benefit a variety of populations.

This project uses the following Novak, Patterson, Gavrin, and Christian (1999) definition of JiTT:

> A teaching and learning strategy comprised of two elements: classroom activities that promote active learning and World Wide Web resources that are used to enhance the classroom component…The students complete these assignments individually, at their own pace, and submit them electronically. In turn, [instructors] adjust and organize the classroom lessons in response to the student submissions "Just-in-Time" [for class].

The online pre-class activities have been coined "warm-ups," "reading quizzes," and "preflights." I will use the term "preflights" throughout this dissertation to indicate a JiTT Web assignment.

Preflights are a combination of multiple choice and free response questions. Instructors integrate student responses into their lessons as appropriate, which creates a feedback loop between students and their instructors (Novak & Patterson, 1998). While answers are usually anonymous if and when shared with the class, students can feel a sense of pride when they see one of their exemplar answers selected for presentation to their peers. This act increases student self confidence and is a way of demonstrating strong examples of scientific reasoning without the use of equations and formulas (Novak & Patterson, 1998).

The primary advantage of preflights is their ability to encourage students to come to class prepared to discuss the content featured in the lesson. Instructors who utilize preflights report that their students arrive to class having read lesson materials because, prior to walking through the classroom door, students are asked to complete Web-based assignments that pertain to that day's lesson objectives (Gavrin et al., 2003; Howard, 2004; Linneman & Plake, 2006; Novak et al., 1999). Preflights are a way to motivate students to break open their textbooks, access course content, or—at the very least—*think* about physics for a few minutes before their instructors say or demonstrate anything about the topic at hand.

Preflights also provide insight for instructors on what their students understand—or more importantly, what they do not understand—before executing their lesson plan (Benedict & Anderton, 2004; Gavrin, et al., 2003; Linneman & Plake, 2006; Novak et al., 1999). Depending on the sophistication of the preflight server, faculty can access auto-graded summaries of student responses to each multiple choice preflight question. This presents a snapshot of a class section's grasp on the material. For instance, if the majority of students understood the concept addressed in preflight question #2, as indicated by a certain percentage of correct responses to the question, then an instructor can spend more class time focusing on a topic where students performed less successfully, like the concept highlighted in preflight question #3.

The threshold of correct responses that indicate a satisfactory level of understanding varies by instructor. One faculty member may feel that 75 percent of students answering a preflight question correctly is acceptable, while a colleague may say 90 percent of students should register the correct answer in order to redirect the lesson toward a different concept. Centering a lesson on student difficulties can prevent boredom and wasted class time reviewing topics with which students already feel comfortable. Examples of preflight assignments for each course in this study are included in Appendix A.

The JiTT element of an active learning environment exposes students to engaged learning opportunities that traditional lectures lack. Hake (1998) conducted a study comparing over 6,000 high school and college students enrolled in introductory physics courses that utilized interactive engagement methods to 2,000 similar students enrolled in traditional lecture courses. For the students exposed to interactive engagement techniques, Hake (1998) found significant gains in two classical mechanics inventories, the Force Concept Inventory (Hestenes et al., 1992) and the Mechanics Baseline Test (Hestenes & Wells, 1992). Since the JiTT pedagogy facilitates active learning methods like those cited in Hake (1992), it has the capability to promote similar improvement in student understanding.

Enhancing student satisfaction within a course is yet another reason to use JiTT (Benedict & Anderton, 2004). Since many students exit an introductory physics course with a deteriorated view of the discipline than when they began (Adams et al., 2006; Redish et al., 1998), slight increases—or even consistent scores—in student attitudes toward the discipline is a great achievement (Novak & Patterson, 1998). In a 2010 introductory electricity and magnetism study, Stelzer et al. uncovered evidence that incorporating JiTT questions with pre-lecture multimedia learning modules and in-class Peer Instruction activities (Mazur, 1997) increased class attendance. In addition to their findings that students exposed to JiTT had a decreased perception of course difficulty, Linneman and Plake (2006) reported similar results to the Stelzer et al. (2010) study.

Brew, Kramer, and Sawtelle (2012) show evidence that analyzing cooperative student learning communities can impact methods to support participation, retention, and persistence in physics. When components of JiTT assignments are integrated with other teaching methods such as collaborative learning, where students work together in small groups towards a common goal (Cutler, 2013), the two pedagogies have the potential to complement each other, increasing learning outcomes for the students involved (Duch et al., 2001, as cited in Docktor & Mestre, 2011).

1.1.3 The Flipped Classroom: JiTT Successor

If Edwin Taylor's reading memo is the predecessor to JiTT, then JiTT is an early form of the flipped classroom. Also called an inverted classroom, this structure for learning earns its name by asking students to introduce themselves to new content *outside* of class—via reading, watching recordings, or listening to podcasts—and work on homework-like problem sets *inside* of class (Strayer, 2012). A stark comparison to the traditional style of a teacher disseminating new information during class and students applying the information to new problems outside of class on homework assignments, a flipped classroom mirrors underlying JiTT strategies such as preparing students for future in-class learning and using class time to address difficulties students encountered with the material (Mason et el., 2013). As with many pedagogical innovations, students may resist inverted classrooms because they must actually do something other than sit quietly when they come to class or because they are uncomfortable with the unfamiliar structure of an inverted classroom (Berrett, 2012; Herreid & Schiller, 2013; Mason et el., 2013; Strayer, 2012). In this setting, students must transform from passive learner to active learner (Berrett, 2012). Even some faculty members have reported their skepticism about inverting their classes because they worry about covering an adequate amount of course content and the time required to prepare the outside pre-class materials (Herreid & Schiller, 2013; Mason et el., 2013).

Students acknowledged in Mason et al. (2013) that in order to succeed in an inverted classroom they had to improve their study routines as well as their self-regulation, reinforcing the aforementioned concept of student ownership of learning. Strayer (2012) reported that the students in his inverted statistics class were more willing to work together on problem solving than those in traditionally taught courses; however, some of the students in an inverted class also had difficulty navigating and orienting themselves with the changing in-class activities.

1.2 Motivation

I personally used the JiTT strategy for two years while teaching undergraduate calculus-based introductory mechanics and electricity and magnetism. During my department's one-week summer faculty orientation program, I received a very brief training on how to use the JiTT pedagogy in class; however, I did not believe that I implemented the teaching innovation with much fidelity because I rarely tailored my lessons based on the feedback I received from my students on their pre-class Web assignments. I looked at the percentages of correctly answered multiple choice questions, quickly skimmed students' typed responses, and copied and pasted a few examples of the stronger and weaker answers into my PowerPoint presentations. I am not confident, though, that what I focused on changed from section to section. Instead I taught the same prescribed lesson to every one of my four sections. As a first-time teacher, I felt overwhelmed by the new institution, the new working environment, and the new curriculum—not to mention the energy required to keep my students "engaged" for up to six hours a day.

Compared to other research-based instructional strategies like Peer Instruction and inquiry-based learning, JiTT adopters have conducted little research on themselves in an effort to reflect on how their fidelity of JiTT implementation and their opinions of JiTT impact student perceptions and performance within physics classes, particularly introductory electricity and magnetism, and upper-division physics courses (Borrego et al., 2013; Docktor & Mestre, 2011). After conducting a search using combinations of the key words "JiTT," "Just-in-Time Teaching," "Just in Time Teaching," "pre-class," "preclass," "physics," "education," "mechanics," "electricity and magnetism," and "E&M" within multiple databases and search engines such as Web of Science, SCOPUS, ERIC, and Google Scholar, I found a limited number of publications within the records that conduct in-depth investigations of the fidelity of incorporating the JiTT strategy into an introductory college electricity and magnetism course, the primary source of research participants in this project (Gavrin et al., 2003; Stelzer et al., 2009, 2010).

In addition, I was unable to uncover extensive research that explored the relationship between student performance on physics graded measures and fidelity of instructor implementation of the JiTT pedagogy. The NRC (2013) report highlights "the quality of implementation is critical" when integrating new teaching tools or methods into classrooms, and Borrego et al. (2013) cite a specific need for further studies of adaptations of JiTT implementation in classrooms.

Many Science, Technology, Engineering and Mathematics (STEM) educators are willing to concede that in today's classroom a substantial disparity exists between the fundamental preconceptions students have about course concepts, how those conceptions are covered during introductory classes, and what students actually learn by the conclusion of the course (Halloun & Hestenes, 1985a; Halloun & Hestenes, 1985b; Hestenes et al, 1992; Higdon & Topaz, 2009; Maloney et al., 2001; Novak et al., 1999; Planinic, 2006). The ubiquity of this problem in higher education adds to my motivation to evaluate the ways in which the JiTT teaching innovation may help to enhance student learning and improve student opinions about their learning experiences.

1.3 Research Questions

Beyond the broad sweeping question of how faculty members integrate the research-based instructional strategy called JiTT into their classrooms, I focus this investigation on the following questions:

1. *With what degree of fidelity is Just-in-Time Teaching implemented in undergraduate physics classrooms? Specifically, does the critical component that characterizes JiTT discriminate between physics faculty members who claimed to use JiTT and those who did not?*
2. *Does a relationship exist between JiTT implementation and student performance? Specifically, do final exam scores, course order of merit, preflight scores, and homework scores predict student perceptions of their instructor's fidelity of JiTT implementation?*
3. *Does student perception of their instructor's fidelity of JiTT implementation correlate with their perceptions of their physics course*

Answering these basic research questions enables the examination of the impact the JiTT innovation has on faculty and students. Uncovering these connections better informs physics faculty members about how to most effectively implement JiTT. While previous research focuses primarily on how JiTT influences student performance in a course, this project seeks to fill the gap between faculty implementation and student achievement.

1.4 Research Approach

Since this study is exploratory in nature, I did not seek to create a new pedagogy or learning theory; however, I did wish to make connections between faculty and student views about a current pedagogy. In addition to student questionnaire responses, grades, and inventory scores, much of the data collected are subjective opinions and observations of JiTT implementation. Therefore, this investigation is well suited for a mixed research approach of qualitative and quantitative methods. I assess instructor fidelity of implementation of preflights through three main data sources:

1. An online physics faculty questionnaire about instructional strategies
2. One-on-one interviews with physics faculty members
3. Observations of undergraduate physics lessons

These data allowed me to probe for deeper insight into instructor understanding of the JiTT pedagogy, its purpose, use, and outcomes. I sought to uncover whether the way in which an instructor used preflights impacted student performance and perceptions of the course.

I measured student achievement as well as student opinions about preflights and physics through the following data sources:

1. Grades
    a. Final exam scores
    b. Homework scores
    c. Preflight scores
    d. Final course order of merit
2. Physics inventory scores
    a. Modified Colorado Learning Attitudes about Science Survey (CLASS)
    b. Conceptual Survey of Electricity and Magnetism (CSEM)
    c. Force Concept Inventory (FCI)
3. An online student questionnaire
4. Focus group interviews with students

Ultimately, this dissertation serves to demonstrate that the way in which an instructor integrates preflights into her/his lessons can influence how meaningful her/his students view the assignment as well as how prepared students feel for class and other graded measures as a result of completing or studying a preflight.

Quantitative data analysis gleaned from student questionnaire responses as well as scores on various assignments, exams, and physics inventories sheds light on the relationship between a student's perception of her/his instructor's fidelity of JiTT implementation and student performance on graded measures in her/his course. While this is not an exhaustive investigation of all research-based instructional strategies, this dissertation serves to lay the foundation for refining future studies of the fidelity of implementation of other reformed teaching strategies not only in undergraduate physics but other disciplines as well.

1.5 Broader Impact and Implications

The fidelity of implementation portion of this research is grounded in an extension of previous doctoral research conducted at the Virginia Polytechnic Institute and State University where Cutler (2013) studied the fidelity of implementation of 10 different research-based instructional strategies—to include Just-in-Time Teaching—in undergraduate engineering (statics) classrooms. Finding common trends in the way reformed teaching techniques are introduced into classrooms across disciplines may help education researchers find more effective ways to introduce students to a novel learning experience. A potential result of easing the transition from traditional to reformed classroom is remediating the resistance students tend to demonstrate toward unfamiliar classroom teaching innovations and interactions, increasing attendance and participation, and reducing course attrition.

Additionally, some departments in higher education may not be aware of or may not support the inclusion of teaching innovations in their curricula. Educational researchers can conduct similar studies as that outlined in this dissertation and use the results to develop and make available to novice instructors and/or skeptics "best practice" guides or training that would support and outline the integration process of new pedagogies and technologies into traditional classroom environments. As such, it is proposed that effective training can potentially improve the implementation of research-based instructional strategies, directly impacting the student learning experience.

1.6 Dissertation Organization

The subsequent chapters of this dissertation provide a more in-depth report of the proposed research. Chapter 2 includes a review of the literature to include the theoretical frameworks supporting this project. I explain in more detail the concept of *fidelity of implementation* within the education community and how it has been applied in measuring outcomes of interventions. Along with this, I expand on how content, pedagogy, and technology are interrelated within a given curriculum. This chapter also features a summary of the concept of *preparation for future learning*, an ancillary to transfer. To expand on this, I look at how JiTT is just one example of a pedagogy that can prepare students for future learning. Finally, I present a review of research that has measured student attitudes toward science and conclude with an appraisal of previous JiTT studies that investigated student performance and perceptions.

In Chapter 3, I present the methodology and research design carried out in this study. I include a comprehensive description of the population under investigation, sampling techniques, research schedule, and data collection methods—to include descriptions of the instrumentation employed. Chapter 4 includes a discussion of the results of the quantitative data analysis as it relates to information garnered from the faculty instructional strategies questionnaire, the student preflight questionnaire, and student performance measures. In Chapter 5, I explain the results of my qualitative analysis of faculty interviews, student focus group interviews, and classroom observations. Finally, Chapter 6 contains overall conclusions drawn from the dissertation to include a summary of the project and the research questions under investigation, how to understand the results in terms of the undergirding theoretical frameworks, the implications of this research, limitations to the study, and ways to expand on this work in the future.

Chapter 2 - Review of the Literature

This chapter is divided into five main sections. The first section covers the theoretical underpinnings for each research question. The chief conceptual framework I discuss is that of *fidelity of implementation* and how its beginnings arose from the *diffusion of innovation theory*. The second theoretical framework nucleates around *Technical Pedagogical Content Knowledge (TPCK)*, while the theory of transfer of learning—and more specifically, the concept of *preparation for future learning*—are discussed third. The fourth section consists of a review of student attitudes toward science and how this impacts learning science concepts. The fifth and final component covers previous JiTT research. While these studies encompass individual aspects of the research, they also serve to create an overarching unification of the ideas addressed in this study.

2.1 Fidelity of Implementation

To address the first research question (*With what degree of fidelity is Just-in-Time Teaching implemented in undergraduate physics classrooms?*), I follow the framework established through the evaluation of fidelity of implementation studies. Assessing precisely how JiTT adopters and instructors enact elements of JiTT in their lessons reveals how high or low fidelity of the pedagogy influences student performance and perceptions. The foundation of much fidelity of implementation research rests upon Rogers' (1995) concept of *diffusion of innovations* (Cutler & Borrego, 2013; Borrego et al., 2013; O'Donnell, 2007; O'Donnell, 2008; Durlak & DuPre, 2008; Dusenbury et al., 2003; Hall & Loucks, 1978). Therefore, I begin this section by offering a review of *diffusion of innovations*.

2.1.1 Diffusion of Innovations

Deconstructing the diffusion of innovations theory, Rogers (1995) defines the first term, *diffusion*, as "the process by which an innovation is communicated through certain channels over time among the members of a social system." Rogers (1995) goes on to provide the following definition of the second term, *innovation*:

> An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption. It matters little, so far as human behavior is concerned, whether or not an idea is "objectively" new as measured by the lapse of time since its first use or

discovery. The perceived newness of the idea for the individual determines his or her reaction to it. If the idea seems new to the individual, it is an innovation.

Hall & Loucks (1978) explain that pedagogical innovations arise to "solve the problem of how to best educate…students" and that innovation research "has centered around learning how to measure and evaluate the effects of implementation." For the purpose of this study, I investigated the diffusion of the JiTT pedagogical innovation.

Since innovations vary widely across disciplines and areas of study, Rogers (1995) defines five key innovation characteristics, which are summarized in the table below. He asserts innovation adoption is influenced by "the receivers' perceptions of the attributes of innovations, not the attributes as classified by experts or change agents." While a school or department may choose to adopt a reformed teaching strategy, unless the users of the pedagogy—the classroom instructors—buy into it, the pedagogy may fail to meet the expectations of its creators.

Table 2.1 Characteristics of Innovations (Rogers, 1995)

Characteristic	Definition	Connection to JiTT Study
1. Relative Advantage	The degree to which an innovation is perceived as better than the idea it supersedes.	Assigning preflights to encourage students to read before class is better than having no preflight and students coming to class unprepared.
2. Compatibility	The degree to which an innovation is perceived as being consistent with existing values, past experiences, and needs of potential adopters.	Preflights answer the need to encourage students to come to class having already introduced themselves to general physics concepts so that more time is spent reviewing more challenging topics in class.
3. Complexity	The degree to which an innovation is perceived as difficult to understand and use.	The idea of using the preflight assignments to inform/guide classroom teaching is not overly challenging to comprehend.
4. Trialability	The degree to which an innovation may be experimented with on a limited basis.	JiTT authors encourage new JiTT adopters to try implementing preflights in a way that best fits their teaching structure/philosophy/environment.
5. Observability	The degree to which the results of an innovation are visible to others.	Through questionnaires, interviews, and observations, this study sheds light on how the use of JiTT impacts student perceptions of the assignment and their physics course and how well JiTT prepares students for future in-class learning.

Implementation occurs when "an individual (or other decision-making unit) puts an innovation into use," and with this comes a certain degree of uncertainty about the outcomes of the innovation at the local user's level (Rogers, 1995). The United States Air Force Academy Department of Physics made an organizational decision in 1999 to permanently adopt the JiTT pedagogy into its core physics curriculum. For the purpose of this study, a *core* physics course or curriculum is defined as any level—regular or honors—of introductory mechanics or introductory electricity and magnetism.

All incoming core physics instructors—that is all new faculty members who will teach a core physics course—attend a mandatory departmental New Faculty Orientation program. During this 15-day summer training, new physics instructors watch existing faculty teach example lessons from the core curriculum. New faculty also had the opportunity to interact with demonstrations of how to manipulate the technology available in a typical classroom. This includes use of the projection system; PowerPoint; clickers, which are remote control voting devices students use to respond to instructor polls to multiple choice questions; TurningPoint, which is the software needed to register and display clickers responses; and online resources like the homework tool *Mastering Physics* and the local preflight server. During this orientation, newcomers have the chance to rehearse at least three lessons in front of fellow physics instructors so they can implement what they learned at the beginning of the program and practice using the classroom technology, to include methods for integrating preflight responses into a lesson.

Although JiTT may not be an innovation for some instructors, those educators who are not familiar with the pedagogy known as Just-in-Time Teaching would need to learn how to integrate the teaching innovation into their lessons. Therefore, at the individual instructor level, a degree of what Rogers (1995) coins "re-invention" occurs. During re-invention, "an innovation is changed or modified by a user in the process of its adoption and implementation." Ultimately, this project seeks to study how varying faculty re-inventions of JiTT affect student perceptions of preflights and physics as well as their performance in the course.

Hall and Loucks (1978) summarize a procedure that Mitroff and Boston (1977) developed to study the use of education-based innovations post-implementation. They used surveys, questionnaires, and interviews to determine whether the innovations were still being used one year after the implementation support had concluded. In addition to these common forms of diffusion of innovation data, I observed several different instructors in their classes. Fullan and Pomfret (1977) caution, however, that no matter what forms of data or instruments are used to measure fidelity, the researchers must view those measurements as mere "snapshot[s] of what users are actually doing with respect to the innovation at one point in time" (as cited in Hall & Loucks, 1978). My goal was to use classroom observations to help narrow the gap between the accuracy of self-reports and actual classroom practices. Of course my announced presence at the back of the classroom could not be ignored either, and I openly acknowledge that this in-turn may have influenced if and how an instructor enacted the JiTT strategy during her/his class.

Stages of Concern and *Levels of Use* are two dimensions that Hall and Loucks (1978) use to describe innovation implementation from an individual's perspective. First, *Stages of Concern* refer to how an instructor "feel[s] about an innovation from the time they first become aware of it until they have mastered it." This ranges from personal belief about how an innovation impacts her/himself to the impact an innovation has on her/his students (Hall & Rutherford, 1976). Hall and Rutherford's (1976) descriptive table of the seven stages of concern is reproduced below in Table 2.2.

Table 2.2 Definitions of Stages of Concern About an Innovation

Level	Label	Definition
0	Awareness	Unconcerned about the innovation
1	Informational	Concerns about general characteristics of the innovation and what is required to use it
2	Personal	Concerns about one's role and possible conflicts between that role and anticipated demands of the innovation
3	Management	Concerns about time, organizing, managing, and making innovation work smoothly
4	Consequence	Concerns about student outcomes
5	Collaboration	Concerns about working with others in use of the innovation
6	Refocusing	Concerns about finding another and even more effective way

Secondly, *Level of Use* refers to the "various states of user behavior," or in other words, precisely what the instructor is doing with the innovation. This ranges from complete nonuse to making drastic modifications to the original innovation (as cited in Hall & Loucks, 1978). A key factor affecting the *Stages of Concern* and *Levels of Use* includes the developer's and trainer's clarity in describing and communicating their innovation and its critical components. Hall and Loucks (1978) conclude with the assertion that educational innovations are fairly evaluated only when their adaptation during implementation is taken into consideration.

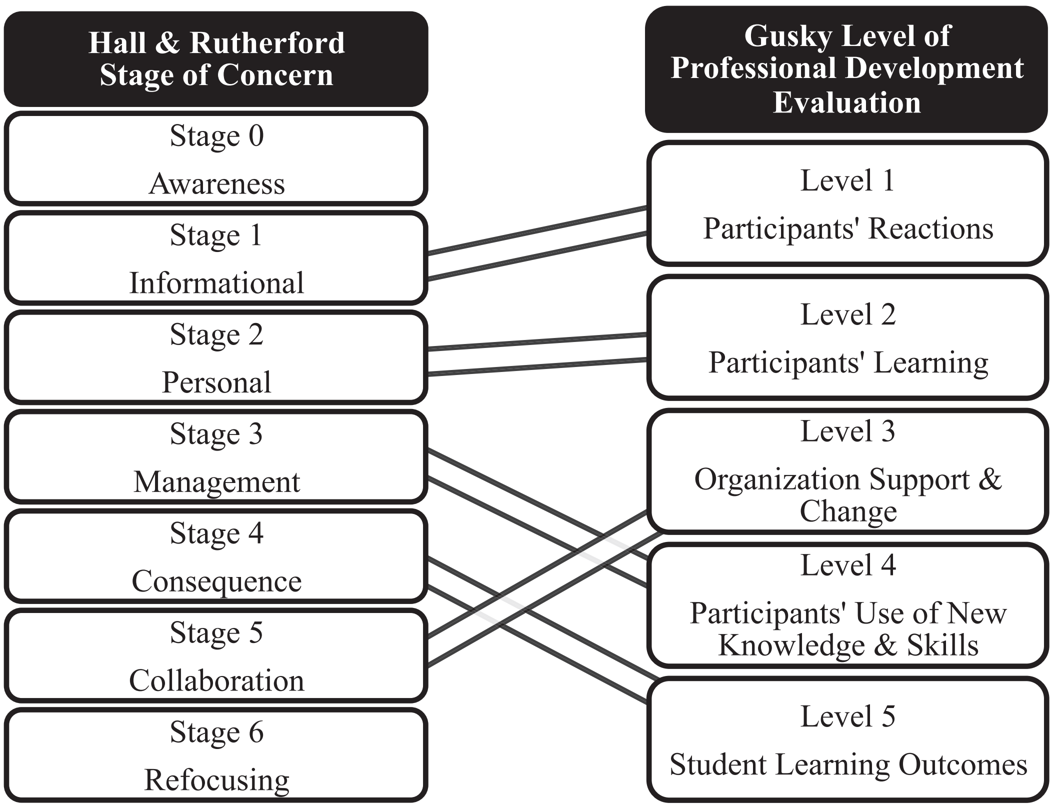
In essence, learning a new pedagogy falls into a category with which many educators are quite familiar: professional development. How adopters of an instructional innovation such as JiTT promote the pedagogy among new users is key to garnering buy-in from potential future adopters. Therefore, departments must take the time to regularly assess the methods by which they conduct such professional development programs, orientations, and the like. Guskey (2002) presents five critical levels for the evaluation of professional development. His hierarchical structure follows a process such that each level of successful evaluation depends upon the success achieved at the previous level. Table 2.3 contains Guskey's process for evaluating professional development.

Table 2.3 Guskey's Five Levels of Professional Development Evaluation

Level	Label	Measurement of Success
1	Participants' Reactions	Initial satisfaction with the experience
2	Participants' Learning	New knowledge and skills acquired by participants
3	Organization Support & Change	Degree of organization's advocacy, support, accommodation, facilitation, and recognition
4	Participants' Use of New Knowledge & Skills	Degree and quality of implementation of new knowledge and skills
5	Student Learning Outcomes	a. Cognitive (performance and achievement) b. Affective (attitudes and dispositions) c. Psychomotor (skills and behaviors)

Guskey's (2002) levels of professional development evaluation look strikingly similar to Hall and Rutherford's (1976) previously mentioned *Stages of Concern*. Since learning how to use a teaching innovation could be considered a form of educational professional development, in Figure 2.1 I map Hall and Rutherford's (1976) *Stages of Concern* to Guskey's (2002) five critical levels for the evaluation of professional development.

Figure 2.1 Mapping Hall & Rutherford's Stages of Concern to Guskey's Professional Development Evaluation



Guskey (2002) describes the process a professional development participant goes through as she/he attends and then enacts what is learned during the training. He highlights that professional development participants, like innovation adopters, begin their evaluation of the experience by determining whether they liked it (Level 1), then they determine what they got out of the experience (Level 2). Next, the participants evaluate how much support they will receive from their institution in their inclusion of and collaboration on new ideas gained from the professional development (Level 3). Once the participants bring the knowledge gained from the training to their classroom, they evaluate how it impacted their teaching practice (Level 4). Finally, participants determine if their professional development had a desirable impact on their students (Level 5).

2.1.2 Fidelity of Implementation

Fidelity of implementation is used to determine the way in which a program is put into action impacts that program's outcomes. Durlak and DuPre (2008) carried out a meta-analysis of implementation fidelity in 483 programs such as the following: academic achievement, substance abuse prevention, mental health, and physical health promotion. They used two primary methods—self-reports and individual behavior observations—for evaluating the fidelity of implementation of such programs and concluded that "[a]chieving good implementation not only increases the chances of program success in statistical terms, but also can lead to much stronger benefits for participants" (Durlak & DuPre, 2008).

I focus this section of the literature review on fidelity of implementation of instructional strategies studies. Loucks (1983) defines fidelity of implementation in this regard as

> the extent to which teachers enact innovation in ways that either follow designers' intentions or replicate practices developed elsewhere, or the extent to which the user's current practice matched the developer's "ideal" (as cited in O'Donnell, 2008).

In other words, fidelity of implementation investigations look at whether programs are executed in the way the original creators of the program intended.

When controlling for prior science grade point average as a measure of prior knowledge, O'Donnell (2007) sought to determine the relationship between a sixth grade science curriculum unit and classroom mean achievement in a quasi-experimental change across instructional strategies used in different classes. She found that high fidelity to the instructional strategies in the treatment classrooms led to increased mean achievement, and low fidelity in the treatment classrooms led to lower mean achievement; no such relationship existed in the comparison condition.

Since fidelity of implementation of research-based instructional strategies is rarely reported in large-scale education studies that examine the effectiveness of reformed pedagogies in higher education, this investigation adheres to an approach aligned with the standard set forth by the Cutler and Borrego (2013) study of the implementation effectiveness of educational interventions in college engineering science courses. In addition to investigating the degree of fidelity of implementation of research-based instructional strategies within statics classrooms, they also researched whether pre-defined critical components characterizing research-based instructional strategies could discriminate between statics teachers who claimed to use certain pedagogies and those who did not.

To conduct their study, the authors developed a Research-Based Instructional Strategies in Engineering Survey that they administered to 285 statics instructors at several accredited mechanical, civil, aeronautical, and aerospace engineering programs across the United States. The engineering survey is split into four parts: 1) faculty beliefs, 2) time spent using critical components of various research-based instructional strategies, 3) level of knowledge and use of named research-based instructional strategies, and 4) demographics. The authors calculated a Cronbach's alpha value of 0.9208 to determine that the instrument's reliability was at an acceptable level (Pedhazur & Schmelkin, 1991, as cited in Cutler & Borrego, 2013).

The authors operationalized a research-based instructional strategy users as instructors "who indicated [on the survey] they were currently using the [research-based instructional strategy] (responded 'I currently use it')," a non-user as a person "who is not currently using the [research-based instructional strategy] (responded in any other way to the item)," and fidelity as the "percentage of users who also spent time on the respective required [research-based instructional strategy] critical components." Critical components are "core components which must be present for the innovation to be in use" (Hall & Loucks, 1978).

Most relevant to this study are the results Cutler and Borrego (2013) reported on as they relate to Just-in-Time Teaching. The authors found 77% of JiTT users spent time on the single critical component associated with the JiTT strategy: "spent time discussing pre-class activities which helped you re-evaluate student learning and adjust your lecture 'just in time.'" However, since only this single critical component characterized JiTT, such a research-based instructional strategy rests on the fact that fidelity is "all or nothing" (Cutler & Borrego, 2013). This poses some difficulty when determining how accurate the label JiTT "user" or "non-JiTT user" is as a researcher classifies individual faculty members.

Although Cutler and Borrego (2013) do not expand on this conclusion, I took the liberty to interpret their thoughts. Unlike most other research-based instructional strategies in their study which have multiple critical components, JiTT's lone defining feature may pose an impediment in recognizing the signs that pedagogy is exercised in the classroom, making it easy to miss if the instructor is not overt in her/his reference to preflights or if she/he seldom references them. The table below summarizes JiTT as it pertains to research-based instructional strategy studies and its associated component.

Table 2.4 Summary of JiTT Use in RBIS Studies

JiTT Definition	
(as shown on the Research-Based Instructional Strategies in Engineering Survey)	Students individually complete Web-based assignments a few hours before class, then the instructor reads through their answers before class and adjusts the lessons accordingly ("just in time").
Required Critical Component	
(as shown on the Research-Based Instructional Strategies in Engineering Survey)	Spent time discussing pre-class activities which helped you re-evaluate student learning and adjust your lecture 'just in time'

Cutler & Borrego (2013)		**Borrego et al. (2013)**	
Faculty reported using JiTT	77% (n not provided)	Faculty reported using JiTT	74% (n = 46)
p-value	Not provided	*p*-value	0.001

In addition to analyzing survey data, the authors conducted interviews at two of the 128 participating institutions. During the interviews, statics instructors answered questions about their teaching methods and how students could evaluate their instruction. Engineering faculty members also provided feedback on a list of several research-based instructional strategies by sharing whether they use or had attempted to use any of the pedagogies and why the strategies might not be used more widely. After combining the survey and interview data, Cutler and Borrego (2013) concluded that fidelity of implementation studies are a lens through which engineering education researchers can investigate innovative teaching strategies and that establishing appropriate critical components of reformed teaching strategies aids in distinguishing research-based instructional strategy users from non-users.

2.2 Technical Pedagogical Content Knowledge

Researching JiTT as it pertains to Technical Pedagogical Content Knowledge (TPCK) affords educators and researchers an opportunity to look beyond what can easily turn into an oversimplified approach to integrating technology into a classroom. TPCK ties into the first research question (*With what degree of fidelity is Just-in-Time Teaching implemented in undergraduate physics classrooms?*) as well because instructors must have an understanding of how to effectively incorporate feedback from electronic preflight responses into their physics classes. This act should entail more than a brief recap of the preflight answers at the start of a lesson.

Koehler and Mishra (2009) wish to move away from viewing technology as a mere "add-on" and instead focus on the interworking among and between technology, content, and pedagogy as they all play their respective role within varying classroom environments. TPCK is an extension of *Pedagogical Content Knowledge (PCK)*, therefore, I will first provide a review of PCK.

2.2.1 Pedagogical Content Knowledge

Shulman (1986) summarizes the rigorous requirements for teaching in America during the late 19th century. As an example he illustrates the testing categories for an 1875 California State Board examination for elementary teachers. Given the many test sections dedicated to content knowledge, it was obvious that the individuals responsible for teaching children had to substantiate that they possessed knowledge of a collection of subject matter as a precondition to entering the classroom. Since only one of the 20 exam categories was dedicated to pedagogy, it was clear that mastery of the theories and practice of teaching had a subordinate status as a qualification to teach.

Today, the pendulum has shifted to where, in many states, instructors are assessed for their ability to teach according to research-based competencies for effective instruction, rather than knowledge of their subject matter content. Studies have been executed to discern forms of instructor behavior that improved student learning; however, Shulman (1986) criticizes that the researchers overlooked a principal part of the classroom environment in their necessary simplification of school teaching: the subject matter. He calls this omission the "missing paradigm," and he asserts that it is a troubling issue when investigators neglect subject matter in their studies. State-level initiatives to assess instructors and much of the pedagogical research that is conducted contain a "blind spot" when it comes to content. Shulman (1986) believes questions about subject matter within a lesson, how student understanding is checked, as well as the explanations instructors provide for clarification to students must also be studied.

Taking a farther step back in history, Shulman includes an interesting passage from Rashdall's *The Universities of Europe in the Middle Ages*. Here it is explained how medieval universities made no distinction between content and pedagogy (i.e., what is known versus how to teach it). Classes were run in an extremely strict fashion, and teachers had to maintain rigid preparatory requirements for each class. Rashdall likened the instructional experience to a "soldier on parade" where almost all aspects of content and pedagogy were controlled by the academy. Similarly, the medieval process to obtain an advanced academic degree was truly a means to graduate master and doctoral "teachers" where the basis of the oral examination was to show that the candidate had a superior level of understanding of content within a given discipline. "How did one demonstrate such understanding in medieval times? By demonstrating the ability to teach the subject" (Ong, 1985, as cited in Shulman 1986). In essence, the oral Doctor of Philosophy defense was an extremely elaborate lesson, complete with a presentation (lecture) followed by an examination (discussion).

Shulman (1986) believes more studies should focus on a question concerning the "transition from expert student to novice teacher." He would like to see investigations of how instructors get ready to teach a topic they have never learned before. Since a sharp distinction exists between content and pedagogical practice, the process of "learning for teaching" is an important area to scrutinize. Tables 2.5 and 2.6 below outline the content knowledge categories and the teacher knowledge categories Shulman (1986) describes. (These are taken mostly word-for-word from the text.)

Table 2.5 Categories of Content Knowledge

1. Subject Matter Content Knowledge (follows Joseph Schwab's breakdown)	•Substantive Structures: ways in which basic concepts and principles of a discipline are organized to incorporate facts. •Syntactic Structure: ways in which truth or falsehood, validity or invalidity, are established. •Instructors must be able to explain *that* something is, AND *why* it is so, AND why it is central to the discipline rather than peripheral (relevance).
2. Pedagogical Content Knowledge	•For the most common topics in a discipline, this includes ways to represent and formulate the discipline that make it comprehensible to others. •Instructors must have an understanding of what makes the learning of specific topics easy or difficult and what strategies can be used to address alternate conceptions.
3. Curricular Content Knowledge	•The full range of programs designed for teaching particular subjects and topics at a given level, the variety of instructional materials available, as well as curricular alternatives available for instruction •Lateral curriculum: instructor's ability to relate content of a given course or lesson to topics or issues being discussed simultaneously in other classes. •Vertical curriculum: familiarity with the topics and issues that have been and will be taught in the same subject area during the preceding and later grades and the materials that embody them.

Table 2.6 Categories of Instructor Knowledge

1. Propositional Knowledge	a) **Disciplined empirical** or **philosophical inquiry** (research-based) b) **Practical experience** (break chalk to prevent squeaking on board) c) **Moral** or **ethical reasoning** (commitments to justice, fairness, equity).
2. Case Knowledge	•Case knowledge is knowledge of specific, well-documented, and richly described events. An *event* can be described, but a *case* must be explicated, interpreted, argued, dissected, and reassembled. •Cases may be exemplars of principles, exemplifying in their detail a more abstract proposition or theoretical claim. •A case can be any combination of types and must be grounded in theory. a) **Prototype** cases exemplify theoretical principles. b) **Precedent** cases capture and communicate principles of practice or maxims (most common). c) **Parable** cases convey norms or values
3. Strategic Knowledge	•Strategic knowledge must be generated to extend understanding beyond principle to the wisdom of practice and is developed when the lessons of single principles contradict one another, or the precedents of particular cases are incompatible (i.e., importance of wait-time vs. maintaining pace of class). It entails wise judgment and decision-making (phronesis). •Instructors must understand that knowledge guarantees freedom and the flexibility to judge, to weigh alternatives, to reason about both ends and means, and then to act while reflecting upon one's actions.

2.2.2 TPCK Overview

Koehler and Mishra (2009) present a breakdown of how content, pedagogy, and technology are all interrelated and form the core of the technology, pedagogy, and content knowledge (TPCK) framework, which is an extension of Shulman's PCK framework in that it also incorporates technological components of the classroom.

Koehler and Mishra (2009) explain how effective teaching is contingent upon the availability of a wide range of abundant, structured, and blended knowledge from a variety of disciplines including knowledge of cognitive thought processes, student learning processes, knowledge of subject matter, and now more than ever before, knowledge about technology—both analog and digital. Digital technologies—such as computers, tablets, smartphones, and software applications—are at the forefront of educational innovations. They are also multifaceted—continually upgraded and altered—and opaque in the sense that "the inner workings are hidden from users" (Koehler and Mishra, 2009).

As a result of the aforementioned characteristics, cutting edge digital technologies bring forth fresh—and perhaps unforeseen—challenges to the instructors who wish to integrate more current technology into their existing teaching practices. This poses amplified dilemmas for teachers who joined the workforce during a time when technology was at a more infantile stage.

Instructors may find it extremely difficult to recognize a new technology's relevance to their curriculum and then subsequently learn how to use and implement it appropriately. This challenge may surface when JiTT adopters must navigate an unfamiliar or unreliable JiTT server.

To address such challenges, educational professional development may require some restructuring, as Shulman (1986) also recommends, in order to help instructors better understand how varying and complex technological advantages and disadvantages might drive if and how they incorporate certain technologies into their lessons. Koehler and Mishra (2009) recommend that "integration efforts should be creatively designed or structured for particular subject matter ideas in specific classroom contexts." Therefore, innovation training may be a key aspect when considering the adoption and perceptions of an educational innovation like the JiTT pedagogy. Further professional development recommendations resulting from this study are disussed in Chapter 5.

The TPCK framework presents a multitude of avenues for exploring continued research in teacher education, professional development, and use of technology. JiTT developers as well as flipped classroom adopters took advantage of the introduction and explosion of the World Wide Web and how dramatically it has contributed to the rise of online learning tools. The arrival of such a technological advancement has forced instructors to address core pedagogical issues, such as how to represent subject matter with accuracy and credibility on the Internet and how to appropriately connect students with content and with one another.

The Venn diagram and associated explanatory chart in Figure 2.2 and Table 2.7, respectively, are reproductions of Koehler & Mishra's (2009) summary of the TPCK framework and its knowledge components.

Figure 2.2 TPCK Components and Explanations

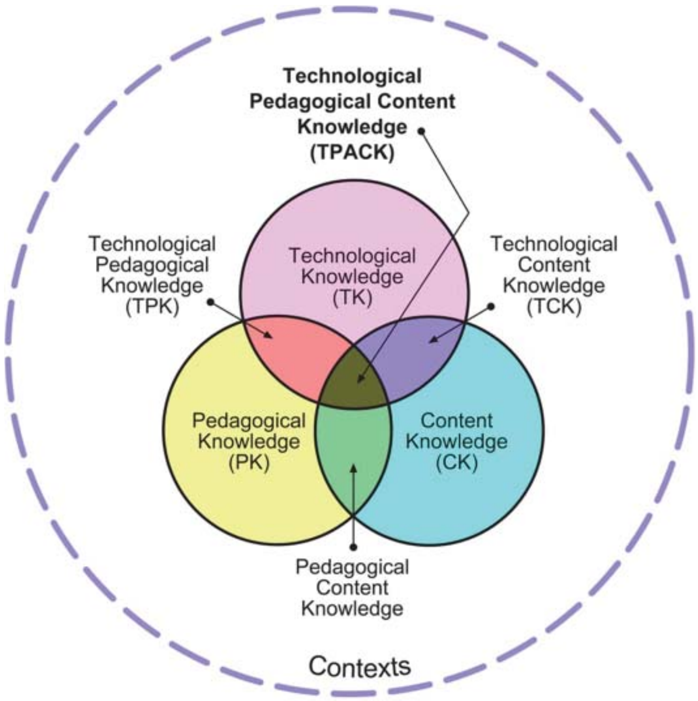


Table 2.7 TPCK Framework Components

Content Knowledge	Includes knowledge of concepts, theories, ideas, organizational frameworks, knowledge of evidence and proof, as well as established practices and approaches toward developing such knowledge. This is an ill-structured domain with disagreements among scholars within specific content domains.
Pedagogical Knowledge	Includes knowledge about techniques or methods used in the classroom, the nature of the target audience, and strategies for evaluating student understanding. This requires an understanding of cognitive, social, and developmental theories of learning and how they apply to students in the classroom.
Pedagogical Content Knowledge	Includes awareness of common misconceptions and ways of looking at them, the importance of forging connections among different content-based ideas, students' prior knowledge, alternative teaching strategies, and flexibility.
Technological Knowledge	This is always in a state of flux and is more that simple computer literacy. It requires a deeper, more essential understanding and mastery of information technology [systems that store, retrieve, send information] for information processing, communication, and problem solving. Teachers must be able to use information technology to adapt novel ways of completing tasks.
Technological Content Knowledge	Includes an understanding of the manner in which technology and content influence and constrain one another since certain content decisions can limit the types of technologies that can be used. Technology can constrain the types of possible representations, but it also can afford the construction of newer and more varied representations. Teachers must know which technologies best complement their content.
Technological Pedagogical Knowledge	Includes understanding of how teaching and learning can change when particular technologies are used in particular ways to advance student learning and understanding. Users should know the pedagogical affordances and constraints of a range of technological tools that appropriately fit teaching strategies in context and purpose. Teachers must learn to reconfigure common technology to fit the *educational* environment (as opposed to business or entertainment uses).
Technology, Pedagogy, and Content Knowledge	All-encompassing. Includes unique combination of these three factors to fit each instructor, classroom, level, discipline and student audience. It requires a deep, flexible, pragmatic, and nuanced understanding of teaching with technology. TPCK is considered a professional knowledge construct where changing one element will ultimately ripple changes in the other elements.

2.3 Preparation for Future Learning

The theory behind the transfer of learning addresses the second research question (*Does a relationship exist between JiTT implementation and student performance?*). Singley and Anderson (1989) define transfer of learning as "the study of how knowledge acquired in one situation applies (or fails to apply) in other situations." Bransford et al. (2000) further explain that students who engage in a metacognitive "deliberate practice" where they "actively monitor" their own learning will experience the most effective learning process. Like reading memos, JiTT affords students the opportunity to recognize areas where they have difficulty with course materials prior to their arrival in class. The reflective operation of formulating questions to be addressed in the presence of the instructor is the cyclic process of seeking and using feedback about a student's learning progress. Transfer is also described as a "dynamic process that requires learners to actively choose and evaluate strategies, consider resources, and receive feedback" in order to "extend what has been learned in one context to new contexts" (Bransford et al., 2000).

Preflights in this research context are assignments where students use previous knowledge and personal experiences to make sense of new physics concepts without instructor assistance. In an ideal world, students would not simply memorize these concepts and their associated mathematical counterparts. Rather, educators desire that their students learn how to activate relevant previous knowledge and either make accommodations for or assimilate it to the new information they encounter. Preflights are a way for instructors to determine if students' understanding of a subject is accurate or not. They respond to Bransford et al.'s (2000) call for instructors to "strive to make students' thinking visible."

Bransford and Schwartz (1999) provide an example of a JiTT-like scenario where a teacher takes into consideration student understanding of a concept so she can adjust her lesson in such a fashion that will allow her students to succeed. In the same work, the authors highlight one form of transfer called *preparation for future learning* where they claim "people's abilities to learn in knowledge rich environments" makes them "better prepared for future learning [and] greater transfer (in terms of speed and/or quality of new learning)." In this sense, preflights can be considered a tool that helps students navigate the information sources available to them (i.e., textbooks, course workbooks, the Internet, peers, tutors etc.) before receiving a formal lesson on the concepts they are investigating on their own as they connect their previous knowledge to the new concepts presented to them. Bransford and Schwartz (1999) claim that preparation for future learning exercises help to place students on a learning trajectory that does not necessarily mean they are assessed on the grounds for if they know how to produce a final answer to a physics calculation, but rather they are assessed by how well equipped they are to learn how to solve a new related problem. Therefore, the metacognitive processes a student goes through in their initial learning trajectory, as in their preliminary thought processes made evident through preflights responses, helps to set up students to learn how to question whether their initial understanding about a concept is appropriate or inappropriate.

2.4 Student Attitudes Toward Science

2.4.1 The Colorado Learning Attitudes about Science Survey (CLASS)

Applying the guidelines set forth by the literature on student attitudes toward science supports the methods I investigated the third and final research question (*Does the fidelity of JiTT implementation correlate with student perceptions of their physics course?*) Uncovering how different instructors enact various pedagogies, like JiTT, may open a door to better understand how instruction influences student beliefs about their physics course. Many students have negative attitudes about introductory physics and some leave a university introductory mechanics course more confused about the content than when they entered (Adams et al., 2006; Perkins et al., 2005; Redish et al., 1997; Redish et al., 1998). This could be due to the fact that the process students go through to build their knowledge of the way the world works often does not resonate with the way their instructors expect them to develop their knowledge (Redish et al., 1998).

Each individual student walks into a physics classroom with an established set of expectations, attitudes, and beliefs about (1) what skills they require to succeed, (2) what they will learn, and (3) what will be expected of them in their physics class. When student expectations do not match instructor expectations, it is likely that the student will exit the course with a deteriorated attitude toward the subject (Redish et al., 1998).

Adams et al. (2006) designed an instrument called the Colorado Learning Attitudes about Science Survey (CLASS). This inventory is commonly used within the Physics Education Research community as a pretest-posttest measure. The CLASS assesses undergraduate student views of physics by asking them to respond to 42 five-point Likert scale survey statements such as "To learn physics, I only need to memorize important equations and definitions." Adams et al. (2006) included the following eight categories of questions:

1. Real World Connection
2. Personal Interest
3. Sense Making/Effort
4. Conceptual Connections
5. Applied Conceptual Understanding
6. Problem Solving (General)
7. Problem Solving (Confidence)
8. Problem Solving (Sophistication)

Adams et al. (2006) found that instructors who make just a humble effort to discuss their students' beliefs in class saw markedly higher results in attitudes (they at least remained constant or did not decrease) compared to instructors who made no such effort. Additionally, students who put more effort into studying physics tended to view physics as being more germane to their personal lives. The authors also reported that students who took more advanced levels of physics courses produced higher initial CLASS scores, and that men tend to have higher "Personal Interest" scores than women, which falls in line with the known gender gap in undergraduate physics. Finally, Adams et al. (2006) caution that most pedagogical approaches to teaching physics have a "detrimental impact" on the various attitudes students have about what they must be able to do in order to succeed in a physics course; hence, my motivation to explore the influence the JiTT pedagogy has on student attitudes.

In another study using CLASS in calculus and algebra-based introductory physics courses, Perkins et al. (2005) found that incoming attitudes associated with "Personal Interest" were more favorable for science majors than non-science majors (74% versus 54%), indicating that those majoring in a science made greater commitments to studying physics because it was more relevant to their personal interests than to the interests of the non-science majors. Additionally, the authors reported that those non-science majors who enrolled in and remained in the second semester course had larger favorable "Personal Interest" scores than those who dropped the class (64% versus 49%), signifying that a relationship exists between favorable views of science and student retention in scientific disciplines.

Perkins et al. (2005) go on to investigate how student attitudes toward individual belief categories correlated with learning gains as measured by the Force Concept Inventory (FCI). It is important to note here that the authors concede that their results are valid for a very specific sample population, in a given learning environment, using certain test measures (e.g., FCI as opposed to another mechanics inventory, like the Force and Motion Conceptual Evaluation). Their correlations are not necessarily generalizable to another unique population; however, they are useful in establishing the types of relationships that can exist between learning and student attitudes. They concluded that students' conceptual learning gains are positively influenced by their incoming beliefs about science: the more favorable their attitudes, the greater the conceptual gains they obtained. A caveat to this is that there could potentially be coinciding confounding factors that influence both beliefs and conceptual learning, but these have yet to be studied.

A common motivation for the use of the CLASS and other inventories like it, such as the Maryland Physics Expectations (MPEX), is to investigate how varying instructional strategies influence student attitudes toward science. Using one of these inventories can help measure the possible affects the JiTT pedagogy has on student perceptions of undergraduate physics courses. Perhaps there are particular aspects of JiTT that lend themselves to improving student attitudes toward physics. If those characteristics are extracted, harnessed, and enhanced we may find evidence for ways to enrich the implementation of JiTT and ultimately create more favorable student views about the physics discipline. Below is a table summarizing the conceptual schemes at the foundation of this JiTT research.

Table 2.8 Summary of Theoretical Frameworks Supporting JiTT Study

Research Question	Framework	Intended Study
1: *With what degree of fidelity is Just-in-Time Teaching implemented in undergraduate physics classrooms?*	Fidelity of Implementation & Diffusion of Innovation	Investigating how instructors carry out critical components of the pedagogical innovation, Just-in-Time Teaching, in their undergraduate physics lessons.
	Technical Pedagogical Content Knowledge	Investigating how teachers make use of and integrate the Web-based component of JiTT in their lessons.
2: *Does a relationship exist between JiTT implementation and student performance?*	Preparation for Future Learning	Investigating how JiTT pre-class assignments prepare students for class.
3: *Does the fidelity of JiTT implementation correlate with student perceptions of their physics course?*	Student Attitudes Toward Science	Investigating how the methods instructors use to integrate JiTT into class influences student beliefs about their physics course.

2.5 Prior Studies on Just-in-Time Teaching

2.5.1 JiTT in Introductory Electricity and Magnetism

Stelzer et al. (2009, 2010) conducted a two-week study with 45 students enrolled at the University of Illinois, Urbaba-Champaign, where they analyzed how integrating multimedia learning modules with JiTT questions influenced student performance and attitudes toward a calculus-based introductory electricity and magnetism course. Multimedia learning modules are narrated online illustrations that contain equations and optional coordinating animations that students can play from the slide. Before advancing to the next slide, students must answer a JiTT question. The authors added the multimedia learning module element to their pre-class work, because their data showed that students were not answering JiTT preflights from an "informed perspective." Rather, students were answering the questions just to get completion points or using only their common sense reasoning. I believe the latter observation is not a deficiency in the JiTT method. When students use their intuition—even if it is incorrect—is informative for instructors because it signifies content areas where students reveal weak comprehension.

From post lecture assessment data, Stelzer et al. (2009, 2010) found statistically significant evidence that students who use multimedia learning modules combined with embedded JiTT questions at the end of each slide performed better and retained more information. They attributed this to the idea that pre-class multimedia learning modules reduce cognitive load, resulting in a stronger introduction to physics material than the typical pre-class textbook exercises. Comparing traditional lecture techniques to the use of a combined multimedia learning module "plus JiTT" strategy, the authors also reported student attendance and attitude toward physics increased, and the perceived difficulty of the course decreased for students exposed to the reformed teaching strategy.

2.5.2 JiTT in Introductory Geology

Linnemn & Plake (2006) conducted a 120-student study in an introductory geology course at Western Washington University. Two instructors taught the same course during the same semester, but one teacher used the JiTT pedagogy and the second taught the control class using a traditional lecture format. The authors reported a high student completion rate of JiTT assignments (>90%) and increased class attendance in the JiTT section. They also felt that students in the JiTT class read the textbook more regularly, yet not necessarily more comprehensively.

Linneman and Plake (2006) found no statistically significant evidence that student achievement or attitude toward the discipline improved. Although they originally planned to conduct a follow-on study of long-term retention, they were unable to maintain enough participants to carry out this part of their research. Even though JiTT did not significantly improve student performance on graded measures, the authors continued enacting the JiTT strategy in their introductory geology classes, mainly because they saw benefits in perpetuating the active learning environment and because of the initial time investment in creating the JiTT materials.

2.5.3 JiTT in Introductory Psychological Statistics

Benedict and Anderton (2004) conducted a 120-student study in a psychological statistics course at James Madison University. The same instructor taught the same curriculum over two semesters where one offering was a reformed class that used JiTT and the other a traditional lecture class. They reported statistically significant evidence that student achievement (final exam) and attitude (Likert-type questionnaire) toward the discipline improved. It must be noted that the authors felt that the quasi-experimental format of the design and potential bias resulting from the same instructor teaching both courses and could have skewed the results. However, the authors felt the JiTT approach created a meaningful classroom experience for students because they received immediate feedback to their questions during class. The main disadvantages cited were (a) the time required to develop the web material from scratch, and (b) the one to two hours per week of additional teacher prep time. Despite this supplemental workload, the department went on to expand JiTT use to general psychology and research methods courses.

Chapter 3 - Research Design and Methodology

This chapter reviews the procedures and methods followed to carry out my investigation of Just-in-Time Teaching in undergraduate physics. The review begins with a description of the setting and course structure in place at the United States Air Force Academy followed by an overview of the population of interest and the sampling frame. Next, I expound upon the methods of sampling faculty and student participants. This is followed by an overview of the instrumentation and data collection methods used for both faculty and student participants. Finally, the procedures and scheduling of the study are outlined.

3.1 Research Setting and Course Structure

This study took place in Colorado Springs at the United States Air Force Academy, a military college with an enrollment of approximately 4,000 undergraduate students. I chose to conduct my research at this institution because I taught introductory courses in their physics department for five semesters and, more importantly, JiTT is engrained in their calculus-based introductory, or *core*, physics curriculum. In recent years, a few upper-division courses and an introductory meteorology course began integrating preflights into their curricula as well. This enabled me to I investigate how JiTT is used in classes other than introductory electricity and magnetism or introductory mechanics. For the purpose of this study, a *non-core* physics course is any course other than introductory electricity and magnetism or mechanics courses that is taught by a physics faculty member. Since the meteorology major is shared between the Department of Physics and the Department of Economics and Geosciences at the United States Air Force Academy, one section of an introductory meteorology course fell within the purview of this research.

The Air Force Academy operates on a semester basis covering 40 lessons per term. Each class period runs for 53 minutes. The class schedule is an every-other-day rotation, not the traditional Monday–Wednesday–Friday and Tuesday–Thursday schedule that exists at most other institutions of higher education. One way to envision this is to assume “A” days and “B” days. If students have an A-day class on a Monday, those students will have it again on Wednesday and Friday; however, A-day classes will not meet again until the following Tuesday and rotate accordingly from there. Likewise, if a B-day class starts its week on a Tuesday, it will meet again on Thursday and again on the following Monday. The schedule continues to alternate like so.

The average physics class size at this school varies as follows: core courses range from a 15:1 to a 25:1 student-teacher ratio, while non-core courses range from a 6:1 to a 14:1 student-teacher ratio. Since every single class period is 53-minutes five days a week, each student is exposed to equal durations of lesson periods.

Both of the core physics courses under investigation are double-periods (i.e., 106 minutes); however, the only instances when instructors are permitted to use both periods back-to-back occur during lessons when either an exam or a laboratory exercise is scheduled. To protect student time, the Dean of the Faculty allocates only 11 of the 40 lessons to be mandatory double-periods. Non-exam and non-laboratory lessons use only the first half of the double-period block for instruction, and the second period is treated as an optional study hall. During this time, students may leave or they may remain in the room to work on physics assignments with the instructor present to provide assistance when needed. Students may alternatively choose to complete other schoolwork during this period. There are no recitation sessions, studios, or teaching assistants for any of the physics courses at the Air Force Academy. For this reason, most core instructors treat the second period as a recitation-like environment where she/he acts as the teaching assistant, circulating around the room helping students who choose to stay with their physics assignments.

Core courses are a combination of interactive and lecture-style instruction with occasional laboratory exercises interspersed throughout the semester. Typically, seven or eight lessons are reserved throughout the semester solely for conducting laboratory experiments. Students are assigned a preflight every lesson except for days when an exam is administered. The preflight is one piece of a three-part pre-class assignment. In addition to submitting answers to an online preflight, a core physics student is also expected to (1) complete a Worked Example worksheet with questions related to an example that is worked out in the textbook, and (2) solve a pre-class workout problem from the back-of-the-chapter. All three parts of the pre-class assignment are graded solely for effort

Core students are also provided a paper copy of the preflight questions in their required course journal, a spiral bound workbook-like publication that the Air Force Academy Department of Physics developed. Within the journal, each lesson reserves pages where students can take notes, write questions about the concepts they will cover in class, and/or work out solutions to problems that require calculations. The journal also includes copies of the pre-class assignments for each lesson. This includes the Worked Examples questions, the pre-class workout problem, and the preflight questions.

The non-core courses in this study complete only online preflight assignments as part of their pre-class work for each lesson. They are not responsible for the additional pre-class work described above for the core classes.

Preflight assignments are worth between six and almost 10 percent of a student's grades, depending on the course in which she/he is enrolled. Examples of preflight assignments are found in Appendix A. Also in Appendix A is a table summarizing how much the pre-class work is worth in each course in this study. Note that preflights are worth more in the non-core classes where preflights are the only pre-class work students are assigned.

Students create an online username and password to access the local JiTT server where preflights are managed on site. For any given lesson, its associated preflight is available to students for a maximum of 48 hours prior to that lesson. This prevents students from entering their answers to multiple preflight assignments too far in advance. One of the goals of the JiTT pedagogy is to encourage students to review course materials before coming to class. Accessing preparatory readings and example problems shortly before a lesson keeps the content fresh in student minds.

In the past, regardless of the time of day a student has her/his physics class, the window of opportunity to complete a preflight assignment ends at 7:00 am on the morning of the lesson for which it is due. However, during this study, individual core physics instructors were permitted to alter the time at which a preflight assignment would be closed to students. For instance, a first period instructor may choose to close preflights the evening prior to a lesson to allow for more time to review student responses. Or an afternoon instructor may wish to allow her/his students more time to complete the assignments, so she/he may leave the preflights open longer.

3.2 Sampling Frame

The target population consisted of undergraduate physics faculty and undergraduate students enrolled in either a core or non-core physics course. The majority of students taking introductory electricity and magnetism do so during the fall semester of their sophomore year, and it is considered the fall on-cycle core course. During this study, 692 students completed introductory electricity and magnetism. Introductory mechanics is the smaller of the two fall semester core courses and is therefore coined the fall off-cycle core course. During this study, 349 students completed introductory mechanics. These enrollment estimates include both *regular* and *honors* sections of each course.

Students who find themselves off the traditional course sequence do so for reasons such as validation (testing out) of a course or repeating a course as a result of the failure to pass the class. Passing the two semesters of core physics is a graduation requirement for all students attending the Air Force Academy, regardless of the student's major area of study.

During an on-cycle core course, about 15 different faculty members share the teaching load by each covering one to three sections of the course. During an off-cycle core course, approximately 10 different faculty members share the teaching load by each covering one to three sections of the course.

Advanced level physics courses see a total enrollment between six and 14 students each with their sections experiencing sizes within the same range of students (C. L. Enloe, personal communication, May 6, 2015). Advanced meteorology courses have a total enrollment between three and nine students each, while introductory meteorology courses can surpass 20 students. Section sizes range from three to 20 students (D. Vollmer, personal communication, May 6, 2015). All of the aforementioned ranges vary depending on the content area and semester. Upper-division and meteorology courses typically have a single instructor who, if the enrollment is large enough, may teach multiple sections of her/his course. Within the United States Air Force Academy Department of Physics, only the following three non-core classes are reported to incorporate the JiTT pedagogy:

1. PHY 370: *Upper Atmospheric and Geo-Space Physics*
2. PHY 486: *Astrophysics*
3. MET 230: *Introduction to Meteorology and Aviation Weather*

(N. Terry, personal communication, January 14, 2014). Therefore, two non-core physics instructors enact JiTT in their teaching practices at this research. The same instructor teaches both PHY 370 and PHY 486.

During the Summer 2014 term, I conducted a pilot study of an electricity and magnetism course consisting of one section of 29 students. Typically, one faculty member directs the summer course, which may have a range of one to four instructors who share the teaching load. Although, four summer instructors were available, I asked for only one to volunteer to participate in the faculty portion of the pilot study. This entailed allowing me to observe her/him while teaching, her/his completion of the online instructional strategies questionnaire, and participation in a one-on-one interview. I then exempted this instructor from participating in the primary Fall 2014 research.

3.3 Participant Sampling

When selecting participants for this study, the goal was to create as little impact as possible on faculty and student time as well as on their respective teaching and academic duties and responsibilities. I designed data collection tools such as the online questionnaires, faculty interview protocols, and focus group protocol such that they would garner as much information as possible without disinclining students or instructors from continuing their participation.

At the conclusion of the Fall 2014 semester, I collected all core physics grade and inventory data from the Air Force Academy's Center for Physics Education Research director. These data included preflight, homework, quiz, laboratory, midterm, final exam, and final course averages as well as course order of merit. Similar data were collected from two additional participating non-core instructors. I also received scores from core physics concept and attitude inventories. Prior to engaging in data collection, and in accordance with both the Air Force Academy's and the Kansas State University's Institutional Review Boards, student and faculty participants were informed of their rights, the nature of the research, and the types of protocols used to obtain information from them.

3.3.1 Student Sampling Methods

I carried out the student recruitment process quite carefully and in a way that would not make students feel coerced by their instructor to join the research project. A total of 1,082 students received the an email containing a link to the online student preflight questionnaire, which is discussed in greater detail in Section 3.4.2.1. This included every student enrolled in a regular or honors core physics course as well as those enrolled in *Upper Atmospheric and Geo-Space Physics* and one section of *Introduction to Meteorology and Aviation Weather*. To complement the quantitative grade, inventory, and student preflight questionnaire data, I conducted six focus group interviews with students. By submitting their email address at the conclusion of the online preflight questionnaire, students volunteered to participate in a focus group that took place during the second half of their double-period physics class. I worked with non-core volunteers on an individual basis to find times when they could meet with one of the established focus groups.

Stewart et al. (2009) recommend an effective focus group consists of six to 12 members. Anticipating some decrease in participation, I accepted a maximum of 13 students in each focus group. This allowed for some students to drop out without affecting the quality of discussion. A total of 45 core students and two non-core students attended a focus group discussion.

Since this research does not deliberately investigate the effects of gender, race, or ethnic differences in student perceptions and performance, I made no effort to stratify the focus groups by such demographics. Rather, the convenience sample was purely based on the number of available volunteers and the course in which they were enrolled (Creswell, 2013). The table below summarizes the student samples for this research.

Table 3.1 Student Sampling Frame

Course	**Timeframe**	**Data Source**	**Number of Participants (*n*)**
Physics 215 (*Regular*) Calculus-Based Core Electricity and Magnetism	Fall 2014	Grades	257
		Conceptual Survey of E&M (CSEM)	161
		Colorado Learning Attitudes about Science Survey (CLASS)	211
		Preflight Questionnaire	257
		Focus Group	16
Physics 215H (*Honors*) Calculus-Based Core Electricity and Magnetism	Fall 2014	Grades	136
		Conceptual Survey of E&M (CSEM)	80
		Colorado Learning Attitudes about Science Survey (CLASS)	93
		Preflight Questionnaire	136
		Focus Group	0
Physics 110 (*Regular*) Calculus-Based Core Classical Mechanics	Fall 2014	Grades	136
		Force Concept Inventory (FCI)	73
		Colorado Learning Attitudes about Science Survey (CLASS)	112
		Preflight Questionnaire	136
		Focus Group	7
Physics 110H (*Honors*) Calculus-Based Core Classical Mechanics	Fall 2014	Grades	95
		Force Concept Inventory (FCI)	54
		Colorado Learning Attitudes about Science Survey (CLASS)	76
		Preflight Questionnaire	91
		Focus Group	22

Introduction to Meteorology and Aviation Weather	Fall 2014	Grades Preflight Questionnaire Focus Group	12 12 1
Upper Atmospheric and Geo-Space Physics	Fall 2014	Grades Preflight Questionnaire Focus Group	12 12 1

3.3.2 Faculty Sampling Methods

The faculty research was open to JiTT-users as well as faculty members who do not use the JiTT pedagogy in their teaching practice. To garner participation, I prepared a flyer, which is included in Appendix B, advertising how all faculty members within the Department of Physics at the Air Force Academy were eligible to participate in the study. I placed a copy of the flyer, which was printed on light blue paper and had my business card stapled to it, under the office door of every physics faculty member to include three fulltime tutors who each taught at least one section of a physics course for the department. The flyer informed faculty—even those instructors who do not use preflights—that they could complete the online instructional strategies in undergraduate physics questionnaire, participate in a one-on-one interview with me, and/or have their classroom teaching observed. Since I was interested in determining whether some instructors used JiTT yet may not have realized that what they did is actually a branded research-based instructional strategy, I encouraged even non-JiTT users to participate in the study.

Following the distribution of the paper advertisement, I sent an email to each physics instructor that included a link to the faculty questionnaire. I also advertised the study by verbal communication within the department. This entailed answering questions about the study by personally visiting offices and having casual conversations within the department. Faculty members received no incentive to complete the questionnaire or allow me to observe their teaching; however, I did offer light refreshments to those instructors who agreed to let me interview them. The provided snacks were paid for out of pocket. The conclusion of the study fell near a department-wide meeting, and at that meeting I provided lunch for the entire physics department as a token of gratitude for allowing me to use their space and resources to collect my research data.

In an effort to look at a spectrum of JiTT-users and non-users and based on faculty responses to the instructional strategies in undergraduate physics questionnaire, I had originally intended to follow Creswell's (2013) guidance for selecting a random stratified sample of instructors to interview individually; however, only half (n = 6) of the anticipated number of physics faculty members agreed to let me interview them. Therefore, I instead accepted any and all instructors who agreed to let me interview them without a purposeful selection based on their teaching experience or use of JiTT.

I made every effort to observe each instructor teach at least three lessons prior to interviewing them. The table below summarizes the faculty samples. The regular and honors courses are not separated because the faculty survey did not offer an answer option that distinguished regular core instructors from honors core instructors.

Table 3.2 Faculty Sampling Frame

Course	Timeframe	Data Source	Number of Participants (*n*)
Physics 215 and 215H (*Regular* + *Honors*) Calculus-Based Core Electricity and Magnetism	Fall 2014	Instructional Strategies Questionnaire	7
		Classroom Observation	8
		Interview	1
Physics 110 and 110H (*Regular* + *Honors*) Calculus-Based Core Classical Mechanics	Fall 2014	Instructional Strategies Questionnaire	11
		Classroom Observation	5
		Interview	2
Non-Core Courses	Fall 2014	Instructional Strategies Questionnaire	3❖
		Classroom Observation	3✚
		Interview	3❖

❖*Includes PHY 264 (Modern Physics), PHY 486 (Astrophysics), and MET 430 (Atmospheric Dynamics I).*
✚*Includes PHY 486 (Upper Atmospheric and Geo-Space Physics), MET 320 (Introduction to Meteorology and Aviation Weather), and MET 330 (Physical Meteorology I).*
❖*Includes PHY 264 (Modern Physics), PHY 486 (Upper Atmospheric and Geo-Space Physics), and MET 320 (Introduction to Meteorology and Aviation Weather).*

3.4 Instrumentation

To accurately and adequately assemble data for this project, I employed a blend of quantitative and qualitative methods to collect information from physics faculty and students about how the JiTT pedagogy is implemented in physics classrooms. The following subsections more explicitly describe each instrument and approach.

3.4.1 Data Collection Methods for Faculty

3.4.1.1 Instructional Strategies in Undergraduate Physics Questionnaire

The Instructional Strategies in Undergraduate Physics Questionnaire I employed was an adaptation of the Research-Based Instructional Strategies in Engineering Survey first developed by Borrego & Cutler (2013) and was described in detail in the review of literature's Section 2.1.2. Only surface-level changes were made to their questionnaire. For example, where "engineering" appears in the original survey, I substituted "physics." I also replaced the engineering courses, societies, and conferences that are referenced with more appropriate or equivalent physics options. In order to gain Institutional Review Board approval of its use at the United States Air Force Academy, I replaced the term "survey" with "questionnaire" wherever it appeared. Finally, in an effort to eliminate the possibility that the inclusion of the "Research-Based" portion of the original title might in some way influence participant responses, I removed it.

Kansas State University maintains a license with the online survey software platform, Qualtrics. Given the capabilities available through Qualtrics, I mirrored as closely as possible the logic used in Borrego and Cutler's (2013) original survey. Once I built the revised questionnaire in Qualtrics, I shared my online version with one of its original authors and successfully gained her approval of my modifications to their work (S. Cutler, personal communication, April 17, 2014). A copy of the faculty questionnaire I administered is included in Appendix C.

All physics faculty members received an invitation email with a link to the questionnaire. The survey was open and available to physics faculty members for three weeks. Since the questionnaire is rather long (approximately 60 questions), respondents had the ability to start the survey and return to it at a later date and time to complete it. The response rate dictated when and how often I sent reminder emails to those who had not yet completed the questionnaire. Following Dillman's (2009) social exchange theory recommendation, I worded my invitation and follow-up reminder emails carefully so as not to put off the faculty thereby discouraging them from responding to the questionnaire. I sent automatically generated thank you emails to those instructors who submitted a completed questionnaire.

3.4.1.2 Faculty Interview Protocols

My goal was to keep the one-on-one faculty interviews under 45 minutes so that a conversation could begin and end comfortably within the timeframe of a single 53-minute class period; therefore, I limited the interview protocols to a maximum of eight main questions that could be further probed where appropriate with two or three sub-questions. Completing the online questionnaire was a prerequisite for the interview. Additionally, as mentioned earlier, I made every effort to observe faculty prior to interviewing them, but this was not always feasible given teaching schedules and my availability.

Based on the Summer 2014 pilot study, I created two versions of the interview protocol. I followed Version A for faculty members who were JiTT users while Version B guided my interviews with non-JiTT users. I took the liberty to modify the interviews based on the responses collected in the interviewee's responses to the online questionnaire. I provided a paper copy of the interview questions to the interviewees at least 24 hours prior to their scheduled interview. In one unique case, a faculty member approached me and asked if I could interview her/him on the spot without prior knowledge of the interview questions. Only two of the interviewees allowed me to audio record their interviews. Versions A and B of the faculty interview protocol are included in Appendix D.

3.4.1.3 Classroom Observation Protocol

Classroom observations served to corroborate what instructors reported in the research-based instructional strategies questionnaire and the individual interviews. I aimed to uncover the views instructors have of their ability to tailor lessons to individual class sections based on student responses to preflight questions. Observations were also an avenue through which differences in the methods that novice and experienced JiTT users utilized when integrating preflights into their respective classes. Along these lines, it might have been revealing to observe non-JiTT users who could potentially highlight areas where faculty use JiTT-like elements in their teaching but may not be cognizant of it. Unfortunately, no non-JiTT users opened their classroom to my observations for this portion of my study. Finally, first hand observations allowed me to investigate overarching patterns and methods of JiTT implementation in undergraduate physics courses. The classroom observation protocol is listed in Appendix E.

3.4.2 Data Collection Methods for Students

3.4.2.1 Student Preflight Questionnaire

Initially I had intended to invite students within the sample population to complete the online preflight questionnaire either (a) as part of an in-class exercise for no points toward the course grade and without the instructor present, or (b) in place of a preflight exercise for the equivalent point value of a preflight assignment. However, course directors did not approve either option. The latter incentive technique might have unintentionally influenced student responses to the questions; therefore, students were asked to complete the questionnaire on their own time and with no incentive.

Following guidelines set forth by *Internet, mail, and mixed-mode surveys: The tailored design method* (Dillman et al., 2009), the student questionnaire is a collection of 15 original questions probing student views about the way preflights influence their preparation and learning in their physics course. It also sought to uncover the perceptions students have about the way their instructor integrates preflights into their lessons. The questionnaire included the following breakdown of question type: seven Likert-type questions (based on a six-point scale), five single answer multiple choice questions, two select-all-that-apply questions, and one open-ended narrative question.

Based on feedback received during the summer pilot study in the form of cognitive interviews conducted with two physics instructors as well as a recent Air Force Academy graduate, the student questionnaire was edited to make question stems and their response options as clear as possible to those completing the questionnaire. During the pilot study's focus group, I also asked students for feedback on the administration and wording of the online questionnaire. To maximize the validity of the instrument, I integrated student and faculty input into the final version of the questionnaire wherever appropriate and feasible.

At the conclusion of the student preflight questionnaire, I included a response option where students had the opportunity to submit their interest in participating in a follow-up focus group by submitting their email address. The student preflight questionnaire is included in Appendix F.

3.4.2.2 Student Focus Group Interview Protocol

The goal of the student focus groups was to further explore the beliefs students have about preflights and their implementation during physics classes as reported in the student preflight questionnaire. As incentive for participation, I offered light refreshments at each of the six focus groups conducted. I followed guidelines set forth in *Focus groups: Theory and practice* (Stewart et al., 2009) when designing and carrying out my focus group protocol. At the beginning of each focus group, I summarized trending responses to the student preflight questionnaire and asked participants to elaborate more about their experiences using JiTT in their physics classes.

To respect student time and keep students to their academic schedules, I made every effort to keep the focus group interviews under 50 minutes so that a fruitful discussion could begin and end comfortably within the timeframe of a single 53-minute class period; therefore, I limited the interviews to 10 main questions that could be further probed where needed. The focus groups consisted of a combination of mechanics as well as electricity and magnitude students. One focus group contained one student from an advanced physics course while a second focus group included one student from an introductory meteorology course. These were the only two students with non-core JiTT exposure who volunteered to participate in a focus group.

Based on feedback from the pilot study, I elected to not provide a copy of the focus group interview questions to the volunteer participants prior to their scheduled interviews. Students from the summer study admitted that they did not read the questions I provided before attending the focus group. All of the students participating in both the summer and fall studies agreed to allow me to audio record their interviews. The student focus group interview protocol is in Appendix G.

3.4.2.3 Modified Colorado Learning Attitudes about Science Survey (CLASS)

The Colorado Learning Attitudes about Science Survey (CLASS) is described in detail in Section 2.4.1. One issue stands out about this type of inventory: are students answering questions as they actually believe or as they think their instructor expects them to? Adams et al. (2006) looked into this dilemma and found that by the end of a term, a student can identify an expert response to a question on the inventory, but their personal belief does not resonate with what they think an expert physicist would say. The authors measured this by having students provide two answers to the CLASS questions. One answer reflected the students' personal belief while the second response indicated what the students thought an expert would say. When Adams et al. (2006) compared the responses students provided to the single-answer CLASS administration to the responses students provided in the double-answer format, they found that students tended to align their responses with '"What do YOU think?" rather than to "What would a physicist say?"' when they answered CLASS questions.

Each student's pretest and posttest scores are determined by calculating the percentage of responses for which the student agrees with the experts' view" (Adams et al., 2006). This is considered the “percent favorable” score. Likewise, the “percent unfavorable” score is found by calculating the percentage of responses for which the student disagrees with the expert beliefs.

It is important to note that the Air Force Academy Department of Physics administers a *modified* version of the CLASS to its core physics students. This is a set of 20 questions, which is reduced from the original 42 CLASS questions. Therefore, the CLASS scores used in this study should not be compared to scores from other studies using the CLASS. The modified CLASS maintains the following 17 CLASS (Version 3) questions: 1, 2, 5, 8, 10, 12, 13, 14, 20, 22, 24, 26, 28, 33, 34, 35, and 37. The department also added the following three questions to the end of their modified CLASS: 1) “I am confident in my abilities to solve physics problems.”; 2) “I am afraid to ask questions in class.”; and 3) “I am always worried about being called on in physics class.” These modified version’s questions map to the following eight categories from the original CLASS instrument:

1. Real World Connection [Questions 13, 16, 17]
2. Personal Interest [Question 13]
3. Sense Making/Effort [Question 11]
4. Conceptual Connections [Questions 1, 3, 7]
5. Applied Conceptual Understanding [Questions 1, 3, 4, 10]
6. Problem Solving (General) [Questions 7, 12, 15]
7. Problem Solving (Confidence) [Questions 15, 18, 19, 20]
8. Problem Solving (Sophistication) [Questions 3, 10, 15]

The modified CLASS inventory used for this study is included in Appendix H.

3.4.2.4 Force Concept Inventory (FCI)

The Air Force Academy Department of Physics utilizes the widely accepted Force Concept Inventory (FCI, August 1995 version) to assess common misunderstandings physics students hold about six overarching Newtonian physics concepts (Hestenes et al., 1992). The six key concept areas include the following (Hestenes et al., 1992):

1. Kinematics
2. Newton’s First Law
3. Newton’s Second Law
4. Newton’s Third Law
5. Superposition Principle.
6. Kinds of Force (solid, fluid, and gravitational contact)

The inventory contains 32 multiple choice questions that address six "common sense" knowledge categories with which students tend to struggle. These are listed below (Hestenes et al., 1992):

1. Kinematics
2. Impetus
3. Active Force
4. Action/Reaction Force Pairs
5. Concatenation of Influences
6. Other Influences on Motion (resistance and gravity)

Hestenes et al. (1992) purposefully selected incorrect multiple choice answer options for the FCI questions so they would serve as "distractors" that—when selected—would reveal specific misconceptions students hold about the concept a particular question assesses. When administered in a pretest—posttest fashion, Hake (1992) demonstrated how instructors and/or researchers can calculate the average normalized gain to disclose changes in students' conceptual understanding of Newtonian physics. Hake (1992) defines normalized gain, <g>, as the ratio between the actual average gain in scores and maximum possible average gain in scores. The mathematical representation for normalized gain is listed below.

$$< g > = \frac{\% < G >}{\% < G >_{max}} = \frac{[(\%posttest\ ) - (\%pretest)]}{[100 - \%pretest]}$$

A copy of this instrument is not included in the appendix because this dissertation will become public, and I do not wish to compromise the integrity of the inventory.

3.4.2.5 Conceptual Survey of Electricity and Magnetism (CSEM)

To assess common misunderstandings physics students hold about 11 overarching electricity and magnetism concepts, the Air Force Academy Department of Physics uses the commonly accepted Conceptual Survey of Electricity and Magnetism (CSEM, Version Form H) (Maloney et al., 2001). The 11 key concept areas include the following (Maloney et al., 2001):

1. Charge distributions on conductors and insulators
2. Coulomb's Force Law
3. Electric Force and Field Superposition
4. Force Caused by an Electric Field
5. Work, Electric Potential, Field, and Force
6. Induced Charge and Electric Field

7. Magnetic Force
8. Magnetic Field Caused by a Current
9. Magnetic Field Superposition
10. Faraday's Law
11. Newton's Third Law.

The inventory contains 32 multiple choice questions that address "common sense" knowledge categories. Like the FCI authors, Maloney et al. (2001) purposefully chose incorrect multiple choice answer options for the CSEM questions. These too serve as "distractors" that—when selected—reveal specific misconceptions students hold about the concept a particular question evaluates. Maloney et al. (2001) also calculate class gains in CSEM scores using the following formula:

$$< g > = \frac{\% < G >}{\% < G >_{max}} = \frac{[(\%posttest) - (\%pretest)]}{[100 - \%pretest]}$$

This equation is the same as that listed for the FCI. As with the FCI, a copy of this instrument is not included in the appendix because this dissertation will become public, and I do not wish to compromise the integrity of the inventory.

3.5 Procedures and Timing

3.5.1 Faculty Research Procedures and Timing

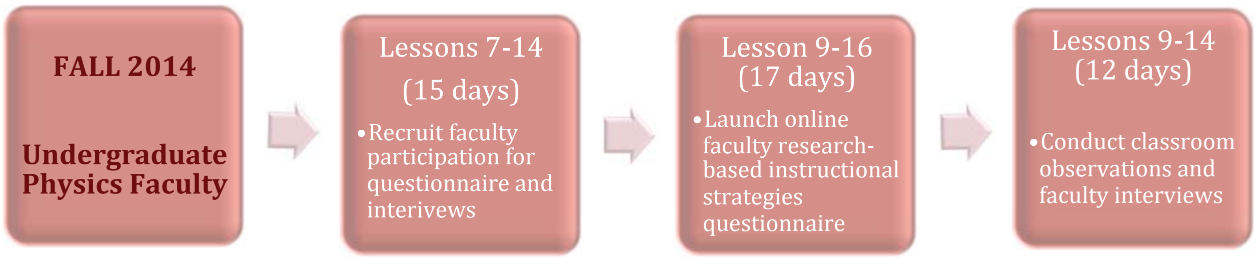
Section 3.3.2 outlines precisely how I recruited faculty research participants. Solicitation began in the Spring 2014 semester and Summer 2014 pilot study when I verbally announced to faculty members that I would conduct a doctoral study of the fidelity of JiTT implementation in undergraduate physics courses during the Fall 2014 semester. Immediately upon my Fall 2014 arrival on-site at the Air Force Academy Department of Physics, I distributed the faculty recruitment flyer described in Section 3.3.2 and found in Appendix B. I subsequently initiated data collection by launching the online faculty Instructional Strategies in Undergraduate Physics Questionnaire on 8 September 2014. This corresponds to the end of the first quarter of the semester. The faculty questionnaire was originally available until 19 September 2014 (12 days), but a low initial response rate prompted me to extend faculty access to the questionnaire to 30 September 2014, which equates to 23 total days. Therefore, on 22 September 2015, I sent a reminder email to only those faculty members who had not yet responded informing them that the survey had been extended to 30 September 2014. This increased faculty participation from 15 to 21 respondents resulting in a 70% faculty response rate.

Since I did not receive as many faculty interview volunteers as I had originally expected, I was unable to select from the pool of volunteers a purposeful sample of new, experienced, and non-JiTT users to interview. Therefore, regardless of their experience level or use of JiTT, I interviewed all six volunteers. As faculty signed up to participate in one-on-one interviews with me, I reminded them that they had to first complete the online questionnaire prior to the interview. This allowed me to review their responses and use them to complement and inform the questions already included in the faculty interview protocols. My first interview took place within the office of the faculty member with whom I was speaking. However, we were constantly interrupted by personal cell phone calls and emails accumulating in the instructor's inbox. Therefore, from that point forward, to limit interruptions and distractions, the subsequent five interviews took place in the office space the department set aside for my use during the study.

Classroom observations began on 10 September and ran through 24 September. The lecture portion of all core physics courses is taught during the first, third and sixth period of each A-day and B-day; therefore, I could observe a maximum of three core classes per day. The two non-core courses that are a part of this study took place during the second and seventh period of B-days, so this did not conflict with the observation schedule. I sat at the rear of the classrooms so as not to distract instructors or students with my presence. Occasionally, while students were working out problems at the boards in my proximity, they would ask me for help. Rather than ignore them or tell them I could not interact with them, I responded and offered my guidance and advice to assist their problem solving endeavors. The instructors did not appear to mind my engagement with their students. In fact, they seemed to appreciate the extra tutelage.

I did not conduct any observations on the two days during which I conducted focus groups even though they occurred during the second half of core physics classes. Instead I used the time between focus groups to reflect on the discussions and to prepare for the next set of students. Figure 3.1 captures the timeline of events for the faculty research portion of this study.

Figure 3.1 Fall 2014 Faculty Research Schedule



3.5.2 Student Research Procedures and Timing

Section 3.3.1 explains the procedures I followed to recruit student participants. This began one week prior to the launch of the online student preflight questionnaire. I personally visited 37 of the available 44 sections of core physics classes and two non-core courses where I briefly shared the purpose of this study and how students could participate by confidentially completing the online student preflight questionnaire and/or talking with me in a focus group setting. Prior to my entrance in their classrooms, I received verbal permission from each faculty member to address their individual sections. Additionally, I promoted the study during either the first five minutes or last five minutes of classes so as not to disrupt the flow of lessons.

The student questionnaire was available for seven days. Given the high initial response rate, I did not feel it was necessary to extend the window of time that students had to complete the questionnaire. I used student feedback from the questionnaire to complement the focus group interview questions in an effort to address outstanding trends in student responses. At the start of each focus group, I highlighted these common student reports and probed those in attendance to explain why a majority of students might share similar sentiments.

As explained in Section 3.4.2.1, students volunteered to participate in one of six focus groups by submitting their email address via the online student preflight questionnaire. The 47 focus group volunteers were grouped based on the period of the school day during which their physics class was scheduled. This way, they would be free to attend the focus group if it was scheduled during the second half of their double-period core physics class. This was the most convenient time for core physics students. It was slightly more challenging to coordinate schedules for the two non-core students who volunteered to participate in a focus group, but I was able to find a time when those two interested parties could join a group of core students.

Of note, the honors sections of the introductory electricity and magnetism courses had a laboratory exercise that conflicted with the days the focus groups were scheduled. Therefore, students who volunteered to participate in a focus group and who were also enrolled in the honors section of introductory electricity and magnetism were not able to attend a focus group interview. That is, they volunteered but were turned down because they were not permitted to miss their laboratory exercise during the second half of their physics class.

Although this affected nine students, it did not negatively impact the number of students present at the focus groups. In fact, I had to alter the last question of the survey where students volunteered to join a focus group to reflect the fact that I had reached a maximum capacity of participants during certain periods of the day and no longer needed volunteers. Following the Stewart et al. (2009) recommendation for ideal focus group size, six to 12 participants, I cut off the number of volunteers at 13 students, anticipating that I would have a few "no-shows" in each focus group. Table 3.3 below summarizes the composition of each focus group.

Table 3.3 Student Focus Group Composition

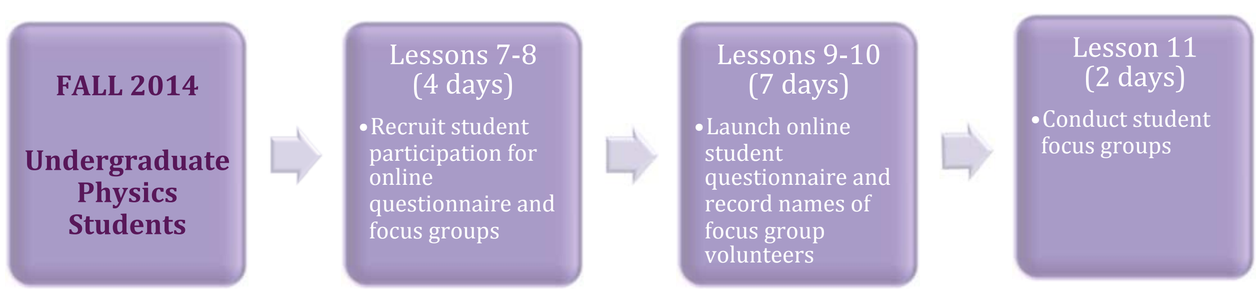
Focus Group	Date Period Lesson	Course	Student Volunteers	Students in Attendance (n)
1	15 September 2014	PHY 110	1	1
	Period 2	PHY 110H	3	3
	Lesson 11	PHY 215	3	3
		PHY 215H*	0	0
		PHY 370	0	0
		MET 320	1	1
			8 = Volunteered	**8/8 Attended**
2	15 September 2014	PHY 110	3	1
	Period 4	PHY 110H	2	1
	Lesson 11	PHY 215	3	2
		PHY 215H*	0	0
		PHY 370	0	0
		MET 320	0	0
			8 = Volunteered	**4/8 Attended**
3	15 September 2014	PHY 110	5	4
	Period 7	PHY 110H	4	4
	Lesson 11	PHY 215	3	2
		PHY 215H*	0	0
		PHY 370	1	1
		MET 320	0	0
			13 = Volunteered	**11/13 Attended**
4	16 September 2014	PHY 110	1	1
	Period 2	PHY 110H	0	0
	Lesson 11	PHY 215	4	3
		PHY 215H*	0	0
		PHY 370	0	0
		MET 320	**5 = Volunteered**	**4/5 Attended**

5	16 September 2014	PHY 110	0	0
	Period 4	PHY 110H	6	6
	Lesson 11	PHY 215	7	7
		PHY 215H*	0	0
		PHY 370	0	0
		MET 320	0	0
			13 = Volunteered	**13/13 Attended**
6	16 September 2014	PHY 110	0	0
	Period 7	PHY 110H	5	5
	Lesson 11	PHY 215	3	2
		PHY 215H*	0	0
		PHY 370	0	0
		MET 320	0	0
			8 = Volunteered	**7/8 Attended**

**Students enrolled in PHY 215H (Honors Introductory Electricity & Magnetism) had a scheduled laboratory exercise that precluded them from participating in focus groups.*

I emailed volunteers from all six focus groups the time and location of their respective focus group and sent individual calendar reminders via Microsoft Outlook at eight o'clock in the morning of the meetings. On the morning of the focus groups, I also posted a flyer printed on pink paper outside each core classroom as a final reminder for participants. A copy of this flyer is included in Appendix I. This helped to avoid an inordinate amount of no-shows to the focus groups. The focus groups took place about one quarter of the way through the semester in a small vacant classroom typically used for advanced physics courses. Figure 3.2 summarized the timeline of events for the student research portion of this project.

Figure 3.2 Fall 2014 Student Research Schedule



3.6 Data Analysis Methods

Since I collected multiple forms of data for this project, I carried out various analysis techniques to draw conclusions about how much fidelity instructors have in their execution of the JiTT pedagogy and how that influences student performance and perceptions in undergraduate physics classes. The first subsection addresses how I analyzed the quantitative data, while the second subsection discusses how I evaluated the qualitative data. Within the sections, I briefly explain how I combined both forms of data in ways that allowed me to address my research questions and assess whether the fidelity of JiTT implementation influences student learning and views about preflights and physics.

3.6.1 Analysis for Quantitative Data

The quantitative *faculty* data for this investigation include responses to the instructional strategies in undergraduate physics questionnaire that pertain to Just-in-Time Teaching, while the quantitative *student* data include responses to the student preflight questionnaire, grades (e.g., final course order of merit, final grade averages, final exam scores, homework scores, and preflight scores), and core inventory scores (e.g., CSEM, FCI, and CLASS). The quantitative data were first cleaned in Microsoft Excel. This entailed eliminating student grade and inventory data for those students who did not complete the student preflight questionnaire. It also included the removal of students who responded to the questionnaire but did not complete the course. Before importing a final comma separated variable data file into the Statistical Package for Social Sciences (SPSS, Version 22) software (Field, 2013), where I executed quantitative data analyses such as linear multiple regressions and correlations, I also carried out basic calculations such as converting raw grade scores into percentage scores and creating codes for class sections and instructors in Microsoft Excel.

Three sections of core mechanics had an instructor who attended a mandatory professional training course at the start of the semester. As a result, she was not present for a significant portion of the term. Three different faculty members covered this instructor's sections while she attended the training. Since the students in these sections were exposed to two different instructors and therefore two different methods of JiTT implementation during this study, the data collected from these students would not be reliable sources to include in the analysis.

To quantitatively answer the first research question, I followed Cutler's (2013) original study by operationalizing the fidelity of JiTT implementation as a calculation of the percentage of JiTT users who also dedicated some class time to the required critical component associated with JiTT. A JiTT user was operationalized as a faculty member who reported "I currently use it" in question 15 of the faculty questionnaire. Non-JiTT users were operationalized as faculty members who reported they were not *currently* using JiTT at the time they completed the questionnaire. If a faculty member reported having spent a percentage of class time greater than zero on the required JiTT critical component, it was an indication that they dedicated some time to discussing pre-class activities which helped them re-evaluate student learning and adjust their lecture 'just in time' for the lesson. Since the categories of JiTT user and non-JiTT user are categorical variables, and the sample sizes were quite small, I ran Fisher's Exact Test to determine the power of the single JiTT critical component to discriminate between JiTT users and non-JiTT users.

To address the second research question quantitatively, I carried out a linear multiple regression using students' final course order of merit, final grade averages, final exam scores, homework scores, and preflight scores as continuous independent variables to predict the dependent variable student perception of their instructor's fidelity of JiTT implementation. The five aforementioned independent variables were the only common performance measures across all six courses in this investigation. I operationalized individual student perception of their instructor's fidelity of JiTT implementation as the sum of a student's responses to the two Likert-type questions on the student preflight questionnaire. These two questions directly addressed the elements described by the required JiTT critical component by allowing students to report their level of agreement with the following statements:

Question 6.3: Our preflight answers clearly guide what we cover in class.

Question 6.4: It is evident that my physics instructor reads all preflight responses before class starts.

For each student response, the survey platform Qualtrics automatically scored these questions on a scale of one to six, where one was the lowest level of agreement and six was the highest level of agreement with each statement. The greater the sum of the two scored questions (the dependent outcome variable in the linear multiple regression analysis), the more favorable the student's perception was of their instructor's fidelity of JiTT implementation.

Before the SPSS software successfully executed the linear multiple regression analysis, the system internally checked for the following Field (2013) assumptions:

1. predictor variables were interval level
2. a non-zero variance existed
3. there was no perfect multicollinearity
4. predictors were not correlated with variables not included in the model
5. homoscedasticity existed
6. residual terms for any two predictors were not correlated

7. errors were distributed normally
8. values of all outcome variables were independent and
9. the relationship being modeled was linear

Since the analysis I ran did not report any errors or violations to the criteria listed above, all of the assumptions were met. I provide a detailed explanation of this in Chapter 4.

To quantitatively answer the third research question, I carried out a two-tailed Pearson correlation to determine the standardized covariance between student perception of their instructor's fidelity of JiTT implementation and the percent of favorable responses students reported on the modified CLASS pretest. The percent of favorable CLASS responses was calculated for each student by summing the number of "agree" and "strongly agree" responses each student reported and then dividing that number by the total number of questions (20) on the inventory.

Since the student preflight survey was administered during the first third of the semester, students had completed only the CLASS *pre*test by that time and had limited exposure to the course and their instructor's method for enacting JiTT into class. Over time, with increased exposure to the course and JiTT implementation, student opinions of both the course and/or their instructor's implementation may have changed throughout the term. Since I do not have a second end-of-semester measurement of student perception of the fidelity of their instructor's JiTT implementation, I did not run a correlation between this and their CLASS *post*test scores.

Before the SPSS software can successfully execute a correlation analysis, the system internally checks for the following Field (2013) assumptions:

1. Data formed normal distributions
2. Data were at least interval level and
3. Homogeneity of variance existed

Since the analysis I ran did not report any errors or violations to the criteria listed above, all of the assumptions were met.

3.6.2 Analysis for Qualitative Data

The qualitative data for this study include six one-on-one faculty interviews, six student focus group interviews, and 23 classroom observations of 16 different faculty members. All six focus groups allowed me to audio record our conversation while only two of the six faculty interviews were audio recorded. I personally transcribed only the portions of the focus groups and interviews that were of the most interest and relevance to this study. I used the faculty interview, observation, and student focus group, protocols outlined in Sections 3.4.1.2, 3.4.1.3, and 3.4.2.2, respectively, to garner the qualitative aspects of the study since I designed them in such a way to elicit common themes; however, they still allowed the me the flexibility to probe any topic that the faculty and students wished to address.

From the transcriptions and field notes taken during the time of the study, I inspected the data for emergent themes that resulted from my discussions within faculty interviews and conversations with students. In order to thoroughly analyze the individual and focus group interviews, I blended elements of case study and phenomenographic research approaches.

Phenomenography is the second qualitative research method I employed in my study. Marton (1981) describes phenomenography as "research which aims at description, analysis, and understanding of experiences; that is, research which is directed towards experiential description" (as cited in Barnard et al., 1999). Although both methods aim to uncover the essence of human experience, phenomeno*graphy* is not to be confused with phenomeno*logy*. The key distinction between the two qualitative research approaches rests in the fact that "[p]henomenography is less interested in individual experience than it is in emphasizing collective meaning" (Barnard et al., 1999). The phenomenon in this project refers to the faculty implementation of, or student exposure to, the JiTT pedagogy. Phenomenography fits well into my JiTT study since I seek to understand the shared experiences physics students have when they are exposed to different ways faculty members integrate the JiTT strategy into their classes. Likewise, I reveal the collective experiences teachers have when they enact JiTT in their classrooms.

Throughout the qualitative analysis, I reflected on, classified, and determined the frequency and patterns of common faculty and student themes within each respective case or group (Creswell, 2013). Barnard et al. (1999), concede that no universal procedure for phenomenographic organization and interpretation exists; however, they recommend that researchers carry out this type of analysis "through comparison of data obtained from a group of participants in an attempt to describe the experience of the phenomenon in terms of the essential meaning of the qualitative variations." Therefore, I sought to discover both fine-grained themes as well as broader themes within the transcriptions and field notes.

Since I was denied Institutional Review Board permission to video record the lessons I observed, I relied heavily on detailed field notes and information recorded on the observational protocol. From the observations, I extracted patterns and details of the structure, format, and means for how instructors integrated--or did not integrate—the JiTT pedagogy into their lessons. For example, I analyzed (1) how preflights are referenced (e.g., is the original question displayed on the board or verbally read to the class), (2) when preflights are addressed (e.g., only at the beginning or middle of class, or interspersed throughout the lesson), (3) how the concept covered within the preflight was clarified in class (e.g., was the concept contained within the preflight question demonstrated with an activity, real world application, video clip, etc), and (4) how students responded to the preflight review (e.g., did any engaging discussions result from addressing the preflight).

3.6.3 Data Analysis Structures for Research Questions

The figures below demonstrate how I used each data source to support the answers to each research question. As a quick reference, below I include the research questions pursued in this dissertation.

1. *With what degree of fidelity is Just-in-Time Teaching implemented in undergraduate physics classrooms? Specifically, does the critical component that characterizes JiTT discriminate between physics faculty members who claimed to use JiTT and those who did not?*
2. *Does a relationship exist between JiTT implementation and student performance? Specifically, do final exam scores, course order of merit, preflight scores, and homework scores predict student perceptions of their instructor's fidelity of JiTT implementation?*
3. *Does student perception of their instructor's fidelity of JiTT implementation correlate with their perceptions of their physics course*

Figure 3.3 Data Analysis Structure for Research Question #1

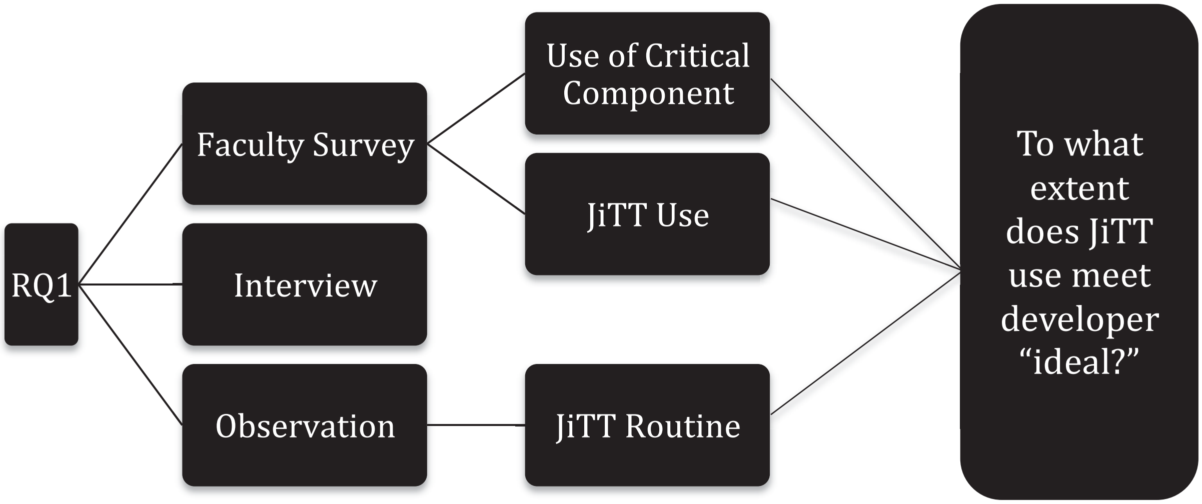


Figure 3.4 Data Analysis Structure for Research Question #2

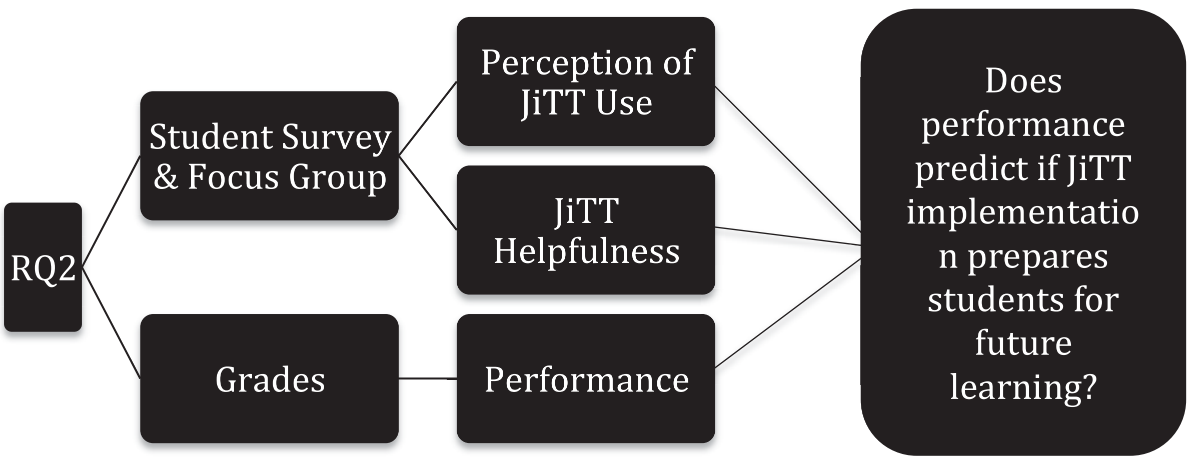
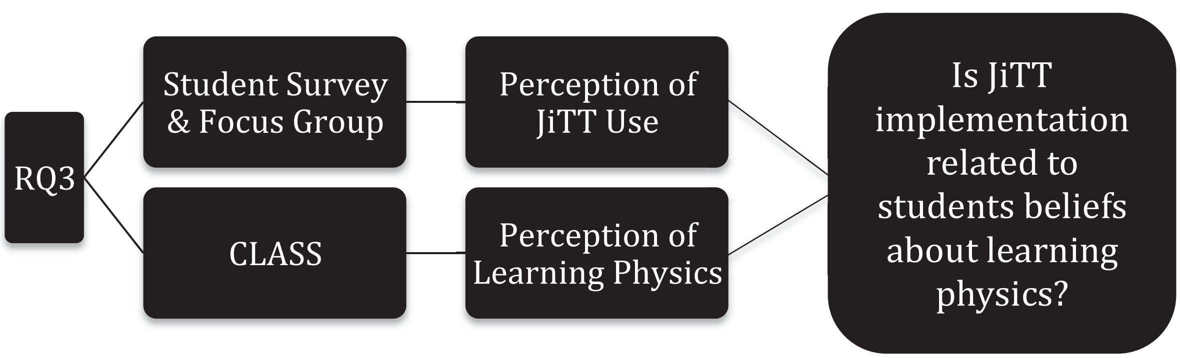


Figure 3.5 Data Analysis Structure for Research Question #3



3.7 Conclusion

In this chapter I outlined the methods by which I assessed instructor fidelity of implementation of the Just-in-Time Teaching pedagogy. I measured this by administering a faculty questionnaire, observing undergraduate physics instructors in their classrooms, and conducting one-on-one interviews with a select few faculty members to probe for deeper insight into their understanding of the JiTT strategy, its purpose, use, and outcomes.

I believe it is possible for the method(s) by which an instructor enacts JiTT impacts student views of preflights and their overall perceptions of physics as well. I will measure this through an online student preflight questionnaire and the modified CLASS inventory. Ultimately, I demonstrate that the way instructors integrate preflights into their lessons can influence how valuable their students find the assignments as well as how the fidelity of JiTT implementation affects student beliefs about physics and how well preflight assignments prepare students for future in-class learning.

Chapter 4 - Quantitative Data Analyses

In this chapter, I discuss the results of the quantitative data analysis carried out for each research question. The faculty data were taken from responses to the instructional strategies in undergraduate physics questionnaire. Specifically, I extracted the information collected from faculty answers to questions 9.4 and 15.2 to carry out the analysis for the first research question. In addition to student grade scores (e.g., final exam, homework, preflight, and course order of merit), the student data used to answer the second research question included responses to questions 6.3 and 6.4 of the preflight questionnaire. Finally, I used the same student preflight questions as well as scores from the Colorado Learning Attitudes about Science Survey to answer the third research question.

In this study, 20 physics faculty members completed an instructional strategies in undergraduate physics questionnaire. Ninety-five percent of respondents (n = 19) reported that teaching accounted for at least half or more of their job responsibilities. Seventy percent of the instructors (n = 14) also reported that over the past two years they talked or corresponded with their colleagues or other physics professors about teaching several weekly or nearly every day during the semester. Eighty-five percent of respondents (n = 17) said that in the past two years they had attended at least one workshop or talk on teaching methods. This included on-campus meetings and professional conferences. The average teaching experience was approximately five and a half years, with a minimum of one year and a maximum of 21 years. Five respondents had an academic rank of Instructor, while 12 were Assistant Professors, two were Associate Professors and one was a Full Professor. Five women and 15 men completed the survey.

From the responses to two specific questions on the instructional strategies in undergraduate physics survey, I evaluated the fidelity of implementation of the pedagogy called Just-in-Time Teaching. This is discussed in Section 4.1.

Section 4.2 addresses the linear multiple regression analysis carried out to explore the second research question, while Section 4.3 expands on the correlation executed to address the third research question. The main data sources for these analyses are student responses to an online preflight questionnaire as well as grades from five undergraduate physics courses and one introductory meteorology course. The majority of the students were either freshmen or sophomores and enrolled in an introductory mechanics or electricity and magnetism course. All of the students in this study were exposed to the Just-in-Time Teaching pedagogy.

4.1 Quantitative Analysis of Research Question #1: With what degree of fidelity is Just-in-Time Teaching implemented in undergraduate physics classrooms?

Here, I specifically investigated whether the critical component that characterizes the Just-in-Time Teaching pedagogy discriminated between physics faculty members who claimed to use JiTT and those who did not. From the instructional strategies in undergraduate physics questionnaire, 19 out of the 20 physics faculty members who completed the questionnaire indicated that they spent at least some time (anything greater than zero percent of their time) “discussing pre-class assignments which helped [her/him] reevaluate student learning and adjust [her/his] lectur**e** ‘just in time’ for class.” These quoted actions define the required JiTT critical component (Cutler, 2013). In fact, the average amount of class time the 19 respondents spent on JiTT was 50.5%.

It is important to note the Air Force Academy Department of Physics core courses include *three* elements of pre-class work. The preflight is just one third of the core pre-class assignments. In addition to the preflight, students must also complete a Worked Example worksheet and evaluate a back-of-the chapter problem before class begins. These exercises are contained within their core physics journal, a workbook-style publication the department produces and requires for its core physics students. The survey question that probed how faculty use feedback gleaned from pre-class responses does not distinguish between the three parts of the core pre-class assignment; therefore, I cannot definitively ascertain from this data source how much of the time faculty indicated they spent on pre-class work is dedicated solely to the review of just the preflight portion of the pre-class exercises. However, in Chapter 5 I discuss qualitative observations of how instructors spend their class time reviewing pre-class assignments.

All 16 faculty members who reported that they currently used the JiTT strategy also reported that they spent time on the required critical component (*Spent time discussing pre-class assignments which helped [her/him] reevaluate student learning and adjust [her/his] lecture* ***e*** *‘just in time’ for class.*). Three out of the four instructors who reported that they did not currently use the JiTT pedagogy indicated that they still spent some time on the required critical component. One faculty member reported that she/he did not currently use the JiTT strategy spend any time on the required critical component. Since the number of respondents for some of the groups is less than five, a Fisher's Exact Test was required (Field, 2013). I then calculated the two-by-two Fisher's Exact Test statistic at the Social Science Statistics website (www.socscistatistics.com/**tests**/**fisher**/default2.aspx). Table 4.1 below summarizes these findings.

Table 4.1 Just-in-Time Teaching Use of Required Critical Component

Critical Component:
Spent time discussing pre-class assignments which helped [her/him] reevaluate student learning and adjust [her/his] lecture 'just in time' for class.

	JiTT User	Non-JiTT User	Marginal Row Totals
Uses Critical Component	16	3	19
Does Not Use Critical Component	0	1	1
Marginal Column Totals	16	4	20 (Grand Total)

Note: Fisher's Exact Test statistic $p = 0.2$, therefore not significant at $p < 0.05$.

There was no statistically significant association between the required JiTT critical component and whether an instructor was a JiTT user or non-JiTT user $p(1) = 0.2$, $p > 0.05$. This was consistent with Cutler's (2013) findings. Since one of the categories yielded zero occurrences, in order to determine the effect size of this data, I performed a zero-cell correction before calculating the odd ratio to avoid calculating a zero or infinite effect size (Durlak, 2009, Grissom & Kim, 2005). This correction entailed adding a small constant, 0.5, to each cell in Table 4.1 and then calculating the odds ratio below (Durlak, 2009, Grissom & Kim, 2005).

$$odds_{\text{JiTT user enacts crit comp}} = \frac{\#\ who\ are\ JiTT\ users\ and\ enact\ JiTT\ crit\ comp}{\#\ who\ are\ JiTT\ users\ but\ don't\ enact\ JiTT\ crit\ comp}$$

$$odds_{\text{JiTT user enacts crit comp}} = \frac{16 + 0.5}{0 + 0.5} = \frac{16.5}{0.5}$$

$$odds_{\text{JiTT user enacts crit comp}} = \mathbf{33}$$

$$odds_{\text{non-JiTT user enacts crit comp}} = \frac{\# \, who \, are \, non - users \, but \, enact \, JiTT \, crit \, comp}{\# \, who \, are \, non - users \, and \, don'tenact \, JiTT \, crit \, comp}$$

$$odds_{\text{non-JiTT user enacts crit comp}} = \frac{3 + 0.5}{1 + 0.5} = \frac{3.5}{1.5}$$

$$odds_{\text{non-JiTT user enacts crit comp}} = \mathbf{2.33}$$

$$odds_{\text{ratio}} = \frac{odds_{\text{JiTT user enacts crit comp}}}{odds_{\text{non-JiTT user enacts crit comp}}} = \frac{33}{2.33}$$

$$odds_{\text{ratio}} = \frac{odds_{\text{JiTT user enacts crit comp}}}{odds_{\text{non-JiTT user enacts crit comp}}} = \mathbf{14.14}$$

After determining the odds ratio with the correction term included, the result indicated that if an instructor was a JiTT user, the odds that she/he spent time on the JiTT critical component were 14.14 times higher than if she/he were a non-JiTT user.

As mentioned in Section 2.1.2, the existence of only one required critical component for the JiTT strategy means it may be difficult to accurately discriminate between JiTT-users and non-JiTT users based on their enactment of this singular critical component. In Chapter 6, I propose a revision of the required JiTT critical component to better discriminate between users and non-users.

4.2 Quantitative Analysis of Research Question #2: Does a relationship exist between JiTT implementation and student performance?

Here, I specifically investigated whether final exam scores, course final order of merit, preflight scores, and homework scores predicted student perceptions of their instructor's fidelity of JiTT implementation. To answer this research question, I ran a linear multiple regression analysis. First I calculated the dependent variable, student perception of their instructor's fidelity of JiTT implementation, by summing responses to questions 6.3 and 6.4, two Likert-type questions, from the student preflight questionnaire that address the two elements of the JiTT critical component. The greater the sum, the more favorably students viewed their instructor's implementation of the JiTT pedagogy. All independent variable scores were converted to percentages since their respective point values differed by course.

Before executing the regression analyses, I removed individual cases where students had two different instructors throughout the semester. This entailed three sections of regular mechanics. A total of 41 students met this criteria and were removed from the data.

Based on previous JiTT research carried out by Stelzer et al. (2009, 2010) and Benedict and Anderton (2004) who found evidence for improved student achievement in classes that incorporated the JiTT pedagogy, I executed a hierarchical (blockwise entry) linear multiple regression analysis. In addition to including graded measures of student performance as independent variables in the regression model, I also included a new predictor variable that I believed would account for most of the variability. This additional independent variable was taken from question 6.1 of the student preflight questionnaire and was a measure of how seriously students took the preflight assignment. The blocking occurred in step one of each model where I entered students' self reported "seriousness" scores. Remaining performance independent variables were entered in step two of each model.

Running the regression at this point, resulted in 14 casewise diagnostic outliers. I considered a case an outlier if it had a standardized residual less than -2.5 or greater than 2.5. Field (2013) considers it a reasonable expectation for 99% of the cases within a data set to have standardized residuals within +/-2.5 standard deviations. Since 2.4% (14 out of 581) of cases in the sample exceeds Field's (2013) limit, I removed the 14 outlying cases and re-ran the regression analysis. This subsequent analysis, with outliers removed, is called Model 1 in Table 4.2. It resulted in only two outlying cases, decreasing the number of outliers to only 0.3% (2 out of 567 cases) of the sample. This falls within Field's (2013) acceptable 1% limit.

In models two and three, I ran the same regression analysis as model one, but I filtered the data to include only cases where students responded on the extreme ends to question 10 of the student preflight questionnaire such that model two reflects the analysis of students who reported preflights helped them prepare for multiple choice and worked out problems on homework, quizzes, and tests, while model three reflects students who reported preflights do *not* help them prepare for any of the aforementioned graded work. Those who said preflights helped them prepare for everything increased the amount of variability for which the first model accounted by 8% while those who said preflights do not help them prepare for anything decreased the amount of variability for which the first model accounted by 6%. The fact that the regression equations in models two and three are different, means model 2 is better than model three at predicting the same outcome variable.

4.2.1 Checking Assumptions

In this section I show evidence that all nine of the assumptions, as outlined in Section 3.6.1, about the regression models were met (Berry, 1993; as cited in Field, 2013).

1. All predictor variables were interval level because they consisted of grade percentages or a sum of two questions scored on a scale from one to six.
2. Step 2 in each hierarchical multiple regression model yielded a non-zero variance (i.e., $R^2 > 0$) in each case.
3. All Pearson correlation coefficients in each model were less than 0.9 (i.e., $r < 0.9$). Additionally, the tolerance statistics for each model remained greater than 0.2 while the Variance Inflation Factor statistics stayed below 10 indicating there was no perfect multicollinearity between predictor variables.
4. One predictor variable that was correlated with final exam score, was final grade average. Although these two independent variables were related, their correlation remained below the 0.9 threshold; therefore, excluding final grade average from the model does not violate the fourth assumption that predictors were not correlated with variables not included in the model.
5. After first downloading Pryce and Garcia-Granero's (2002) SPSS macro for the Breusch-Pagan test and then entering the dependent variable and the five predictor variables used in this linear multiple regression analysis into their computer code, I was able to run the Breusch-Pagan test for heteroscedasticity directly from the SPSS syntax editor. The Breusch-Pagan macro produced a Chi-square test statistic of $\chi^2(5, N = 567) = 8.278$, $p = 0.14$. Since this was not significant at the $p < 0.05$ level, the test for heteroscedasticity failed; therefore, the homoscedasticity assumption is met.
6. The Durbin-Watson test for independent errors yielded no values greater than 2.25 or less than 1.5 for any of the models; therefore, residual terms for any two predictors were not correlated. Generally, when values for this statistic are greater than three or

less than one, a greater chance exists that that residual terms for any two observations could be correlated (Field, 2013).

7. The bell curve overlaying the histogram in Figure 4.1 in addition to the minimal deviations from the line in the probability plot in Figure 4.2 show evidence of a normal distribution of errors; therefore, most of the differences between the regression model and the observed data are nearly equal to zero or equal to zero.
8. One outcome variable was used, and it was a determined by summing two questions from the student preflight questionnaire. Neither of these variables were used as independent predictor variables in the analysis; therefore, it is assumed that the value of the dependent variable is independent.
9. Since no curvilinear relationships presented themselves in the partial regression scatterplots, the relationship being modeled was linear. These scatter plots are included in Appendix J.

Figure 4.1 Histogram of Regression Model 1 Standardized Residual

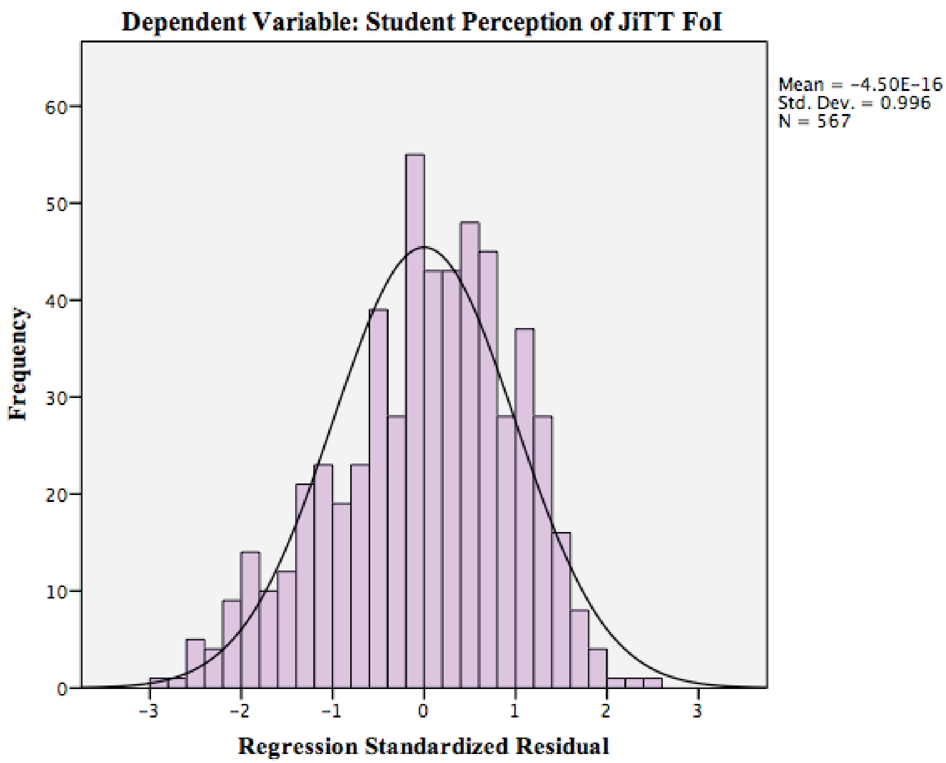
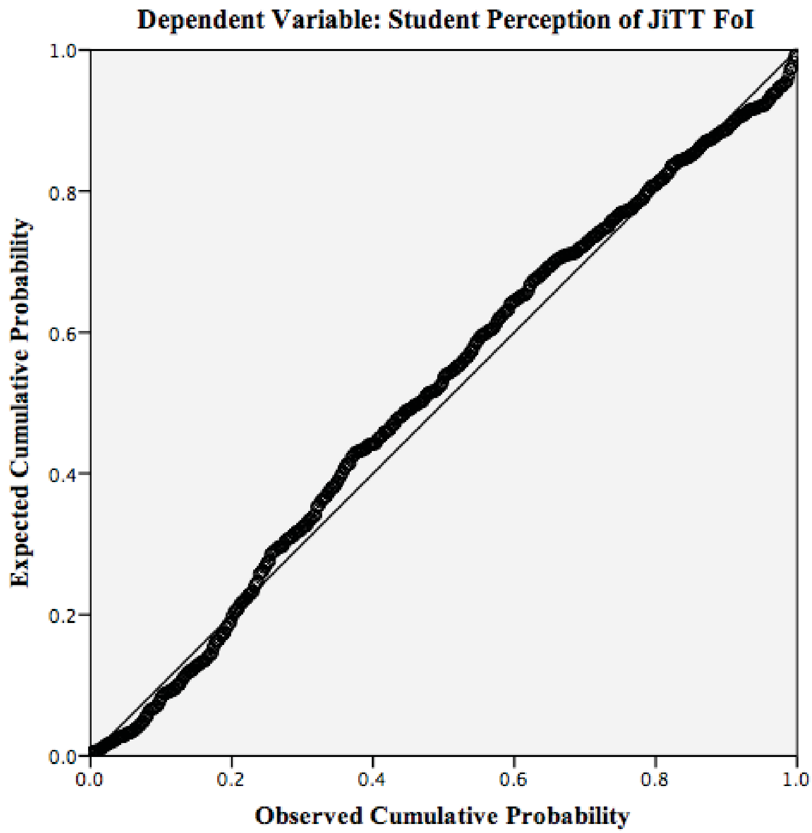


Figure 4.2 Model 1 Normal Probability Plot of the Regression Standardized Residual



Finally, to compare how well the multiple regression analysis worked for each individual course, I ran the analysis six additional times, filtering the data for each of the courses in this study. Half of the analyses yielded one predictor variable at the $p < 0.001$ level. In both the regular and honors electricity and magnetism as well as the regular mechanics course, how seriously students take the preflight assignment was the only variable that statistically significantly predicted student perception of their instructors fidelity of JiTT implementation.

Both steps in the first regression model statistically significantly ($p < 0.001$ for both steps) fit the data better than a comparison of the means. The ANOVA F-ratio for step one, F(565) = 64.26, was statistically significantly higher than the F-ratio for step two, F(561) = 20.79, of the model. Therefore, the first regression equation reflects step one of the first regression model.

Only the second step in the second regression model was a statistically significantly better fit for the data than a comparison of the means (F(70) = 0.002, $p < 0.01$). The third model failed to produce any steps that were statistically significantly ($p > 0.05$ for both steps) better fits of the data than a comparison of means.

Both steps of the fourth model, where the data were filtered to include only regular electricity and magnetism cases, were statistically significantly better fits of the data than a comparison of means. The first step ($F(238) = 19.81$, $p < 0.001$) was a better predictor because its ANOVA F-ratio was statistically significantly higher than the second step ($F(234) = 4.51$, $p < 0.01$).

Similar to the previous model, both steps of the fifth model, where the data were filtered to include only honors electricity and magnetism cases, were statistically significantly better fits of the data than a comparison of means. The first step ($F(128) = 12.61$, $p < 0.01$) was a better predictor because its ANOVA F-ratio was statistically significantly higher than the second step ($F(234) = 3.34$, $p < 0.01$).

The sixth and final regression model executed an analysis that filtered the data for regular mechanics cases. Both steps of the last model were statistically significantly better fits of the data than a comparison of means. The first step ($F(84) = 9.51$, $p < 0.01$) was a better predictor because its ANOVA F-ratio was statistically significantly higher than the second ($F(80) = 2.60$, $p < 0.05$).

Filtering the data for the remaining courses resulted in no significant predictive models for the outcome variable. Table 4.2 contains the statistics for the six regression models while Table 4.3 summarizes the final regression equations for each model. The unstandardized coefficients, B, in Table 4.2 indicate the individual contribution of each independent variable to the model "*if the effects of all other predictors are held constant"* (Field, 2013). In other words, they tell the strength of the relationship between the predictor variable and the dependent variable. A negative unstandardized coefficient means a negative or inverse relationship exists between the independent variable and the outcome variable. The Standard Error is a measurement of whether B differs significantly from zero. The standardized coefficients, β, have the unit of standard deviation (distance from the mean value) and indicate the number of standard deviations that the dependent variable would change if the independent variable changed by one standard deviation. The ANOVA F-ratio is included to show which steps for each regression model were significantly better fits of the data. A bold number in the ANOVA F-ratio column indicates the regression model and step maintained for each sample.

Table 4.2 Linear Multiple Regression Models for Student Perception of Their Instructor's Fidelity of JiTT Implementation

	Unstandardized Coefficients		Standardized Coefficients	ANOVA F-ratio
	B	Standard Error	β	
Model 1				
All Courses | No Filter (N = 567)				
Step 1				**64.263*** **
Constant	7.475	0.252		
Preflight Seriousness	0.454	0.057	0.320***	
Step 2				20.786***
Constant	10.593	0.772		
Preflight Seriousness	0.430	0.058	0.303***	
Final Exam Score (%)	-0.013	0.005	-0.122**	
Homework Score (%)	-0.010	0.005	-0.096	
Preflight Score (%)	-0.007	0.008	-0.042	
Order of Merit	-0.004	0.001	-0.278***	
Notes. $R^2 = 0.102$ *in Step 1,* $\Delta R^2 = 0.054$ *in Step 2; **p < 0.01, ***p < 0.001*				
Model 2				
Filtered for Preflights Help Prepare for Everything (*n* = 76)				
Step 1				1.094
Constant	9.412	1.005		
Preflight Seriousness	0.210	0.201	0.121	
Step 2				**4.370** **
Constant	11.427	1.859		
Preflight Seriousness	0.034	0.190	0.019	
Final Exam Score (%)	-0.019	0.011	-0.210	
Homework Score (%)	-0.027	0.014	-0.233	
Preflight Score (%)	0.035	0.018	0.236	
Order of Merit	-0.008	0.002	-0.547***	
Notes. $R^2 = 0.015$ *in Step 1,* $\Delta R^2 = 0.223$ *in Step 2; **p < 0.01, ***p < 0.001*				
Model 3				
Filtered for Preflights Help Prepare for Nothing (*n* = 84)				

Step 1				0.002
Constant	8.151	0.493		
Preflight Seriousness	-0.006	0.132	-0.005	
Step 2				1.662
Constant	10.409	2.319		
Preflight Seriousness	0.070	0.144	0.059	
Final Exam Score (%)	0.006	0.020	0.047	
Homework Score (%)	-0.023	0.016	-0.220	
Preflight Score (%)	-0.006	0.019	-0.049	
Order of Merit	-0.003	0.002	-0.172	
Notes. *R^2 = 0.000023 in Step 1, ΔR^2 = 0.096 in Step 2; not a statistically significant model*				
Model 4 Filtered for Regular Electricity & Magnetism (n = 240)				
Step 1				**19.808*** **
Constant	7.323	0.358		
Preflight Seriousness	0.382	0.086	0.277***	
Step 2				4.510***
Constant	8.147	2.028		
Preflight Seriousness	0.370	0.089	0.268***	
Final Exam Score (%)	-0.009	0.016	-0.066	
Homework Score (%)	-0.002	0.009	-0.017	
Preflight Score (%)	0.004	0.014	0.024	
Order of Merit	-0.002	0.002	-0.148	
Notes. *R^2 = 0.077 in Step 1, ΔR^2 = 0.011 in Step 2; ***$p < 0.001$*				

Model 5 Filtered for Honors Electricity & Magnetism (*n* = 130)				
Step 1				**12.614*** **
Constant	7.765	0.516		
Preflight Seriousness	0.407	0.114	0.300***	
Step 2				3.336**
Constant	6.742	3.125		
Preflight Seriousness	0.416	0.120	0.306***	
Final Exam Score (%)	0.019	0.023	0.143	
Homework Score (%)	-0.013	0.010	0.134	
Preflight Score (%)	0.007	0.015	0.050	
Order of Merit	0.000	0.004	0.006	
Notes. $R^2 = 0.090$ *in Step 1,* $\Delta R^2 = 0.029$ *in Step 2; **p < 0.01, ***p < 0.001*				
Model 6 Filtered for Regular Mechanics (*n* = 86)				
Step 1				**9.508** **
Constant	8.180	0.593		
Preflight Seriousness	0.415	0.135	0.319**	
Step 2				2.603*
Constant	11.828	2.255		
Preflight Seriousness	0.459	0.139	0.353***	
Final Exam Score (%)	-0.013	0.017	-0.126	
Homework Score (%)	-0.003	0.012	-0.027	
Preflight Score (%)	-0.030	0.020	-0.185	
Order of Merit	-0.002	0.004	-0.108	
Notes. $R^2 = 0.102$ *in Step 1,* $\Delta R^2 = 0.038$ *in Step 2; *p < 0.05, **p < 0.01, ***p < 0.001*				

Table 4.3 Equations for Regression Models

Regression Model	Regression Equation
1	All courses | No filters (N = 567) $\boldsymbol{FoI = 7.48 + (0.45serious_i)}$
2	All courses | Filtered for Preflights Help Prepare for Everything (n = 76) $\boldsymbol{FoI = 11.43 - (0.008OM_i)}$
3	All courses | Filtered for Preflights Help Prepare for Nothing (n = 84) No significant regression model or predictor variables
4	Only Regular Electricity & Magnetism | No filter (n = 240) $\boldsymbol{FoI = 7.32 + (0.38serious_i)}$
5	Only Honors Electricity & Magnetism | No filter (n = 130) $\boldsymbol{FoI = 7.77 + (0.41serious_i)}$
6	Only Regular Mechanics | No filter (n = 86) $\boldsymbol{FoI = 8.18 + (0.42serious_i)}$

Note.
FoI = student perception of instructor's fidelity of implementation
Serious = how seriously student takes the preflight assignment
OM = order of merit in course

To summarize the quantitative findings for research question two, it is clear that generally speaking student performance is not a strong predictor of student perception of their instructor's fidelity of JiTT implementation. Model two, where the entire sample is filtered for students who say preflights help them prepare for other graded work, is the only model whose relationship between course order of merit and the dependent variable resulted in a considerable effect size ($R^2_{Model2} = 0.238$; Ellis, 2010; Üstün and Eryilmaz, 2014). It makes sense that the relationship is negative since a higher order of merit is associated with smaller numbers (e.g., finishing #1 in a course is better than #100). When the sample was parsed into individual courses, student performance did not at all predict student perception of their instructor's fidelity of JiTT implementation. However, including the new predictor variable, how seriously students take the preflight assignment, was a significant predictor of student perception of their instructor's fidelity of JiTT implementation in four out of the six models with small to medium effect sizes ($R^2_{Model1} = 0.102$; $R^2_{Model4} = 0.077$; $R^2_{Model5} = 0.090$; $R^2_{Model6} = 0.102$; Ellis, 2010; Üstün and Eryilmaz, 2014).

4.3 Quantitative Analysis of Research Question #3: Does student perception of their instructor's fidelity of JiTT implementation correlate with their perceptions of their physics course?

Using the data collected from the online student preflight questionnaire and the modified Colorado Learning Attitudes about Science Survey (CLASS), I compared the perceptions core physics students have about their physics course and their perception of their instructor's fidelity of JiTT implementation. The modified CLASS pretest and posttest scores were measured by calculating the percent of favorable answers students recorded on the instrument; the higher the percentage, the more favorable their view of the course (Adams et al., 2006). This entailed tallying the number of "Strongly Agree" and "Agree" responses a student recorded for positively worded questions (e.g., questions 2, 8, 11, 12, 13, 15, 17, and 18) and the number of "Strongly Disagree" and "Disagree" responses a student recorded for negatively worded questions (e.g., questions 1, 3, 4, 5, 6, 7, 9, 10, 14, 16, 19, and 20). Student perception of their instructor's fidelity of JiTT implementation was measured the same way I described in the previous section. The higher the sum of the two Likert-type questionnaire questions, the more favorably a student viewed her/his instructor's JiTT implementation. In the correlation analysis, I also included student's normalized gain in their modified CLASS score. This reflects whether a score increases or decreases from pretest to posttest. Below is the equation used to calculate normalize gain (Adams et al., 2006):

$$normalized\ gain\ = \frac{\% < G >}{\% < G >_{max}} = \frac{[(\%posttest) - (\%pretest)]}{[100 - \%pretest]}$$

I limited the analysis for this research questions to only the core physics courses because the modified CLASS inventory was administered in only these four courses. Some core students were missing scores for either the pretest or posttest, and those students were excluded from the analysis. The final number of cases included in the correlation analysis was 426. Table 4.4 includes the descriptive statistics for the CLASS data in this study.

Table 4.4 CLASS Descriptive Statistics for Core Physics Students

	Mean (%)	Standard Deviation (%)
CLASS Pretest	39.13	16.99
CLASS Posttest	45.19	27.21
CLASS Normalized Gain	0.045	0.55

Note: n = 426

Student perception of their physics course at the start of the semester, as measured by the modified CLASS pretest, was not statistically significantly related to student perception of their instructor's fidelity of JiTT implementation ($r_{pre} = -0.054$, $p_{pre} = 0.196$). However, posttest scores on the modified CLASS indicated student perception of their physics course at the end of the semester and their overall change of view of the course, as measured by the normalized gain in the modified CLASS score) was statistically significantly related to student perception of their instructor's fidelity of JiTT implementation ($r_{post} = 0.117$, $p_{post} = 0.005$; and $r_{gain} = 0.125$, $p_{gain} = 0.003$). Although the relationships were significant, the overall effect sizes ($r^2_{post} = 0.013$, $r^2_{gain} = 0.015$) were relatively small (Ellis, 2010; Üstün and Eryilmaz, 2014). The table below summarizes these findings for all core courses in the study. Appendix K includes correlation tables for each individual core course.

Table 4.5 Correlation Between Student Perception of Instructor Fidelity of JiTT Implementation and Student Perception of Course

	Student Perception of Instructor's Fidelity of JiTT Implementation	CLASS Pretest	CLASS Posttest	CLASS Normalized Gain
Student Perception of Instructor's Fidelity of JiTT Implementation	1	-0.054	0.117**	0.125**
CLASS Pretest	-0.054	1	0.153**	-0.354**
CLASS Posttest	0.117**	0.153**	1	0.783**
CLASS Normalized Gain	0.125**	-0.354**	0.783**	1

*Note. n = 426; **Correlation is significant at the p < 0.01 level (two-tailed).*

4.4 Summary

Based on the quantitative analysis performed, the 19 out of 20 questionnaire respondents reported that they currently use JiTT in their teaching practice, while only 16 out of 20 reported that they spend class time on the required JiTT critical component. No statistically significant relationship existed between those who reported spending time on the required JiTT critical component and their categorization as a JiTT user or a non-JiTT user.

Additionally, student performances—as measured by final exam scores, homework scores, preflight scores, and course order of merit—in their respective classes did not statistically significantly predict their perception of their instructor's fidelity of JiTT implementation—as measured by the sum of their responses to questions 6.3 and 6.4 on the student preflight questionnaire. One exception to this occurred when the data were filtered for students who indicated on the questionnaire that preflights helped them prepare for other assignments such as homework, multiple choice questions on quizzes and tests, and evaluated problems on quizzes and tests. The second regression model yielded a statistically significant relationship between course order of merit and student perception of their instructor's implementation of JiTT. When a measure of how seriously students took the preflight assignment was included in the regression analysis, it became a statistically significant predictor of the outcome for the following four models: 1) when all cases were analyzed (Model 1), when only the regular electricity and magnetism course was kept in the analysis (Model 4), when only the honors electricity and magnetism course was kept in the analysis (Model 5), and when only the regular mechanics course was kept in the analysis (Model 6).

Finally, no statistically significant relationship existed between student perceptions of their instructor's fidelity of JiTT implementation and their views about learning physics at the beginning of the semester as measured by the modified CLASS pretest. However, a small, positive statistically significant relationship existed between student perceptions of their instructor's fidelity of JiTT implementation and the modified CLASS posttest. A small, positive statistically significant relationship also existed between student perceptions of their instructor's fidelity of JiTT implementation and the normalized gains in the modified CLASS.

Chapter 5 - Qualitative Analyses

In this section I discuss the results of the qualitative data analysis carried out for each research question. The sources from which the faculty data were gleaned include open-ended feedback from 20 respondents to the instructional strategies in undergraduate physics questionnaire, field notes from six individual interviews (two of which were audio recorded and transcribed), and field notes from classroom observations. The sources from which the student data were garnered include 566 open-ended comments from respondents to the student preflight questionnaire and transcripts from six focus group interviews.

For the faculty and student questionnaire responses, I cut typed feedback from the Qualtrics survey output files and pasted the text into Microsoft Word documents. Recorded interview and focus group audio files were transcribed by Rev transcription services. Finally, I transcribed hand-written field notes from interviews and classroom observations. All qualitative unstructured text data were stored in Microsoft Word documents that were then uploaded into the qualitative data analysis software program as source files.

All of these text data sources were coded in QSR International's NVivo 10. Initial coding began with what Creswell (2013) termed "lean codes" that I perceived as overarching themes within the data when it was first collected and reflected upon. Faculty data sources were coded separately from student data sources. I repeatedly read through the data sources and expanded on the initial categories, or "nodes" as they are called in NVivo 10, as they emerged from each data set. I classified the passages from the data sources as I saw fit, creating new nodes or sub-nodes as necessary. This entailed manually highlighting text in the individual data sources within the in NVivo 10 program and binning it in either a predetermined node or in a new node. Some passages are double-coded, meaning if a part of the data fit into a specific sub-node, I included it in the parent node as well. Saldaña (2013) calls this technique "nested" coding. Following Glaser and Strauss' (1967) recommendation, I created categories that fit the data in a conceptually appropriate way, while refraining from making the categories so abstract that they lost their ability to sensitively categorize the data (as cited in Saldaña, 2013).

I do not report frequency counts for the number of times a theme or phenomenon occurs within a given node or sub-node because this conveys a quantitative procedure and does distinguish between related but opposing reports that might have been contained within one category (Creswell, 2013). However, I did initially use summative frequency counts that NVivo 10 computed to determine which dominant themes within the data warranted deeper investigation. Appendix L (faculty) and Appendix M (students) contain the parent and sub-node structures evaluated in this chapter (i.e., code books).

In an exploratory fashion, I carried out an eclectic combination of descriptive, in vivo, values, versus, evaluation, and verbal exchange coding (Saldaña, 2013). Table 5.1 below summarizes the key features of each of the aforementioned coding methods.

Table 5.1 Qualitative Coding Methods Used

Coding Method	Key Features
Descriptive	Codes are topic summaries. "It is important that these [codes] are identifications of the topic, not abbreviations of the content. The topic is what is talked or written about. The content is the substance of the message" (Tesch, 1990, as cited in Saldaña, 2013).
In Vivo	Codes use the language of the participants. (Strauss, 1987, as cited in Saldaña, 2013).
Values	Participant beliefs coded based on the importance the person attributes to their personal experience and perceptions (Saldaña, 2013).
Versus	Codes dichotomous expressions that conflict with one another within a sample, operation, impression, etc. (Saldaña, 2013).
Evaluation	Codes assign "merit, worth, or significance" to a process, approach, etc. (Rallis and Rossman, 2003, as cited in Saldaña, 2013).
Verbal Exchange	Codes categorize, analyze and interpret conversation types, and "personal meanings of key moments in the exchanges" of verbatim transcripts (Saldaña, 2013).

I employed a new auto-coding feature in NVivo 10 to check for inter-rater reliability. NVivo 10's automatic coder follows a pattern-based coding scheme that mimics the coding structure established by the researcher. Essentially, the researcher trains the program how to code at either the paragraph or sentence level using an existing coding pattern ([a]QSR International; Robertson, 2014). The researcher also has the option to direct the program to code to all established nodes or to only a set of selected nodes. I enlisted NVivo 10 to auto-code at the sentence level to all of the nodes I created such that when the program encountered a passage that had similar wording to content I previously coded to a node, the program coded the new text in the passage to that node. Upon the completion of the automatic coding, NVivo 10 generated a summary of the suitability of the nodes, and if an issue presented itself, NVivo 10 notified me by presenting a list of nodes where the program experienced difficulty matching my coding pattern.

This occurred primarily in nodes where there were few occurrences (i.e., textual examples) of the themed category previously binned by me. For this part of the study, I only maintained the nodes where NVivo 10 reported no issues with suitability between coders.

I found discrepancies in the literature about how to establish inter-rater reliability, which is the level of agreement between coders. QSR International suggested that values greater than 75 percent agreement between coders is “excellent” ([b]QSR International), while Miles and Huberman (1994) suggest 80 percent agreement is a more acceptable value (as cited in Creswell, 2013). DeCuir-Gunby et al. (2011) report a minimum of 90 percent agreement is needed to establish a reliable coding structure. For this study, I considered inter-rater agreement greater than 85 percent acceptable. NVivo 10 automatically generated these values and they are included in Appendix X. I calculated the inter-rater reliability between my coding and a colleague who has six years of Physic Education Research experience using the following Miles and Huberman (1994) equation (as cited in DeCuir-Gunby et al., 2011):

$$\% \, Agreement = \frac{total\ codes\ in\ agreement}{total\ codes\ in\ agreement\ and\ disagreement}$$

To ensure the program had enough examples to establish a reliable pattern from which it could learn how to code on its own, I coded a minimum of 50 percent of the data for faculty and students. I coded all of the qualitative faculty data from the questionnaire manually before running the NVivo 10 automatic coder, and I coded all 566 open-ended responses to the student preflight questionnaire and one focus group transcript before auto-coding the remaining five student focus group transcripts.

I was then able to check the text NVivo 10 coded to assess its accuracy in three ways. First, I manually checked a random set of nodes to inspect the text NVivo 10 binned into those nodes. Second, I opened the focus group transcript that I manually coded and turned on the “coding stripes” feature. Viewing coding stripes allowed me to review in the margin of the source document which passages I coded to a specific node, indicated by a colored stripe assigned that node, and if NVivo 10 coded the same passage to the same node, indicated by a black stripe. Throughout the analysis, the initials “NV” represented the NVivo 10 coder, while the initials “JD” indicated my coding selections within the program.

As a final inter-rater reliability check, I executed a "coding comparison" query within NVivo 10. Running this query assessed the degree to which my coding and NVivo 10's coding agreed for each data resource file. The coding comparison function produced a summary table containing a measurement of agreement and disagreement displayed as percentages. The lowest agreement, as averaged across all data resource files, between my coding and NVivo 10's coding was 98.8 percent for students and 89.3 percent for faculty. The output tables from the NVivo 10 coding-comparison queries for the faculty and student data are included in Appendix N.

Since the automatic coder feature of NVivo 10 is still in an experimental phase, I also conducted an inter-rater reliability check with another researcher. We each coded 10 percent of typed student responses to the preflight questionnaire and one faculty interview transcript. From the student data, I randomly selected 10 percent of the responses from each course so that one course did not dominate the sample data set. The inter-rater reliability agreement between my former colleague and me was 98.1 percent for students and 90 percent for faculty. A table summarizing our agreement is also included in at the bottom of Appendix N.

Throughout my analysis of the qualitative data, I blended elements of case study and phenomenography. The cases consisted of large samples within the population (e.g., faculty and students, core and non-core courses). Recall that "[p]henomenography is less interested in individual experience than it is in emphasizing collective meaning" (Barnard et al., 1999). Since I did not focus this investigation on one single faculty member or one individual student, it was important for me to maintain a broad view of the experiences, opinions, and recommendations that faculty and students shared as a whole. I report on the most common themes that continually surfaced within the questionnaires, interviews, and observations.

Sections 5.1 through 5.3 address each research question in a qualitative capacity and highlight findings that were worthy of attention.

5.1 Qualitative Analysis of Research Question #1: With what degree of fidelity is JiTT implemented in undergraduate physics classrooms?

During one-on-one interviews, faculty members outlined their routine for implementing the JiTT strategy from start to finish (i.e., from the time they logged into the JiTT server to access student answers until the time they reviewed the questions during their lesson). Similarly, yet in a focus group setting, I asked students about the methods their instructors used to incorporate preflights during class. From this feedback, I found that little divergence exists in the techniques instructors used to address student misunderstandings presented themselves in preflights.

The core preflight assignment can be divided into three parts. The first question, "*What topic from the lesson would you like to discuss during class?*" gives students an opportunity to make a specific request to their instructor. The opening preflight questions in the honors electricity and magnetism course also include two multiple choice questions that ask students to gauge how well they felt they understood the material covered in the two other pre-class assignments. These assignments include the "self-explanation prompts" on the Worked Example worksheet and the back-of-the chapter "workout" or "pre-class" problem. The next one or two preflight questions are usually multiple choice and/or true-false questions, and the last question is typically an open-ended "critical thinking exercise" that sometimes ties a concept from the reading into a real world application. The non-core preflights also open with a question asking students to report what they would like talk about in class. The meteorology course includes a combination of multiple choice and free response preflight questions about the reading, while the space physics course tends to include only open-ended preflight questions. The enrollments for the non-core courses were substantially smaller than the core courses with only one section of 12-20 students as opposed to a core instructor who was typically responsible for three sections of about 20 students. Therefore, including more free response question in the preflight assignment is more manageable in the non-core courses since the instructors did not have as many open-ended entries to review before the start of class. If all of the core preflight questions were open-ended, it would be a rather daunting task for an instructor to thoroughly appraise such a high volume of written student feedback in a short period of time prior to class.

Within the faculty parent node, "JiTT Implementation," emerged three dominant sub-categories: 1) sharing student questions and answers, 2) using preflights as a lesson guide, and 3) time, specifically as it related to time spent prior to class in preparation for a lesson and the use class time to discuss preflight assignments. Figure 5.1 is a graphic organizing the major themes that emerged from faculty data. The size of the blocks indicates the relative preponderance of the category. For example, feedback on *sharing student questions and answers* surfaced more often than comments about *time*.

Figure 5.1 Hierarchy of Dominant JiTT Implementation Nodes From Faculty Data

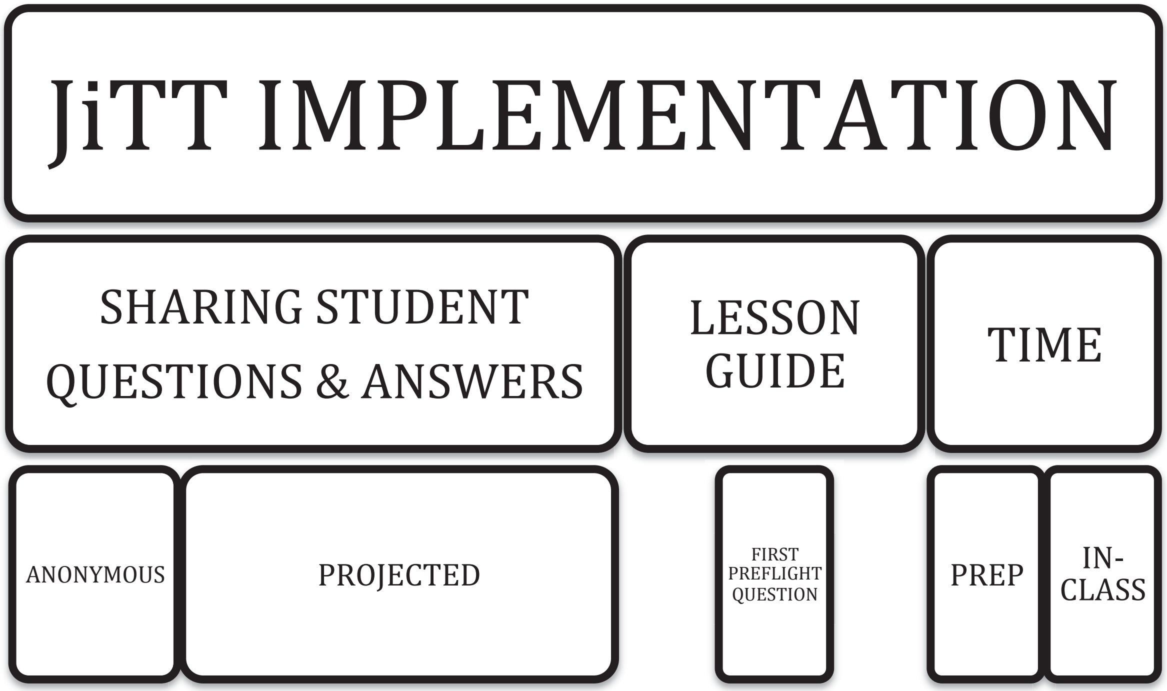


Table 5.2 contains representative quoted interview text from faculty or passages from the notes taken during interviews or classroom observations. These excerpts reflect faculty experiences with their implementation of the JiTT pedagogy as they relate to each of the three main themes. A complete table with more coded data is included in Appendix O. Please note that if the text is not italicized and quoted, the passage was taken from either observation or interview notes I made in the field.

Table 5.2 Representative Coded Faculty Text

<u>Sharing Student Preflight Questions and Answers</u>
"I try and pick a variety of things that allow us to chat about this stuff…I leave it anonymous… I want everybody to see their responses at one point or another. Otherwise, they might get the impression, 'Well, [my instructor]'s not reading mine.' Or 'Mine aren't worthy of noting.' Kind of mindful of that." [Instructor 21 interview transcript]
<u>Using Preflights as a Lesson Guide</u>
Instructor 7 used JiTT to make class more conversational and to drive what is covered.
Instructor 18 felt the first JiTT question is the most important question for guiding class.

Time Required to Implement JiTT

Preparatory

"*They close [preflights] out generally at 7. It used to be classes started at 7:15, now classes start at 7:30. I usually get in…about 6:30. About an hour before, because you have to. You need at least 45 minutes to do that. Then, you have to gather stuff up and get to your classroom and do all the other things you need to prep."* Instructor 15 interview transcript]

In-Class

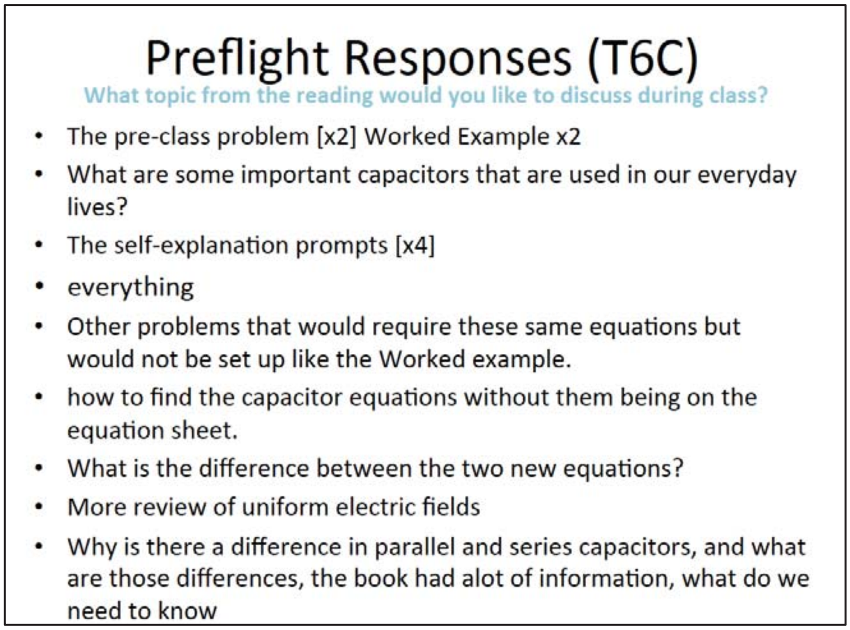
"It's all about time... can't do it all when you have 53 minutes, 2-3x per week. Given unlimited time, I'd probably use them all at some point or another during the semester." [Referencing multiple instructional strategies; taken from written response to faculty questionnaire]

Almost every observed instructor pasted quoted student feedback that was taken directly from the first preflight question into a PowerPoint slide and displayed it early in the lesson; oftentimes, this was the very first item an instructor covered. In the classes I observed, when faculty projected student answers on the board it was always done so anonymously; however, from the student focus groups, I learned that some core instructors posted names or initials beside students' displayed responses. During our interview, Instructor 18 shared with me that she/he posted the last names of students whose preflight did not register as being completed. This was not done to embarrass students. Rather, earlier in the semester the JiTT server was not logging student submissions, so the instructor started posting student names so they could alert her/him to the error in the server and ensure they received credit for their work. Instructor 6 experienced trouble projecting her/his PowerPoint presentation from her/his laptop during one of the lessons I observed but was able to recall from memory common requests students submitted in the first preflight question.

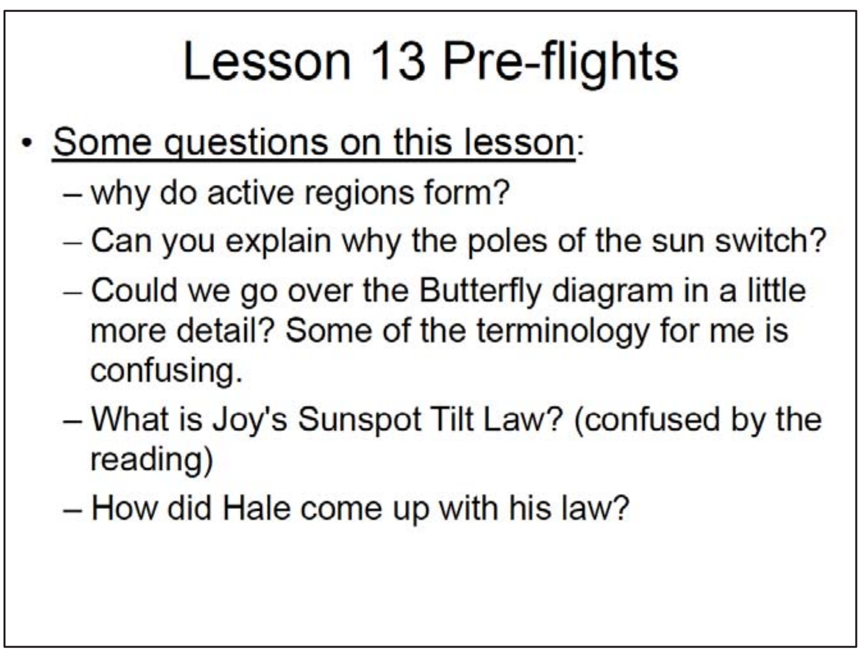
A few core physics instructors and both of the non-core instructors dedicated several minutes at the beginning of class solely to the review of the first preflight question. Both students and faculty highly valued this reoccurring opening preflight question because it was a way for students to communicate information about their learning difficulties directly to their instructors. Instructor 7 and Instructor 22 reported that they display the feedback provided by every student and felt that it was class time well spent to explicitly address each student's concern. It took about 8-12 minutes to cover individual student responses and served as the instructor's guide for what concepts to highlight in greater detail either at the outset of class or during another appropriate time in the lesson. Figure 5.2 includes examples of PowerPoint slides that a core instructor and a non-core instructor used to display student feedback to the first preflight question. Additional examples are included in Appendix P.

Figure 5.2 Samples of Faculty Displays of Student Responses to the First Preflight Question: ***What topic from the lesson would you like to discuss during class?***

Core Class



Non-Core Class



Several instructors reported on either the questionnaire or in their interview that they use the first preflight question specifically to guide their lessons, and confirmed this during my observations. If an instructor did not address every student concern explicitly (even if she/he projected student responses on the board), she/he would at least verbally acknowledge that they were aware a certain concept or problem gave the class trouble. Students appeared to be satisfied with either approach: 1) discussing each challenge directly at the outset of class or 2) acknowledging student issues as the content to which they pertained came up during the lesson. I did not witness an instructor carry out a combination of the two techniques such that she/he displayed quoted text from a student's preflight response to the first question intermittently throughout the lesson.

About half of the instructors also created a PowerPoint slide for each multiple choice preflight question and provided the answer to it. Some also shared the percentage of students in the section who correctly answered the questions as a way for students to gauge their understanding. A couple of instructors went so far as to make clicker questions out of the multiple choice preflight questions so students could poll their answers again. The instructors could then compare the number of students who answered the preflight correctly prior to class and then again after a short in-class discussion. The number of correct responses increased in both cases.

When it came to the review of multiple choice preflight questions during class, instructors might spend as little as less than a minute or up to several minutes reviewing one of the multiple choice preflight questions, but only if many students experienced difficulty with it as indicated by a low percentage of correct responses. A longer more in depth preflight review did not occur as consistently as the thorough solving of the pre-class workout problem from the back of the chapter at the boards. Some preflight multiple choice questions were not discussed at all during class either because so many students answered it correctly that it did warrant a formal review or because the instructor ran out of class time to go over it.

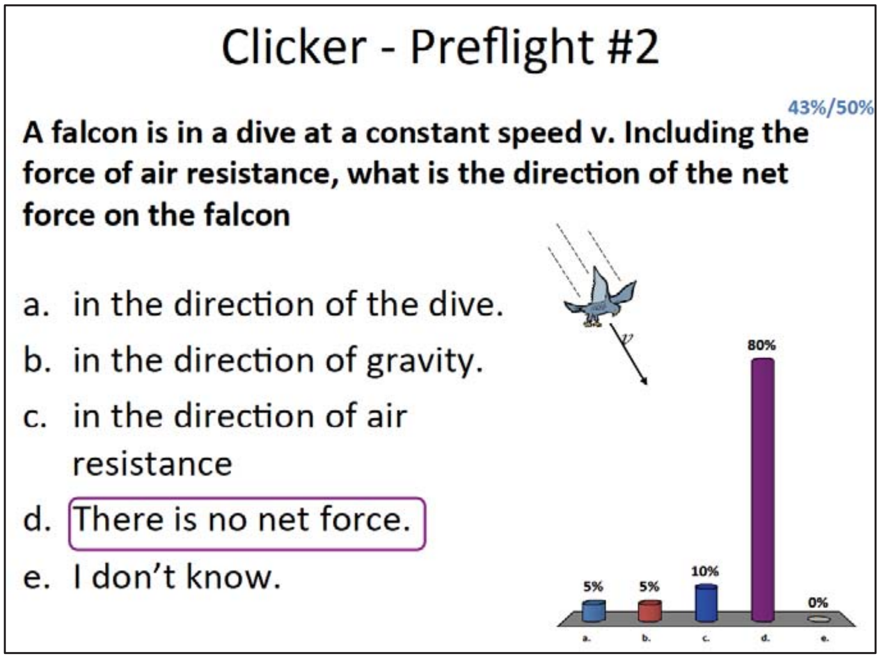
Within the dominant theme, "time," existed a second sub-category in the faculty data: the amount of time instructors spent using JiTT to prepare for class. This ranged from 15 minutes to 45 minutes and included the time required to log into the JiTT server, access student responses and then cut and paste typed student feedback and percentages of correct responses to multiple choice questions into PowerPoint slides. Some of the core instructors who shared their lesson

PowerPoint slides with me and are responsible for multiple sections customized their lessons by section meaning each section had its own slide of student responses dedicated to it. The instructor could remove from the slideshow the responses from their other sections using the "Hide Slide" feature of PowerPoint.

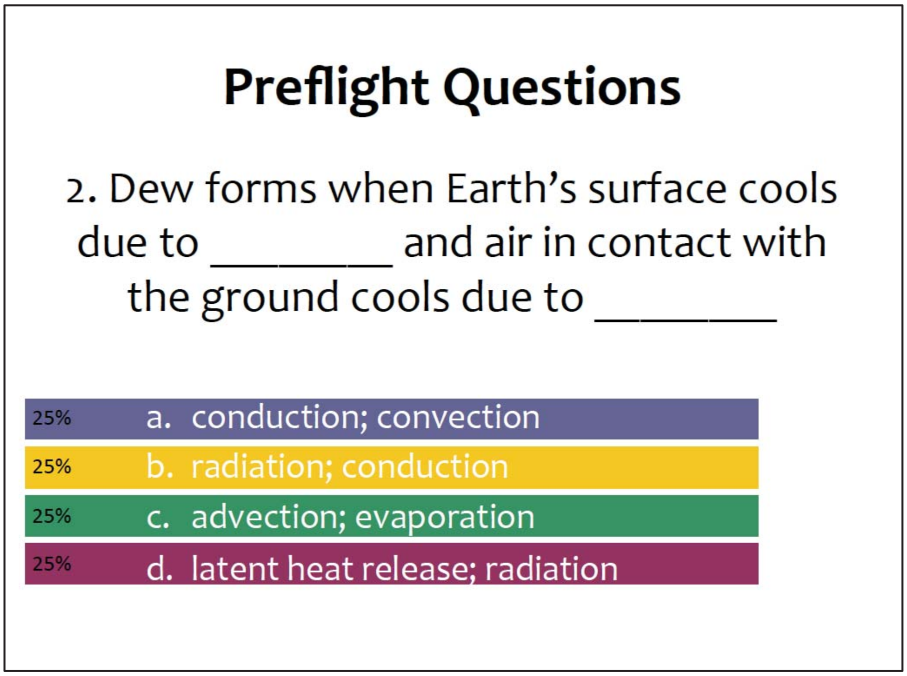
A smaller fraction of instructors also included PowerPoint slides containing recreations of the multiple choice preflight questions where they included the percentage of students who answered the question correctly. Some even turned these multiple choice preflight questions into clicker questions where students could re-poll their answer after a brief "mini" lesson on the concept addressed by the preflight question in the hopes that those who answered incorrectly on the originally submitted prefight would answer correctly in class. Instructors looked for a higher percentage of correct answers in the clicker responses to the preflight questions. Figure 5.3 includes examples of how instructors displayed multiple choice preflight questions. Please note that the slides containing equal percentages listed next to the answer choices is a default setting to evenly divide the proportion of responses when the clicker slide is not opened in a program that supports active polling. Those slides do not reflect actual student responses. Additional examples are included in Appendix Q.

Figure 5.3 Samples of Faculty Displays of Student Responses to Multiple Choice Preflight Questions

Core Class



Non-Core Class



While the faculty survey could not determine how much class time instructors dedicated to the JiTT portion of the core pre-class assignments, as noted in the previous chapter, classroom observational data indicated a trend that generated the first sub-category of the *JiTT Implementation Time* sub-node. When core faculty addressed pre-class work during a lesson, they consistently spent the most class time covering the back-of-the chapter problem. This entailed having students work out the problem in groups of two or three at the white board. If it appeared that most students correctly solved the problem prior to class, some instructors would have students solve a different word problem at the board. While students evaluated the problem at the board, instructors circulated the room to either help students who struggled with their problem solving or to grade students' journals (where they complete their pre-class work).

The focus on the pre-class workout problem and its associated board work does not necessarily mean the preflight assignment was completely disregarded during class, rather the nature of the preflight's simplistic structure and introductory level of difficulty lend themselves to a brief mention of a multiple choice answer paired with a not overly complex explanation. Keep in mind that an elaborate explanation of the preflight question usually only happened when the majority of students in a class answer it incorrectly. Even when a significant portion of a class answered a preflight question correctly, most core instructors shared—at a minimum—the letter answers to the multiple choice preflight questions (e.g., "The answer to preflight #2 is C." The answer to preflight #3 is B."). Instructors felt obligated to inform students of the correct preflight answers, albeit sometimes rapidly and without great detail, because students did not otherwise know if they answered a preflight question correctly until their instructor shares the solution. The JiTT pedagogy is meant to inform instructors of student difficulties. If student feedback via preflight responses indicated that most students understood a given concept, then the instructor did not spend much time on that topic and redirected conversation toward another activity or assignment.

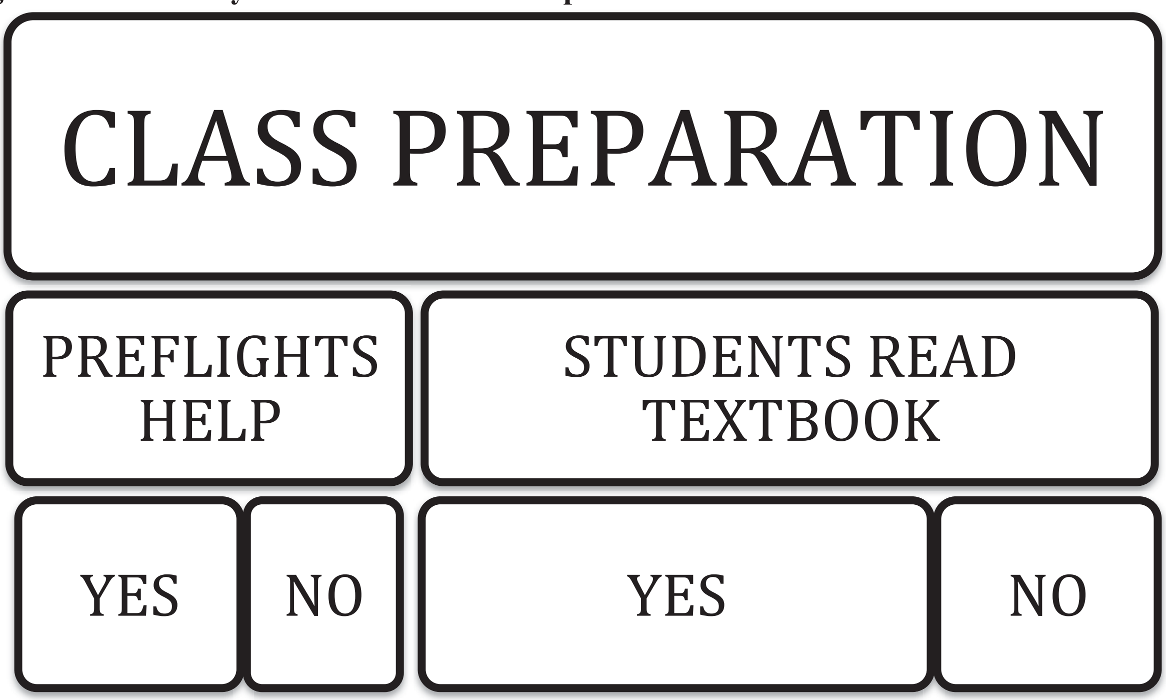
These data revealed that the instructors who enacted JiTT in their classrooms did so in a fashion that agrees with the techniques set forth by Novak et al. (1999) such that the faculty who are JiTT-users report that they read student preflight responses prior to the start of class and incorporate student feedback into their lessons by cutting and pasting typed responses to the first preflight question into PowerPoint slides. Sometimes faculty also displayed percentages of correct student responses to multiple choice preflight questions in PowerPoint slides as well. Faculty did not spend much class time on reviewing preflight questions where students recorded mostly correct answers. Additionally, the lesson tailoring that the JiTT pedagogy promotes was reflected in the section-specific PowerPoint slides containing student responses to the first preflight question. The responsive instruction that took place as a result of the student feedback to this opening preflight question was the main aspect that varied from section to section. For example, if an instructor's first period section contained a request to go over question #4 on the Worked Example worksheet, they would review it during the first period lesson, but not necessarily during their third or sixth period section, unless students requested it in these sections as well.

5.2 Qualitative Analysis of Research Question #2: Does a relationship exist between JiTT implementation and student performance?

To qualitatively address the second research question, I looked for evidence that students felt the preflight assignment helped them prepare for future learning in class which would in turn influence how prepared they felt for graded measures such as homework, quizzes, and exams. Using student feedback on the preflight questionnaire and focus group discussions as data sources to answer this question, I filtered out responses that did not directly pertain to the preflight assignment. I received reflections that related to the "self explanation prompt" questions contained within the Worked Examples worksheet as well as comments regarding the pre-class workout problem from the back of the chapter that students also complete as a part of their pre-class assignment. It was evident in some cases that students reported on the pre-class assignments in general, instead of just the JiTT component of the pre-class work. Therefore, I limited this portion of the analysis to only comments that pertained to preflights.

Within the parent node "Class Preparation" I created the following two sub-categories: 1) "Preflights Help" (Yes or No) and 2) "Students Read Textbook" (Yes or No). Figure 5.4 is a graphic representing student beliefs about JiTT and whether it serves as a tool to help them prepare for future learning in-class. As with Figure 5.3, the size of the block indicates which nodes were the more dominate categories within the combined student questionnaire and focus group data.

Figure 5.4 Hierarchy of Dominant Class Preparation Nodes From Student Data



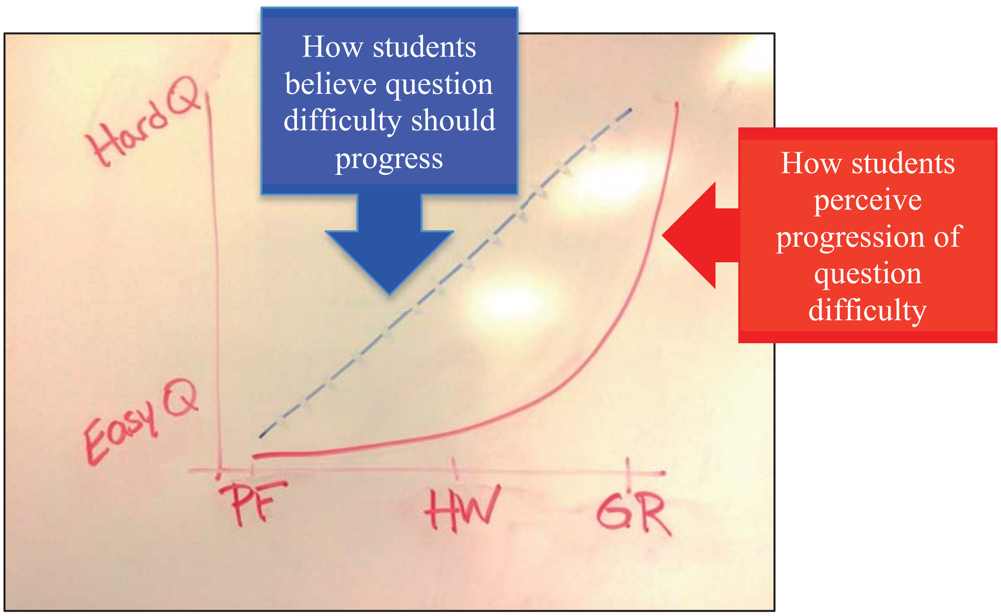
The majority of students who commented on whether they found preflights a helpful tool to prepare them for in-class learning indicated that they did find the assignment useful in their preparation for class. A few students pointed out that they found the first preflight question especially beneficial because the faculty were responsive to their and their classmates' needs when instructors spent time directly addressing the concerns students submitted electronically in the preflight. Students also reported that they generally felt more confident that they would be able to better understand what would be covered in an upcoming lesson after completing a preflight. A few students expressed during focus group sessions that the preflight assignment served as their "final check" for understanding before considering their preparation for physics class complete.

Core physics students who did not feel preflights adequately prepared them for future in-class learning generally believed the level of preflight question difficulty was not challenging enough. In fact, I was quite surprised by the number of students who felt preflight questions were too easy. Of course there were also cases where students reported that the questions were too advanced; however, the overwhelming majority of students who provided feedback related to question difficulty, reported they did not feel preflights were hard enough to prepare them for the type of question they would be expected to answer on a later assessment like a quiz or exam. This created the impression that a large gap existed between the level of difficulty of preflight questions and questions on which students would later be graded for correctness. The disconnection in question difficulty did not appear to exist in the non-core classes, although one student in each non-core class suggested that their preflight questions could afford to go into more depth of the material.

When I recognized this sentiment was common in the student preflight questionnaire, I brought it up during the focus group interviews. In this setting, students shared that, ideally, they would like the "ramp-up" of question difficulty to occur during a lesson and on homework assignments, but students did not feel that this was taking place in the core physics classrooms. Instructors might spend a lot of class time covering the easier pre-class work because that is what students are assigned to complete to prepare for class. As a result, many of the responses to the first preflight question contain requests to review other elements of the pre-class work. Therefore, a significant portion of class time can be dedicated just to the review of problems from pre-class assignments—those less challenging preparatory problems. As a result, instructors are left with limited opportunities within a 53-minute lesson to progressively expose students to the increasingly difficult physics problems they crave.

Students in focus groups agreed that they felt as though an exponential jump in difficulty occurred from what they were expected to be able to understand in an initial JiTT question to the type of problem on which they would be assessed on a quiz or exam. Figure 5.5 contains a photo of a reproduction of a graphical representation drawn during a focus group where I demonstrated how students described their experience with the progression of question difficulty in their current learning experiences (red, solid line) compared to how they felt question difficulty should progress (blue, dotted line) in their physics education. This student perception is not unfounded. Even Instructor 7 and Instructor 18 acknowledged during interviews that they felt many of the multiple choice core preflight questions were too easy and did not aid instructors—or students for that matter—in accurately assessing how well students understood the lesson material.

Figure 5.5 Graphical Representation of How Students Perceive Progression of Question Difficulty



Recall the central goal of the JiTT pedagogy is to encourage students to come to class prepared to learn by exposing themselves to course materials (e.g., the textbook) prior to class. The second sub-node within the *Class Preparation* parent node, “Students Read Textbook,” directly addresses this element of the instructional strategy and reveals how well students felt the textbook prepared—or failed to prepare—them for in-class learning as well as for subsequent graded measures.

Most students who provided feedback on their reading habits are reading the textbook; however, many who read were left feeling lost or confused by the textbook reading assignments. Several students appreciated the way preflights helped by directing them to pertinent sections in the textbook that would set the foundation for what would be covered in an upcoming lesson.

Yet from my experience, physics concepts, particularly those related to electricity and magnetism, are rather abstract for students in introductory level courses to visualize and fully comprehend even after multiple in-depth lessons.

As a result of the sometimes skewed expectation students have for themselves to master course content prior to class, some core students overtly admitted to not reading the textbook at all, but these cases were certainly the minority. While this investigation revealed that some students have serious difficulty navigating and deconstructing the explanations of the concepts contained within the core physics textbooks, students are—for the most part—reading what they are expected to read, but they are not necessarily making complete sense of what the authors are conveying within the assigned pages.

Since this dissertation is not meant to serve as a critique of physics textbooks, I will neither comment on deficiencies that may exist in the textbooks the Air Force Academy physics department chooses to use nor question their philosophy in selecting the textbooks they feel have supplied evidence to best communicate physics concepts to students. However, I do feel it is worth noting that the "intimidation factor" that seems to exist has in many cases resulted in an overall negative and discouraging experience for students. Ideally the textbook should serve as a reliable resource to which students can resort when their instructors are not present. Instead, some students are frustrated by their inability to grasp just a fundamental understanding of new physics concepts as they are presented in their textbook. The danger arises when students reach a threshold where they are so turned off that they stop reading altogether. Fortunately, this does not appear to be taking place in high volume at this research site.

Table 5.3 contains representative quoted text from student responses to the preflight questionnaire about their experiences with JiTT as a tool that helps and/or encourages them to read course materials as a way to prepare for class. Additional excerpts from students are included in Appendix R.

Table 5.3 Student Quoted Text About JiTT and Class Preparation

Preflights Help

"They definitely help me feel better prepared than in other classes that don't use preflights."

"Honestly, preflights help me a lot with my physics learning experience…I genuinely feel that preflights help me understand more during class."

"Honestly I find that the few basic concepts in the few questions is a good way to conduct preflights. I am able to dip into the concept without having to fully understand it. This shows me what I need to ask my instructor during class and what concepts do not make sense to me naturally."

"I think the preflight assignments are helpful. I enjoy the fact that the preflight questions aren't too specific in Meteorology 320. They make sure you understand the concepts from your reading."

Preflights Do Not Help

"The preflight assignments are just too easy for the material that is covered in class. If they covered ideas relating to the same topic but were more difficult conceptually they would be more helpful."

"My first physics teacher never went over them so I never got anything out of them."

"The questions asked as well as our preclass homework is either way too easy like V=Er or extremely difficult. They don't help me with of the [multiple choice] questions. I wish we could go over the problems in depth."

Students Read Textbook

"I think the preflight system is effective in accomplishing it's [sic] goal of encouraging students to do their readings and homework questions."

"[T]hey are really hard to do when you have no idea about the material and have actually tried to read and learn it."

"[T]he readings are typically very confusing and normally leave me more confused or not sure where to start on a problem."

"I think preflights are beneficial to learning the concepts, because they guide what I look for in the reading."

Students Do Not Read Textbook

"As it is now, we can guess and get it right without doing the reading."

"The book is very hard to read and often misguides me. I don't like to sit down and try to understand it before class because I might come to a wrong conclusion about something."

Below are additional passages from focus group conversations. In the first exchange, a student explained why she/he did not read the textbook before class. The second and third exchanges show evidence that students use the preflights to gauge what they already know before reading the textbook. If they cannot confidently answer the preflight question, they reference the appropriate section(s) in the textbook then attempt to answer the preflight question.

From Focus Group #2:

Student 5: I have a really bad routine.

Interviewer: That's okay. This is what I wanted.

Student 5: I do not read the book.

Interviewer: Okay.

Student 5: I'll open it up. I'm afraid of gaining a misunderstanding of the material before coming to class so I BS the [Worked Example] self-explanation, and I try not to do the pre-flights.

From Focus Group #1:

Interviewer: Just briefly, what's your routine once you log into the [JiTT] server?

Student 1: I will read the book, and then I go in and do [the preflights] straight into the computer. Then if there's one I have trouble on then I'll go back and look at the examples [in the textbook]. Generally I don't look at the examples.

Interviewer: Before doing the pre-flight? That's okay. That's interesting. Everybody has a different order of operations. "I'm going to do the journal the night before, and then first thing in the morning I'll do the pre-flight." That's what I'm just trying to get a feel for…what everybody's routine is. Ma'am?

Student 2: I skim through the book. Try to work through one of the examples that's in the book. Then into the Worked Example self-explanation, pre-flight questions, and then I enter [preflight answers] online.

Interviewer: Is that usually all in one sitting or do you break it up?

Student 2: All in one sitting.

Interviewer: All in one sitting. Okay. Sir?

Student 3: Normally login, see what [the preflights are] asking me, open the book, and then base my reading off what [the preflights are] asking me.

Interviewer: Okay. That's interesting.

Student 3: Key points.

Interviewer: You use the pre-flight as your study guide, so to say. What you're going to read.

<u>From Focus Group #2</u>:

Student 4: A lot of it is more review, so I just look at what I need to review more.

Interviewer: Got it. The pre-flight and journal drive what you read. And when you're reading, is it the textbook you're reading or other sources, Hyper-Physics [mentioned earlier in transcript] or-

Student 4: Normally the textbook.

Interviewer: Okay.

Student 4: It depends on the subject. Sometimes I might just try to branch off to try to get more in depth.

Interviewer: That's good, taking the initiative. Okay, I'll let you go next, sir.

Student 3: For [sic] the first pre-flight I, read the text and then tried to answer it, but now I will look at it, since they're so easy, I'll look at them and see if I can do it from-

Interviewer: Cold.

Student 3: Yes.

Interviewer: Not having looked at the example?

Student 3: Yes, and then I'm like, "Well, it looks like I have to read some of the book, and then do the [back-of-the-chapter] workout problem, and then end my day with the pre-flight.

Interviewer: Okay, so you read the pre-flight, not necessarily enter answers [right away]-

Student 3: Yes.

Interviewer: Then go back and read journal questions because you've got the workout problem as well as the-

Student 3: Right.

Interviewer: Worked example-

Student 3: Yes.

Interviewer: With those questions and then at the end of the day, use your pre-flight to gauge what you've done.

Student 3: Yes.

An issue that surfaced during a focus group interview and also appeared in a few survey comments from core students was worth highlighting. The matter in question pertained to the amount of time students spent reading in preparation for class. It became evident that some students were not ready—or perhaps willing—to dedicate the amount of time necessary to adequately prepare for their core physics class. Maybe they did not need to spend much time preparing for class in order to experience academic success prior to their university level physics courses. However, through their written or spoken feedback to me, a few discovered that they struggled to persist given the volume of reading and practice required to keep them up to speed and prepared for their current physics classes. The focus group exchange with the student below, who was enrolled in introductory electricity and magnetism for the second time due to a previous failure to pass the course, shows evidence of this phenomenon.

From Focus Group #0:

Student 1: My main problem with [preflights] is that before you even go into class you are also expected by the teacher to read through the textbook. Read for comprehension, which means a whole lot of time.

Interviewer: Spend a lot of time.

Student 1: Exactly and you have to go through a worked example and you have to answer general questions, or I think they are called self explanation questions now, and you have to a pre-class problem [from the back of the chapter], and you have to do your pre-flights. That's all before you even walk in the door and especially if it's a concept that you don't get. Like we did flux today and that took me forever to get during the [previous] semester. Literally, I had ended up writing I don't know for almost all of the stuff and so especially when it's a difficult concept and you've got all that [pre-class] stuff, and then you've got your [Mastering Physics] homework problems that you were doing from last lesson as well.

I think it's a lot of time to be spending on physics, and if you want us to go more towards reading through the textbook and going for explanation maybe have pre-flights instead of general questions.

Interviewer: Ok. Thank you.

While I have no solid evidence for it, based on my personal experience as an introductory physics instructor in higher educations and conversations with my colleagues, I presumed this student's sentiment was more common than what my data showed. I believe students at this research site make every attempt to be as efficient in their studies as possible and may not allow themselves the time they need to assimilate or accommodate the new knowledge they encounter during their first exposures to the physics course readings. A faculty member echoed my presumption in her/his response to the instructional strategies questionnaire saying,

> I believe that the basic, unavoidable equation that governs education is learning = [intelligence x time on task], and I think that most modern pedagogies attempt to somehow get around that equation, especially for less capable students, who need more time on task than their more capable peers.

This instructor also indicated in her/his interview that she/he believed when students were given more time to complete an assignment, they choose to spend it on themselves rather than on their academics. She/he felt students were given plenty of time to complete their studies—to include preparatory readings and exercises—but they continued to "waste it" on activities not related to their learning.

While this analysis revealed that most students read their textbook before class and felt the preflight prepared them to learn during class, many students did not feel prepared for the quizzes and exams that assessed their summative learning experiences. Some students indicated that they did not feel their in-class learning prepared them for the "next level" of difficulty that would bridge the gap between the knowledge for which they were responsible at the time of preflight completion and the knowledge for which they were responsible at the time of a formal assessment. From this, I conclude that students believed their performance on graded measures suffered when there was little or no escalation in problem difficulty from the initial preflight assignments to their quizzes and exams.

5.3 Qualitative Analysis of Research Question #3: Does student perception of their instructor's fidelity of JiTT implementation correlate with their perceptions of their physics course?

When students experience frustration with the preflight assignment, it has the potential to compound what might already be an adverse view of the course in which they are enrolled, but I would not go so far to say that one piece of a three-part pre-class assignment alone has the capability to drastically improve or reduce a student's overall opinion of their physics course. If a student in this study reported a negative opinion of how the preflight was enacted during a lesson, it was common for that sentiment to be accompanied with some other negative judgment of the course or even the instructor such that the unfavorable view was not solely attributed to the preflight assignment. The two central JiTT implementation requests students reported was for their instructor to 1) go over the preflight assignment during class and 2) connect the preflight concepts to the lesson material and/or new problems.

In all but two of the classes I observed, the instructor clearly referenced and went over at least one preflight question. The most commonly ignored preflight in the observed core physics classes was the concluding open-ended critical thinking exercise question. Students undoubtedly noticed this neglect. Several students reported in their responses to the preflight questionnaire and focus groups frustration with the fact that their instructors hardly ever reviewed the critical thinking exercise part of the preflight assignment during class. These exercises are the last question in the core physics preflight assignment, is typically more challenging than the preceding questions, and requires a typed explanation. On some occasions the critical thinking exercise also attempts to tie the new course material into a real-world application. Students were bothered that they received little feedback on whether their understanding of the application was accurate. In some cases, this inattention resulted in a decline in the effort core students put into answering the critical thinking exercise. I show evidence of this from in the interview excerpt below where a few students in Focus Group #2 reported that their instructors "rarely" or "never" reviewed the critical thinking exercise contained within the core preflight assignment. The discussion shows evidence for a lack of JiTT attention to the critical thinking exercises and real world connections to the concepts covered during class.

From Focus Group #2:

Interviewer: Extending even further. Okay. All right. Do you guys do the critical-thinking exercises?

Student 2: I don't like those.

Interviewer: Are they in your journals or pre-flights? Not every course has it, that's why ...

Student 2: Yeah. Are you thinking of the problems where it relates stuff to the world or whatever?

Interviewer: Yes, that's what I'm talking about. Does that sound familiar to anybody else?

Student 2: Those are usually the ones you have to write in on the pre-flights.

Interviewer: Okay, the last question, like question 4.

Student 2: I personally don't like those because I have no idea, I'm barely comprehending… If you ask me a real world example and I literally almost always I just write something down because I don't know what else to say.

Student 3: Oh yeah, I'm with you on that.

Interviewer: All right. How often does your instructor cover that pre-flight question in class? Because that was a complaint, "Why do we have to do the critical-thinking exercise when we never go over that in class?" I get it. If I'm your instructor and I don't go over something, that's a sign to you guys that it's not important. Possibly. Maybe that's how you're interpreting it. Maybe I was just short on time and I do value it, but if it's a consistent thing and it's never covered then yeah, that might be a concern. Is never or rarely that-

Student 3: Rarely.

Interviewer: Rarely that critical-thinking exercise is-

Student 2: Never.

Interviewer: Never.

Student 2: I don't recall doing that.

Student 4: If there's something that applies to real-world stuff, the instructor just comes up with their own stuff.

Interviewer: Their own, okay, it's not from the pre-flight?

Student 2: I think the pre-flights should solely be multiple choice, and then it will pop back with your correct answer so that you can get those down and then know those for future [exam]s and stuff.

Based on the student feedback related to the critical thinking exercise, I asked about this preflight question during faculty interviews. Instructor 7 reported that she/he did read the responses to the critical thinking exercises before class, but only "sometimes" went over them during class because most of the students answered them correctly. When Instructor 6 reviewed the critical thinking exercises during class, she/he said that she/he displayed student responses and had students use a clicker to vote on the best answer. Instructor 18 explained that when she/he displayed student answers to the critical thinking exercise, she/he included multiple student responses and let students discuss or even debate the best answer. During my observations of these three faculty members, they all mentioned the answer to their respective lesson's critical thinking exercise, but I did not witness the latter two critical thinking exercise implementation techniques during those observations.

While Instructor 18 said she/he did her/his best to incorporate as much pre-class work as possible into a lesson, she/he also acknowledged the fact that if she/he did not go over something from the pre-class work on a consistent basis, that sent a message to the students that she/he did not value it, and they in return would not put a great effort into it. Therefore, some instructors are aware that their inattention has the potential to result in a decline in the effort students put the entire preflight assignment.

Another area where students expressed displeasure with the implementation of JiTT was associated with a lack of connection to the lesson objectives or content. This manifested itself in two ways. The first, more predominant, group of students did not see how the preflight questions related to the course readings and/or the other two elements of the pre-class work (i.e., the Worked Examples worksheet and the pre-class workout problem). This is concerning because the preflight questions are designed to check for student understanding of the textbook readings for its associated lesson. Perhaps this means students are not reading the correct materials for a given preflight, or perhaps they are not carrying out the comprehensive reading necessary to recognize the relationships between the preflight questions and the reading assignments. The student comments from the previous section regarding time spent on class preparation might lead one to believe the latter could be a more accurate assumption.

The second, smaller, group of students reported on how their instructors either connected or did not connect the preflight concepts to other related topics during class. In particular, students had a desire for their instructors to link and extend the basic underlying concepts from the preflight questions beyond the initial exposure and toward a more challenging application of the same concepts. Examples of student feedback regarding how preflights were integrated into their lessons are listed in Table 5.4. Additional excerpts from students are included in Appendix S.

Table 5.4 Student Views About Their Instructor's Implementation of JiTT

Favorable Implementation Feedback
"The first question which asks what we would like to discuss is always helpful because I can put down any question I have before class and my teacher will most likely go over it in class."
"I believe my teacher does an excellent job with the preflights and discussing them in class."
"My teacher tries to base the class off of pre-flight responses. The first question, here is what you would like to go over in class? She makes that mandatory."
"[Displaying student responses] is good because then you can see the different ones that you relate to and you know that you're not the only one struggling with that."
Unfavorable Implementation Feedback
"Encourage the instructors to read over pre-flight responses in order to tailor the lesson to what the students don't understand from the reading."
"If the teacher went over the questions more, then I would be less confused."
"The set up of the preflight could be incredibly helpful if the teacher would actually review the questions in class. Right now, there is no way for me to know if I got the questions correct and if my explanations were correct because my teacher doesn't review them in class."
"We don't really go over stuff when we have labs. Normally [my instructor] is really good about going over it, but I know there have been, like the first lab we did. I messed something up in my pre-flight. I was lost the entire lab, and I had no idea what was going on because everybody else took control in the group. I was like, 'I have no idea what's going on.' We didn't go over [the pre-flight] and I didn't know what I did wrong."
Preflight Lacks Connection to Lesson Topics and/or Readings
"The preflights would be more useful if they were more clearly connected to what was taught in the book."
"[E]very once in a while there will be something seemingly somewhat unconnected questions."
"Preflight questions could be improved by making them a couple questions longer to connect more to the reading."

"I do the preflight assignments however often go into the next class and do not feel a connection between the two. I have questions about the lesson going in from doing the preflight, but often end the class with the same questions."

"My instructor will then go over the preflight questions in class but not explain other types of problems on the same subject matter."

Below are excerpts taken from transcripts of student focus groups. In the first two passages, students reflected on poor connections between preflight assignments and the subsequent lesson topics, while the last conversation shows evidence of a student pleased with how her/his instructor ties preflights into class.

From Focus Group #5:

Interviewer: Okay. So, with that, [the preflight] seems a little disconnected from-

Student 7: Yeah. From the readings, and then the pre-class problem, and then the pre-flight, I'm like, "Where did this come from? How does this relate? I have no idea."

Interviewer: Okay. So [the preflight]'s disconnected from the other assignments.

Student 7: Yeah.

From Focus Group #6:

Student 4: Usually, when there are one or two people who have a problem, [my instructor]'ll just encourage you to come into the second period.

Interviewer: That's a good added point, too. The people who didn't get it don't feel left behind, like, "Okay, everybody else gets it but me." Okay, that's good. That's good to hear. Very good. Sir?

Student 5: We use the clickers and it's fantastic!

Interviewer: Clickers are nice teaching tool.

Student 5: Oh, it's great. [My instructor] goes over the questions and hands out the clickers. [My instructor] puts in their answer and then talks about it. [My instructor]'s like, "Okay, this is the basics on that, and then this is how it's going to relate to what we're going to have to do today."

I carried out a comparison of the lesson learning objectives to the questions asked in the corresponding preflights for both the core and non-core classes I observed. I felt that the preflight questions did relate to the learning objectives for their respective lessons, and the instructors remained on-topic unless they acknowledged that a certain topic would reoccur in a future lesson. Each of the four core journals and the lesson materials available for one of the non-core classes explicitly and conveniently list the learning objectives at the beginning of every lesson; therefore, I must conclude that students who felt the preflights were disconnected from the other pre-class work or in-class discussion did not read the learning objectives, disregarded them, or genuinely struggled to make the connections on their own and relied heavily on their instructors to overtly verbalize the relationships for them.

5.4 Summary

Based on the qualitative feedback from the research participants, a general consensus existed that students wanted their instructors to review preflights during class, and they expected faculty to connect and expand upon the concepts introduced in each preflight question. Core instructors made every effort they could to incorporate as many preflight questions as often as possible during a lesson, but they also had the Worked Example worksheet and pre-class workout problem to which they felt obligated to dedicate their attention. As a result, core faculty found it difficult to effectively cover all preflight questions when time must also be reserved for the review of the other two pre-class components.

In addition to a coverage issue, students also had a desire to connect and explore physics concepts in more depth during class; however, the part of the pre-class work that allows for this, the critical thinking exercise, did not receive much in-class attention. Students recognized this, and in some cases were conditioned to put less effort into an assignment or portion of an assignment that received little review during class. Unfortunately, this behavior appears to be rewarded. The preflights are graded online for effort, while the remaining two core pre-class assignments are graded for effort during class in student journals. Some students have reported that they realized their instructors did not have time to accurately discern between a strong and a weak effort. As long as a student submits something in the online preflight and jots down something for their Worked Examples worksheet and pre-class workout problem, instructors did not seem to differentiate their grading based on the student who dedicated a significant amount of effort from the student who put in a minimal effort. This was confirmed by the high percentage of points students earned, on average, for their pre-class assignments (92% for preflights, 92% for core Worked Examples and back-of-the-chapter problem).

If the implementation of JiTT could be improved by dedicating more attention to the critical thinking exercises, then perhaps students would put in a more concerted effort into these questions. Adams et al. (2006) suggest that encouraging students to "make larger commitments to studying" for class leads to a more favorable view the course. Specifically, reviewing the critical thinking exercises that make real world connections more regularly might improve a student's view of the course by positively influencing their responses to questions 8 (*I study physics to learn knowledge that will be useful in my life outside of physics*.), 13 (*Learning physics changes my ideas about how the world works.*), and 16 (*The subject of physics has little relation to what I experience in the real world.*) on the modified CLASS inventory. However, I surmise if this instructional change were made, any improvement in student attitude toward the course would be very small.

Additionally, when instructors did not dedicate class time to review other preflight questions nor made clear connections between the concepts in the preflight questions and other topics covered during a lesson, some students did not view the preflight assignment as a way to prepare for in-class learning. However, the preponderance of the written feedback from the student questionnaire indicated that students did feel that the preflights assignment helped them prepare for in-class learning. This is in agreement with quantitative data also taken from the student preflight questionnaire, where 76 percent of respondents across all of the courses under investigation reported that they agreed with the statement: "Preflights prepare me to learn new physics concepts during class."

Ultimately, students wanted their instructors to go over all of the preflights answers during the lessons, regardless of how well the class collectively performed in answering the questions, so that they know if the answers they submitted were correct. Otherwise, the students never received feedback about whether their answers were right or wrong, and therefore how well they understand the concepts they discuss in class.

Chapter 6 - Conclusions

This chapter summarizes the findings that emerged from this investigation. I begin with an overview of the investigation, followed by a presentation of theoretical connections to their associated answered research questions. Since I carried out a mixed methods study, I synthesize the quantitative and qualitative data analyses as they pertained to each research question. In Section 6.3, I discuss implications and recommendations that surfaced in this research. I acknowledge the limitations of this dissertation in Section 6.4, and Section 6.5 presents ways this study can be expanded upon in future works.

6.1 Overview of Investigation

The goal of this project was to conduct an investigation of how undergraduate physics instructors enacted the pedagogy called Just-in-Time Teaching and how their practice may influence student performance and perceptions of the course.

As a recap, the online JiTT assignments in this study are referred to as "preflights" and are a combination of multiple choice and free response questions. Instructors integrate student responses to preflight questions into their lessons as appropriate, which creates a feedback loop between students and their instructors (Novak & Patterson, 1998). The primary advantage of preflights is their ability to encourage students to come to class prepared to discuss the content featured in the lesson (Novak et al., 1999).

In 2001, Maloney et al. concluded their report on the Conceptual Survey of Electricity and Magnetism by highlighting a need for additional research on instructional strategies so that education researchers can accurately determine the impact a particular pedagogical technique has on student performance. This research also grounds its relevance in its response to the 2013 National Research Council's report on undergraduate physics education and their charge for increased study using research-based approaches to improve undergraduate physics education. To this, I would also include a motivation to determine the impact teaching strategies have on student perceptions of their physics course (Adams et al., 2006) and how well pre-class assignments prepare students to transfer new knowledge during in-class learning (Singley and Anderson, 1989; Bransford et al., 2000).

I enlisted a blend of quantitative and qualitative data analysis to answer the following three research questions:

1. *With what degree of fidelity is Just-in-Time Teaching implemented in undergraduate physics classrooms? Specifically, does the critical component that characterizes JiTT discriminate between physics faculty members who claimed to use JiTT and those who did not?*
2. *Does a relationship exist between JiTT implementation and student performance? Specifically, do final exam scores, course order of merit, preflight scores, and homework scores predict student perceptions of their instructor's fidelity of JiTT implementation?*
3. *Does student perception of their instructor's fidelity of JiTT implementation correlate with their perceptions of their physics course?*

I carried out the month-long data collection during the Fall 2014 semester at the United States Air Force Academy in Colorado Springs, Colorado. The research was done in the context of undergraduate introductory, or *core*, physics courses but also as it related to two *non-core* physics courses: *Upper Atmosphere and Geo-Space Physics* and *Introduction to Meteorology and Aviation Weather*. Faculty data entailed the responses to an instructional strategies in undergraduate physics questionnaire, one-on-one interviews with volunteer physics instructors, and classroom observations. Student data included responses to an online preflight questionnaire, focus group interviews, end of course grades, and responses to the modified Colorado Learning Attitudes about Science Survey (CLASS).

6.2 Review of Theoretical Connections to Answered Research Questions

In this section, I link the four theoretical frameworks discussed in Chapter 2 to the answered research question(s) they supported throughout this dissertation, and I synthesize the quantitative and qualitative findings for each presented research question.

6.2.1 Understanding this Work in Terms of Diffusion of Innovations

I grounded all three research questions in Rogers' (1995) *Diffusion of Innovations* theory, whereby I investigated the extent to which undergraduate physics instructors enacted the JiTT innovation such that they adhered to the JiTT creators' intentions and used enactment techniques that mirrored the creators' "ideal" (Loucks, 1983). Extending this to the concept of fidelity of implementation of a program, I searched for evidence that followed Durlak and DuPre's (2008) idea that "[a]chieving good implementation not only increases the chances of program success…but can also lead to much stronger benefits for participants." In this study, I considered the benefits of improved student performance and a more favorable view of a course as possible results of the sound implementation of the JiTT pedagogy.

6.2.1.1 Research Question #1: With what degree of fidelity is Just-in-Time Teaching implemented in undergraduate physics classrooms?

Faculty responses to the instructional strategies in undergraduate physics questionnaire indicated that no statistically significant relationship existed between faculty who reported spending time on the required JiTT critical component (*Spent time discussing pre-class assignments which helped [her/him] reevaluate student learning and adjust [her/his] lecture 'just in time' for class.*) and their designation as a JiTT user or a non-JiTT user. All (n = 16) questionnaire respondents who reported they currently used the pedagogy also reported spending time on the required JiTT critical component. Three faculty members who reported they were *not* currently using the JiTT strategy indicated spending time on the required JiTT critical component. This contradiction showed evidence that some instructors were not aware they were enacting the branded JiTT strategy their teaching practice.

Relating these findings to Hall and Rutherford's (1976) *Stages of Concern*, novice instructors were just as likely as experienced instructors to have trouble reconciling personal concerns about their role and possible conflicts between that role and the anticipated demands of the innovation as well as concerns about managing time, organization, and making the innovation work smoothly.

Seventy percent (n = 14) of physics faculty members reported regularly talking and/or corresponding with their colleagues about their teaching practices in the past two years, which showed evidence that instructors dedicated time to working with others on course content, pedagogies, or other teaching topics. This is not consistent with Hall & Rutherford's (1976) fifth stage of concern, collaboration, where faculty may experience issues working with others in their use of an innovation. This is most likely result of JiTT being well established among the physics faculty members at this research site.

A few instructors reported in their interviews that they did not usually have time to address the sixth stage of concern, refocusing, during a semester. Rather, they found other and even more effective ways to enact the innovation when they had more time in between terms.

Only one non-JiTT user agreed to participate in an interview, and combining information garnered from that dialog along with responses to the instructional strategies questionnaire, I learned about barriers faculty perceived while implementing the JiTT pedagogy. To begin, 25 percent (*n* = 5) of questionnaire respondents cited a lack of evidence supporting the efficacy of the instructional strategy as a factor that seriously discouraged their plans for using the pedagogy in the future. This barrier fell within Rogers' (1995) *Observability* innovation characteristic in that faculty desired more research literature supporting the learning benefits of JiTT.

Two core faculty members commented on the lack of instructor autonomy when teaching a core physics class. Since JiTT is imbedded in the core physics curriculum, an instructor in one of these courses has no choice but to include preflights in her/his syllabus. This relates to Rogers' (1995) *Trialability* component of innovations in that core instructors do not have the option to experiment with JiTT and then remove it from their teaching practice if they feel it is not consistent to their teaching philosophy or style or if they do not believe their students benefit from it.

The next two barriers related to time and map to the *Compatibility* aspect of Rogers' (1995) characteristics of innovations such that some faculty did not see JiTT as being consistent with their existing instructional values, experiences, and needs. First, three faculty members believed incorporating JiTT took up too much class time to cover the necessary materials on their syllabus. Second, 35 percent (*n* = 7) of respondents felt JiTT required too much advanced preparation time. From the faculty interviews I found instructors spent an average of 30 minutes prior to class incorporating preflight responses into their lessons, and one instructor adamantly stated that she/he did not see value in increasing an instructor's workload for minimal gains in student performance.

Generally speaking, while non-JiTT users might have believed the purpose of the JiTT pedagogy is worthy, they did not believe JiTT's *Relative Advantage*, or the degree to which a teaching innovation is perceived to be better than the idea it supercedes, nor its *Observability* merited its incorporation into their teaching practice. Chiefly, non-JiTT users did not feel it was worth their time to review preflight responses because they could anticipate what concepts would give their students the most trouble during class, plus they did not believe there was enough scientific evidence to support the beneficial impact—namely an increase in student performance—the JiTT strategy had on student learning.

While consistent with Novak et al.'s (1999) recommended ideal JiTT implementation (Loucks, 1983), from my observations, I did not witness much variation in the way JiTT-users integrated preflights into their classes, even between core and non-core courses. This may be a result of how JiTT is first explained and demonstrated to new faculty members who go through the department's orientation program. Instructors may be mimicking what they see in their initial training during the orientation or while observing other experienced faculty members enact JiTT. The non-core instructors had prior experience using JiTT in core classes, so they it is likely that their core JiTT techniques transferred to their non-core courses.

A key element to JiTT implementation was incorporating student answers into class. Most faculty displayed on a PowerPoint slide direct feedback from students about what they wanted to go over in class. Some instructors would also recreate the multiple choice questions on PowerPoint slides and review the answers so the students could find out if what they submitted online before class was correct.

6.2.1.2 Research Question #2: Does a relationship exist between JiTT implementation and student performance?

The linear multiple regression analysis described in Chapter 4 showed no statistical evidence that a student's performance on their final exam, homework, or preflights were predictors of their view of their instructor's fidelity of JiTT implementation. Student perception of their instructor's fidelity of JiTT implementation was a summed measurement of two Likert-type questions (scale of 1-6) from the student preflight questionnaire that accounted for the level of agree with the following two statements: 1) *It is evident that my physics instructor reads all preflight responses before class starts*; and 2) *Our preflight answers clearly guide what we cover in class*. The higher the sum, the more favorably a student viewed her/his instructor's JiTT implementation.

In the second regression model, where the data were filtered for only those students who reported that preflights helped them prepare for all graded measures (homework, quizzes, and exams), final course order of merit was the only statistically significant predictor of student perception of their instructor's fidelity of JiTT implementation.

Although not a measure of performance, I chose to include in the regression models a score of how seriously students took the preflight assignment based on their responses to a Likert-type question (scale of 1-6) from the student preflight questionnaire assessing the level of agreement with the following statement: *I take physics preflights seriously.* Once this independent variable was included, it became a significant predictor of student perception of their instructor's fidelity of JiTT implementation in the following four models:

Model 1: all core and non-core students in the study,

Model 4: only regular electricity and magnetism students,

Model 5: only honors electricity and magnetism students, and

Model 6: only regular mechanics students.

This showed evidence that when a student puts a genuine effort into completing her/his preflight assignment she/he also tends to have a more favorable view of her/his instructor's implementation of JiTT. This may also mean that students who took the assignment more seriously were reading their textbook more thoroughly than those who did not take the assignment seriously and therefore feel more prepared for future in-class learning. However, data about how *comprehensively* students read is needed to show evidence of this assumption.

Putting this in terms of Hall and Rutherford's (1976) *Stages of Concern*, disagreement existed among faculty members regarding the fourth *Consequence* stage and their concerns about student outcomes. Here, some instructors believed preflights encouraged their students to read their textbook as a way to prepare for class, while others did not believe students read their textbook comprehensively enough to make preflights a worthwhile assignment. Many students who reported that they read the textbook also said they experienced such difficulty understanding what they were reading they could not establish a solid knowledge foundation for class.

6.2.1.3 Research Question #3: Does student perception of their instructor's fidelity of JiTT implementation correlate with their perceptions of their physics course?

Student perceptions about their respective core physics course were measured using a modified version of the Colorado Learning Attitudes about Science Survey (CLASS; Adams et al., 2006; included in Appendix H). This survey was administered twice during the Fall 2014 semester, once at the beginning (pretest) and once at the end (posttest). Investigating how instructors enact teaching strategies like JiTT revealed how instruction can influence student beliefs about their physics course.

I found a higher correlation between student perception of their instructor's fidelity of JiTT implementation and the modified CLASS *post*test scores than between student perception of their instructor's fidelity of JiTT implementation and the modified CLASS *pre*test scores. This showed evidence that with increased exposure to the JiTT pedagogy, students had a more favorable view of their course. However, the dilemma of *tertium quid* exists such that there exist other confounding factors that were not evaluated in this study, which may also influence scores on the modified CLASS (Field, 2013). Therefore, I cannot definitively say that JiTT exposure increased student views about their core physics course.

One experienced instructor felt she/he could anticipate student misunderstandings without the need for a preflight to reveal this information to her/him. Likewise, two novice instructors indicated in interviews that they could often foretell student struggles after only one semester teaching a course. The ability to forecast student confusion, though, does not take into account the affective impact JiTT has on students when they see their concerns and/or answers displayed in class. If students perceive that their instructor is reading their feedback via their preflight responses, they may view the assignment, and potentially the course, more favorably.

The qualitative data supported this claim. Student feedback in questionnaire responses and in interviews showed evidence that students highly valued *seeing* their responses to the first preflight question (*What would you like to discuss during class?*) displayed during class and felt that instructors were responsive to this feedback. Students had a favorable view of instructor implementation of JiTT when the faculty members made it clear that they used student preflight answers to drive class discussion, as indicated by the overall student agreement with the preflight questionnaire statement *Our preflight answers clearly guide what we cover in class*.

6.2.2 Understanding this Work in Terms of Technical Pedagogical Content Knowledge

6.2.2.1 Research Question #1: With what degree of fidelity is Just-in-Time Teaching implemented in undergraduate physics classrooms?

In Section 2.2.2 I discussed Koehler and Mishra's (2009) Technical Pedagogical Content Knowledge (TPCK) theoretical framework. One aspect of TPCK examines how the introduction of technology into the classroom environment can pose amplified dilemmas for teachers who joined the education workforce during a time when technology was at a more rudimentary stage in its development. Based on faculty interviews, some physics instructors found it difficult, particularly when they first learned how to access and incorporate preflights into their classes, to recognize the relevance of the innovation's technology to their curriculum and lesson planning. One faculty member cited a "generational gap" as the reason for her/his difficulty with overcoming cumbersome computerized aspects of the assignment.

Subsequently, the proverbial "learning curve" on which some faculty set forth as they implement the JiTT pedagogy in a way that suited their teaching style was steeper than the curve for an instructor who might have been more comfortable with available classroom technologies. This challenge surfaced when some JiTT adopters had to navigate the initially unfamiliar—or unreliable—JiTT Web server. To mitigate this concern, thorough innovation training may be a critical aspect when considering the adoption and perceptions of an educational innovation like JiTT (Shulman, 1986). Instructors reported either during interviews or on the instructional strategies questionnaire that they learned how to use the JiTT pedagogy during a new faculty orientation program the physics department hosted or during a brown bag lunch seminar that the department's Center for Physics Education Research sponsored. Only one instructor indicated that he read Novak et al.'s (1999) Just-in-Time Teaching book.

All but one class that I observed incorporated PowerPoint slides into the lesson. The one lesson that went without PowerPoint was the result of a laptop malfunction; however, after dedicating a few minutes to troubleshoot the problem, the instructor acknowledged the complication and quickly adapted. She/he recalled from memory and verbally shared common student issues that surfaced in the preflights she/he had read before class. Remaining flexible during these situations is paramount to the *technical knowledge* element of TPCK so that instructors can simultaneously maintain the orientation of their *pedagogical knowledge* as they attempt to maximize student learning using JiTT methods.

Since technological capabilities are perpetually in a state of flux, instructors must keep their computer literacy skills current to be able to adapt quickly to changing classroom tools. While technology can be a great asset to teaching, it is not completely fail proof, and instructors who choose to use programs such as PowerPoint should always have a backup plan in the event their electronic presentation becomes unavailable, they experience a computer "crash," or a projector bulb burns out during class.

In addition to hardware failures, JiTT was vulnerable to software failures as well, and this brought to light another barrier to effective JiTT implementation. Three of the instructors who participated in an interview voiced their frustration with the unreliability of the current JiTT server, which has had regular outages throughout the years. Whenever the JiTT server went down, instructors had to manually modify grades and deal with an influx of student emails and complaints or concerns about their missing submissions.

6.2.2.2 Research Question #2: Does a relationship exist between JiTT implementation and student performance?

Continual problems with the JiTT server made it sometimes difficult for two interviewed instructors to buy into the innovation's relevance to the physics curriculum because it posed such a hindrance to their *technical pedagogical knowledge* when they had to make aforementioned adjustments to grades and teaching. These "annoyances" affected student learning by becoming regular distractions that took away from instruction whenever the faculty members had to acknowledge JiTT service interruptions. Continually dedicating valuable class time to discuss and/or resolve problems with JiTT technology was an obstruction rather than a benefit to student learning, which—if it occurred frequently enough—could later impact student performance.

6.2.2.3 Research Question #3: Does student perception of their instructor's fidelity of JiTT implementation correlate with their perceptions of their physics course?

Like faculty, students also voiced their irritation with the shortcomings of the JiTT server and its tendency to present difficulties with accessing and completing their preflights online. I did not believe that this greatly impacted their overall view of the course in general, but it did create a negative view of the preflight element of the pre-class work for some students.

6.2.3 Understanding this Work in Terms of Class Preparation

6.2.3.1 Research Question #2: Does a relationship exist between JiTT implementation and student performance?

The linear multiple regression analysis carried out in Chapter 4 indicated that students who believed the preflight assignment helped them prepare for other graded work such as homework, quizzes, and tests, and who had a better order of merit viewed their instructor's fidelity of JiTT implementation more favorably. Students who reported taking the preflight assignment seriously might have also been putting more of a genuine effort into the completion of preflights and, as a result, were more prepared for future in-class learning. These students tended to perform better on graded measures. The correlation table at the end of Appendix J indicated that statistically significant positive correlations existed between students who took preflights seriously and the following four performance measures:

1) final course average (r = 0.235, $p < 0.01$)
2) final exam score (r = 0.129, $p < 0.01$)
3) homework score (r = 0.180, $p < 0.01$) and
4) preflight score (r = 0.247, $p < 0.01$).

This aligns with Bransford and Schwartz's (1999) claim that pre-class exercises like JiTT can set students on a learning trajectory that, with in-class instructional support, can carry their transfer of knowledge much farther than if they arrived to class with zero exposure to lesson content. However, there may be other confounding factors not included in this correlation that also influence student preparation for class and subsequent performance.

Some core students reported in focus groups and in responses to the preflight questionnaire that they did not always see a connection between preflight questions and their textbook readings; nor did they feel that the foundational concepts introduced in preflight questions were adequately connected and built upon during their physics lessons. If students establish the foundational knowledge they need for future learning during a lesson, then it is the instructors' responsibility to foster an environment where their students' knowledge can continue to grow from their in-class learning experiences. Perhaps instructors need to be more explicit in how they are expanding on pre-class assignments during their lessons.

6.2.4 Understanding This Work in Terms of Student Attitudes Toward Science

6.2.4.1 Research Question #3: Does student perception of their instructor's fidelity of JiTT implementation correlate with their perceptions of their physics course?

The correlation analysis performed in Chapter 4 showed evidence that student perception of their instructor's use of preflights was not related to their views about learning physics at the beginning of the course as measured by the modified CLASS pretest; however, a small positive correlation existed between student perception of their instructor's use of preflights and their views about learning physics at the end of the course as measured by the modified CLASS posttest. A slightly larger positive correlation existed between student perception of their instructor's use of preflights and their overall change in views about learning physics as measured by the normalized gain in modified CLASS scores. Correlation, however, is not terms for causation (Harris, 1998; Field, 2013). Therefore, I cannot make a conclusive statement about the direct impact JiTT implementation may or may not have had on student views about learning physics. Since all of the core courses in this study used the JiTT innovation, I was unable to determine the direct impact JiTT might have had on student views of their physics course by comparing JiTT classes to non-JiTT classes.

6.3 "So What?": Research Implications & Recommendations

In this section I discuss the implications of this study and offer recommendations for the implementation of Just-in-Time Teaching in future physics courses at the United States Air Force Academy.

6.3.1 Implications

This investigation revealed that some instructors might not be unaware that they were using a branded pedagogy in their teaching practice. Evidence for this resided in the fact that some instructors who reported they were not currently using JiTT were spending some time on the predefined JiTT critical component. Additionally, since JiTT users did enact the JiTT strategy according to the way its creator's originally intended, this population of faculty members can serve as a model for JiTT implementation in other courses within the department, in other disciplines, and/or at other institutions of higher education. This study also suggested that JiTT achieves its goal of encouraging students to access their textbook and preparing students for in-class learning; however, it is not clear how comprehensively students are reading. Finally, the data showed that instructors must make overt connections between preflights and textbook readings, lesson discussions, and other assignments; otherwise, students may miss how the various exercises are related to one another.

6.3.2 Recommendations

6.3.2.1 Explain the JiTT Philosophy to Faculty and Students

From the student focus groups, I learned that many students were not aware of the philosophy behind the JiTT pedagogy and their associated preflight assignments. This gave rise to the student sentiment that preflights were easy "gimme" points since they were graded for completion and not for correctness. During the focus groups, I asked students whose instructors had explained the purpose of the preflight assignments to share what they knew with the rest of the group. I saw nods and raised eyebrows from the students who had not fully understood the purpose of the assignment prior to their peer's explanation. This indicated a need for instructors to dedicate time at the start of a term to explain *in depth* the reason why students are asked to complete preflights.

While the idea of reading a textbook and answering a few basic questions about what one just read is not difficult to understand, some students were mistaken in their thinking that they were expected to show mastery of the topics they read about before arriving to class. I believe instructors should dedicate a few minutes at the beginning of a semester to thoroughly explain the philosophy behind the JiTT assignment. This goes beyond the fact that the assignment informs instructors about what their students understand or do not understand before class starts, but that students also gain the capacity to "extend what has been learned in one context [pre-class assignments] to new contexts [in-class activities]" (Bransford, 2000). Preflights also help students learn how to articulate to their instructors what they do not comprehend (Novak et al., 1999).

A few core students reported grievances in the preflight questionnaire that they felt they should not be expected to teach themselves from the textbook because the explanations of the novel ideas were too complex to understand without help from their instructor, and, on average, students only "somewhat agreed" that preflights were worth their time. This attitude might be improved if instructors clearly explained what they expected of their students when completing the preflight assignments. Again, some students felt they had to master physics concepts in their initial exposure to the material and then reflect that mastery in their performance on preflights (and other pre-class assignments). This is neither the goal of JiTT nor the expectation faculty should have for their students; rather, the intent of the preflight assignment is for students to acquaint themselves with new physics concepts so they can assess what they do not understand and then articulate their confusion to their instructors via the online JiTT questions.

Informing students how a teaching innovation is designed to enhanced their in-class learning experiences may increase the quality of their pre-class preparation and therefore the quality of their in-class learning, but students can only receive this information if their instructors fully understand the purpose of the innovation themselves. If instructors receive poor training on the philosophy and/or the implementation of a teaching strategy like JiTT, it can negatively impact the adoption and perceptions of the educational innovation (Shulman, 1986).

6.3.2.2 JiTT Server Upgrade

An overwhelmingly common thread throughout not only instructors (regardless of experience) and students was the lack of robustness of the JiTT Web server. Several times throughout a semester, the JiTT server experienced a malfunction or crash. The effects of this included students being locked out of the server and unable to submit answers to an assignment, the submission deadline shifting for random sections within a course, instructors not having access to all student responses, instructors being forced to manually adjust grades, and an overall distraction from learning and class discussion. This created an extraordinary amount of frustration for students who were trying to complete their pre-class work in a timely fashion, and for faculty who did not have a complete set of responses on which to base their lessons and who had to adjust grades or unlock the assignment so students could revisit a preflight for a past lesson so they could complete it just for the points toward their grade. JiTT server failures affect courses not only in the department of physics, but also other departments at the Air Force Academy that include preflights in their coursework. Therefore, it was clear to me that the JiTT server at this research site was in need of a significant upgrade so that it will be more reliable and robust. Below are additional features that faculty suggested would help their implementation of the JiTT pedagogy and improve the functionality of the JiTT server.

1. **Include a dialog box with multiple choice and true/false preflight questions where students can type text justifying their answer(s).** This would allow a snapshot of whether student reasoning in their answer selection was correct. This feature may increase instructor prep time because it will take longer to read the written entries, so perhaps limiting the number of characters in the dialog box would keep student responses concise.
2. **Establish a way to export written student answers to preflight questions.** In the existing system, faculty must cut and paste student answers from an internet page. Sometimes surrounding Web features are also picked up when text is cut from the JiTT server. This results in 1) formatting issues when the text is then pasted into a PowerPoint slide, and 2) increased preparation time to make additional edits to their lesson presentation.
3. **Institute an auto-grading function for text answers to preflights.** This feature would entail training the program to give credit for an answer only if it contained a previously determined key word(s). This way, students would receive credit only if they entered

words that were in the "ballpark" of the concept covered in a question. Students would not receive credit if they entered an answer that was completely unrelated to the concept covered in the question.

Below are additional features that students suggested would help them get more out of the JiTT pedagogy and improve the functionality of the JiTT server.

1. **Provide immediate correctness feedback to students once their preflight answers are submitted.** Students reported a desire to know if the answers they submitted in their online preflights were right or wrong because then they would know if they needed to revisit a certain topic before class or what questions they would need to ask their instructors during class. A screen could pop-up containing a summary of the student's performance on the multiple choice or true/false questions. For example, a green check mark beside a problem would indicate they answered a question correctly and a red "X" beside a problem would indicate they answered a question incorrectly. Yes, students could pass down the answers from semester to semester, but since preflights are graded for effort rather than correctness, students would not benefit from this lack of integrity. In fact, they would put themselves at a disadvantage by entering a correct answer to a question they did not really understand (and might otherwise answer wrong). If a significant portion of the class recorded correct answers when in actuality they did not know how to answer the question, an instructor may not go over the problem in as great a depth as necessary.
2. **Include a feature that has the webpage automatically change to a different screen to notify students that they have been idle too long and that they have been logged out.** I do not believe it is necessary for the system to save student progress since the assignments are short—usually only about four questions. Not saving the answers students submit might also encourage them to focus on completing the assignment in one sitting, rather than answering one question, getting distracted, returning to it to answer another question, getting distracted, and so forth. Students in all courses except the space physics course had paper copies of the preflight questions available ahead of time, so they always have the option to work out the problems on paper first, then simply transfer their answers to the website.
3.

6.3.2.3 Reorganize the Core Physics Pre-Class Work

Both core faculty and students felt they were responsible for too much pre-class work. Faculty had a hard time keeping up with grading the core journals where students completed the Worked Example worksheet and pre-class workout problem from the end of the chapter. One instructor even shared that she/he never looked at the journals and awarded students all of the possible points. She/he felt her/his time was better spent on class discussion and addressing student issues.

As a core physics instructor myself, I too found it difficult to strike a balance between giving students feedback on their journal work and paying attention to their needs while grading in class. One instructor chose to grade journals during the second hour of class, but I did not prefer this approach because it took away from students' personal time and made it difficult for me to determine if a student had the work completed prior to the start of the first period of class (when it was due) or if they worked on the problems during the lesson I just taught.

An alternative would be to make the journal work optional. Two instructors felt students were "lucky" to earn so many points toward their grade for work they should be doing anyway to prepare and study for class. While I cannot make any conclusive statements about whether students would complete the Worked Example worksheet or pre-class workout problem in their journals if they did not receive credit for it, students reported, on average, that they would not complete preflights if they were not worth points toward their grade.

Perhaps core students and faculty would feel less overwhelmed if they had fewer pre-class assignments. This does not necessarily mean the total elimination of any single element. Reorganization could entail shifting a selection of the Worked Examples questions to the online preflight assignment. This way, instructors could view student thought processes outside of class and reserve valuable class time to discuss student difficulties. Indeed, this adds to instructor preparation time outside of class, but it would also give faculty a chance to view student work uninterrupted and without diverting their attention from student needs while they graded journals during class. Also, students could focus their pre-class attention in one place.

Another alternative would be to limit the online preflight question to only the first "*What would you like to discuss during class?*" and have student complete the multiple choice preflight questions in their journals. This option does not solve the journal grading issue, but it keeps the majority of the pre-class assignments in one location while still providing a way for students to communicate their difficulties to their instructor before class.

A third alternative might be to limit the type of pre-class assignment used throughout the semester. For instance, even lessons could have a preflight while odd lessons could have a Worked Example worksheet. This however, would not inform instructors of student challenges prior to every class, and it may become confusing to remember which pre-class assignment is associated with a given lesson.

6.3.2.4 Incorporate More Difficult Questions Into the JiTT Assignments

Students and faculty felt that preflight questions were too easy. Many students believed the questions did not mirror the level of difficulty they would be expected to answer on a quiz or exam. The instructors did not feel the questions accurately informed what should be covered during a lesson. To address this, including a "challenge" problem after each introductory preflight question would help students gauge what level of understanding would be expected of them later in the course, and faculty would be able to determine a range of capability for the students in their sections. These challenge questions would be graded for effort, just like the preparatory JiTT questions, but would give students a flavor of the level of difficulty they should expect to encounter on a future graded measure.

6.4 Limitations of this Study

6.4.1 Research Site

While education researchers might have the impression that United States military academies are places where cadets and midshipmen are robotic students who do all of their homework and earn perfect scores on their exams, they would be mistaken. Yes, the United States Military, Naval, Air Force, Coast Guard and Merchant Marine Academies all attract disciplined, motivated, and high performing young men and women. The fact remains, though, that they are drawn from the same population of applicants as other prestigious institutions of higher education. They are still—with only a few exceptions—18 year-olds when they embark on their college studies. Service academy cadets still have to learn how to transition from being a high school student to being a college student. The participants in this study experienced failure and got homesick just like other college students. They learned how to budget their time and balance their academic, athletic, and military commitments. Even though they wore a uniform to class, the students in this investigation were still maturing, and they continue to learn how to adapt to new challenges just like their peers at civilian institutions of higher education.

While the academic requirements for admission to the United States Air Force Academy might be higher than students attending other colleges or universities, regular mechanics students' scores on the Force Concept Inventory (FCI) mirrored that of high school physics students in the Hestenes et al. (1992) study within one standard deviation, while honors mechanics students in this dissertation performed at levels similar to the universities in the same Hestenes et al. study (1992), also within one standard deviation. Students in both the regular and honors electricity and magnetism courses, however, earned scores on the Conceptual Survey of Electricity and Magnetism (CSEM), which were lower than students in equivalent courses in the Maloney et al. (2001) study. CSEM scores in this project were within two standard deviations of the Maloney et al. (2001) averages. Both the FCI and CSEM inventories were described in Chapter 3, and output tables summarizing the FCI and CSEM scores for the students in this study can be found in Appendix T. Although these findings may not be generalizable to other populations, the study is certainly transferable.

6.4.2 Self-Reported Faculty and Student Data

As with most surveys, the faculty and student questionnaires administered for this study risked suffering from response biases. Faculty might have overestimated their use of the JiTT pedagogy, particularly since most were aware that this study focused on Just-in-Time Teaching. All core physics courses incorporate preflights into their curriculum, and most of the faculty (18 out of 20 respondents) indicated that they had taught a core physics course within the past two years. The high reporting of JiTT use was, therefore, accurate since the pedagogy is a part of the core curriculum. However, this too may pose its own limitation to the study in that I conducted it at an institution where JiTT is deeply engrained in the physics curriculum. This is the result of the fact that two of the teaching innovation's original four authors were both employed by the college. Regardless, as with the Cutler (2013) dissertation, the goal of this investigation was not to determine how many instructors used JiTT, but rather how they understood the JiTT pedagogy and how they adapted it to fit their teaching practices.

I responded to Cutler's (2013) study's limitation of not having classroom observations by watching various core and non-core faculty members teach. However, Fullan and Pomfret (1977) caution that no matter what forms of data or types of instruments are used to measure the fidelity of implementation of an innovation, researchers must consider those measurements as only "snapshot[s] of what users are actually doing with respect to the innovation at one point in time" (as cited in Hall & Loucks, 1978). While observing instructors as they taught helped to narrow the gap between the accuracy of self-reports and actual classroom practices, the instructors under observation were all aware that I was in the room and that I was conducting a study about JiTT. This might have made the instructor under observation feel as though they had to enact JiTT in a prescribed way or make their use of JiTT more obvious than they normally would.

Students might have answered preflight questionnaire or CLASS questions in ways they thought their instructors or I would expect rather than how they really felt (Adams, et al., 2006). I did my best to combat this during my verbal invitation to complete the questionnaire when I encouraged students to answer honestly about their opinions of the preflight assignment and provide constructive feedback that I could use to improve the way preflights are administered and implemented in future physics lessons.

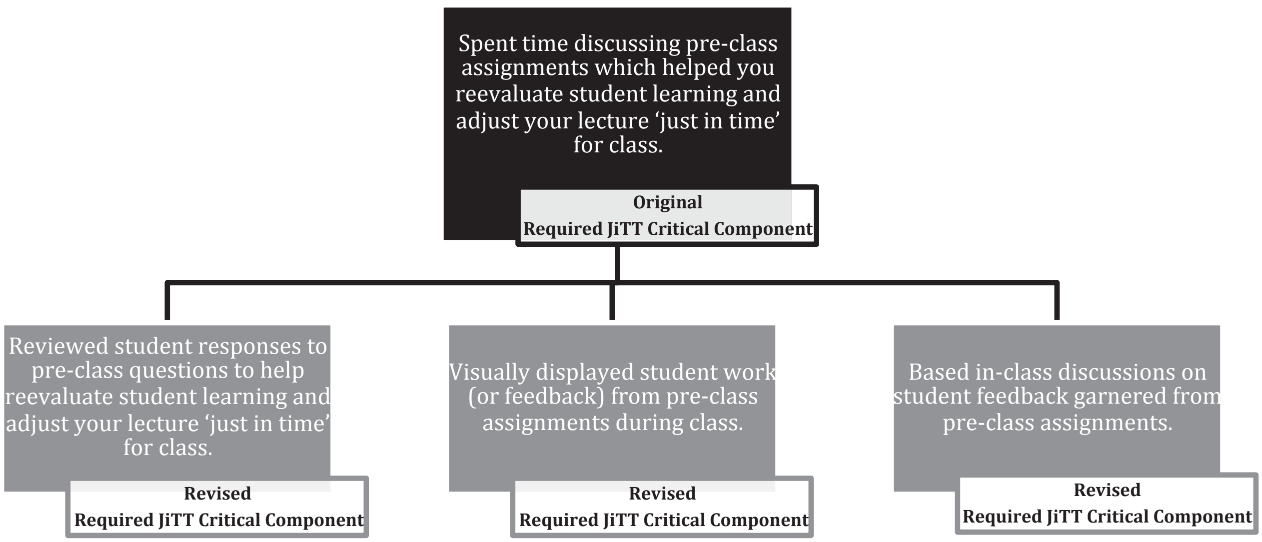
6.4.3 Interviews

Both faculty and student interviews contained three main types of questions: 1) questions about their understanding of the purpose behind the preflights, 2) questions about their routines in either implementing or completing JiTT assignments, and 3) questions about ways to improve how preflights are administered. As with the self-reported data from the faculty and student questionnaires, those who volunteered to participate in the one-on-one faculty interview or one of the student focus groups might have felt an inclination to me tell what they thought I wanted to hear. However, I had a strong sense that I received very candid feedback from both instructors and students in the interview settings. In fact, all but two of the instructors did not feel comfortable having their interview recorded because they did not want to risk any chance that the things they told me in confidence would leak out and be associated with them, even though I assured safeguarding the recordings. Each focus group of students allowed me to record them without fear of reprisals for what they might say about their instructor or the preflight assignment.

6.5 Future Work

First, and most importantly, since the instrument used to measure the fidelity of implementation of the JiTT pedagogy defined only one required critical component to distinguish JiTT users from non-JiTT users, I would reconfigure the required critical component structure for the Just-in-Time Teaching innovation. This would entail increasing the number of required JiTT critical components an instructor enacted to produce a stronger discriminating factor for JiTT users and a non-JiTT users. I would divide the lone JiTT critical component into the three parts displayed below in Figure 6.1.

Figure 6.1 Reconfiguration of Required JiTT Critical Components



In addition to revising the critical components, I would include questions on the instructional strategies questionnaire that asked instructors to share the specific methods they used to integrate student pre-class feedback into lessons and how that feedback is used to guide lessons. This goes beyond the techniques faculty enlist to review the answers to the pre-class questions, and may include asking instructors specifically how they build upon the concepts introduced in pre-class assignments during their lessons.

It would also be informative to conduct a more in-depth study of a limited number of faculty members and their techniques for implementing JiTT. This way, researchers would gain a better understanding how the attributes of an individual instructor (e.g., teaching experience, teaching philosophy, etc.) and her/his course (i.e., content and level of class, section size, age of students, time of day a section is taught, etc.) impact their implementation of JiTT.

Other concerns in physics education research include the gender gap and the retention of underrepresented minorities (Doktor & Mestre, 2011; NRC, 2013). By incorporating demographic information such as gender, race, and/or ethnicity into the current data set, a researcher could compare how different populations of students respond to the way(s) their instructors enact JiTT in their classes and/or how these differing populations view JiTT as a preparatory tool to assist with in-class learning.

Another aspect that lends itself to an extension of this project would be to investigate how well JiTT works in combination with other research-based instructional strategies. For instance, how might performance or attitudes about learning physics be enhanced when preflights are combined with Think-Pair-Share activities versus Collaborative Learning activities? Does JiTT complement certain teaching innovations better than others?

A final area to test would be to design a pilot study where students received automated feedback on their multiple choice or true/false JiTT submissions (i.e., only whether their answers were correct or incorrect). What students do with that information could be assessed, and then it could be determined if students utilize that information in a particular way that improves their preparation for in-class learning compared to if they received no feedback at all, which is how the system is currently designed. I would also research whether feedback altered the students' awareness of their understanding a positive way. Would it motivate them to re-submit their answers even though preflights are not graded for correctness? Would it prompt them to do a little extra reading or other type of preparation before going to class? Would it help them to articulate what they might be struggling with conceptually or mathematically?

6.6 Final Thoughts

Considering the impacts beyond this project, I must reiterate comments two faculty members shared on the instructional strategies in undergraduate physics questionnaire. They each resonated with me and reside at the heart of what I believe to be true about undergraduate physics instruction. The first thought relates to the sheer volume of pedagogical practices available to physics instructors. While this investigation focused on Just-in-Time Teaching, the faculty questionnaire I administered assessed the fidelity of implementation of the following 10 research-based instructional strategies:

1. Active Learning
2. Just-in-Time Teaching
3. Think-Pair-Share
4. Concept Tests
5. Peer Instruction
6. Collaborative Learning
7. Cooperative Learning
8. Inquiry-Based Learning
9. Problem-Based Learning
10. Physics Concept Inventories

This list is by no means exhaustive. For instance, the Air Force Academy incorporates the Worked Examples teaching innovation into their core physics courses as well.

To summarize this pedagogical buffet, one instructor highlighted that a teaching "strategy overload" existed and that instructors "can't do them all (even if they each have merit)." Although educational innovations have shown evidence to influence student learning or student views about their course (Adams et al., 2006; Docktor & Mestre, 2011; NRC Report, 2013), I affirm this faculty member's belief that it is unreasonable to expect instructors, especially new instructors with little teaching experience, to effectively incorporate multiple strategies into one lesson. Departments, course directors, and instructors should carefully assess Rogers' (1995) *Characteristics of Innovations* as well as Hall and Rutherford's (1976) *Stages of Concern* about an innovation when considering the adoption of a new pedagogy. Understanding how the role and demands of a teaching strategy will resonate with the practitioners who will ultimately enact the innovation will help garner buy-in from instructors and make the innovation adoption smooth and effective.

Another undergraduate physics instructor offered the second insightful comment I would like to emphasize. "A student's positive attitude toward learning is key to his/her success…" This reasoning holds true in many aspects of life in general, not just learning. The instructor goes on to add to that "…unfortunately very few students display that [positive attitude]." As a former undergraduate physics instructor, I believed it was my responsibility to help make a student's learning experience a positive one. This meant I sometimes needed to remove my "teaching" hat and replace it with a "coaching" hat. Recalling my days as an undergraduate physics student, my number one barrier to learning was myself. Thankfully, my advisor and teachers believed in my capabilities when I was most doubtful, and their support carried me through some of the most challenging courses in which I was enrolled. I am now compelled to do the same for my students.

I believe all students have the mental capacity to learn physics. Some take longer to grasp the concepts, and it is my job to reassure those students who lack confidence in themselves and to encourage them to persist. Persistence requires preparation and a good attitude. If the way an instructor enacts a teaching innovation can positively impact student preparation for class, in-class learning trajectories can expand. Even though the effective implementation of a teaching strategy may not lead to huge gains in overall student performance, if a teaching practice can positively influence how a student views learning physics, then perhaps students will come to enjoy and appreciate all of the extraordinary aspects of the physics discipline. In sum, we as instructors must care about our students and care about our teaching practices so that we can foster the growth of the next generation of scientifically literate citizens.

References

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). 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, 2.*

Bain, K. (2004) *What the best college teachers do*. Cambridge, Massachusetts: Harvard University Press.

Barnard, A., McCosker, H., & Gerber, R. (1999). Phenomenography: A qualitative research approach for exploring understanding in health care. *Qualitative Health Research*, *9*(2), 212-226.

Benedict, J. O., & Anderton, J. B. (2004). Applying the just-in-time teaching approach to teaching statistics. *Teaching of Psychology, 31*(3), 197-199.

Berrett, D. (2012). How ‘flipping’ the classroom can improve the traditional lecture. *The Chronicle of Higher Education*, *19*.

Borrego, M. J., Cutler, S. L., Prince, M., Henderson, C., & Froyd, J. E. (2013). Fidelity of implementation of research-based instructional strategies (RBIS) in engineering science courses. *Journal of Engineering Education*, *102*(3), 394-425.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). Learning and transfer. In *How people learn: Brain, mind, experience, and school* (pp. 51-78). Washington, D.C.: National Academy Press.

Bransford, J. D., & Schwartz, D. L. (1999). Rethinking transfer: A simple proposal with multiple implications. *Review of Research in Education*, *24*, 61-100.

Carroll, C., Patterson, M., Wood, S., Booth, A., Rick, J., & Balain, S. (2007). A conceptual framework for implementation fidelity. *Implementation Science*, *2*(40), 1-9.

Creswell, J. W. (2013). *Qualitative inquiry & research design: Choosing among five approaches* (3rd Edition). Thousand Oaks, CA: SAGE Publications, Inc.

Cutler, S. L. (2013). *How static is the statics classroom? An investigation into how innovations, specifically research-based instructional strategies, are adopted into the statics classroom* (Doctoral dissertation). Virginia Polytechnic Institute and State University, Blacksburg, VA.

Cutler, S., & Borrego, M. J. (2013). *An analysis of the fidelity of implementation of research-based instructional strategies in the statics classroom*. Paper presented at the 120th ASEE Annual Conference & Exposition, Atlanta, GA.

Davidson College. (2015). *About Davidson: Fast Facts*. Retrieved from http://www.davidson.edu/about/fast-facts.

DeCuir-Gunby, J. T., Marshall, P. L., & McCulloch, A. W. (2011). Developing and using a codebook for the analysis of interview data: an example from a professional development research project. *Field Methods*, *23*(2), 136-155.

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2009). *Internet, mail, and mixed-mode surveys: The tailored design method* (3rd Edition). Hoboken, NJ: John Wiley & Sons, Inc.

Docktor, J. L., & Mestre, J. P. (2011). A synthesis of discipline-based education research in physics. In *Second Committee Meeting on the Status, Contributions, and Future Directions of Discipline-Based Education Research.*

Durlak, J. A. (2009) How to select, calculate, and interpret effect sizes. *Journal of Pediatric Psychology*, *34*(9), 917-928.

Durlak, J. A., & DuPre, E. P. (2008). Implementation matters: A review of research on the influence of implementation on program outcomes and the factors affecting implementation. *American Journal of Community Psychology*, *41*(3-4), 327-350.

Dusenbury, L., Brannigan, R., Falco, M., & Hansen, W. B. (2003). A review of research on fidelity of implementation: implications for drug abuse prevention in school settings. *Health Education Research*, *18*(2), 237-256.

Ellis, P.D. (2010). *The essential guide to effect sizes: statistical power, meta-analysis, and the interpretation of research results*. Cambridge, United Kingdom: University Press.

Enghag, M., & Niedderer, H. (2008). Two dimensions of student ownership of learning during small-group work in physics. *International Journal of Science and Mathematics Education, 6*(4), 629-653.

Etkina, E., & Van Heuvelen, A. (2007). Investigative science learning environment – a science process approach to learning physics. *Research-based Reform of University Physics, 1*. Retrieved from http://paer.rutgers.edu/scientificabilities/downloads/papers/isle-2007.pdf

Field, A. (2013). *Discovering statistics using SPSS* (4th Edition). Thousand Oaks, CA: SAGE Publications, Inc.

Freier, P. (2005). *Teachers as cultural workers: Letters to those who dare teach*. Cambridge, MA: Westview Press.

Gavrin, A., Watt, J. X., Marrs, K., & Blake, R. E. (2003). Just-in-time teaching (JiTT): Using the web to enhance classroom learning. *Proceedings of the 2003 American Society for Engineering Education*, 129-141.

Goertzen, R. M., Brewe, E., Kramer, L. H., Wells, L., & Jones, D. (2011). Moving toward change: Institutionalizing reform through implementation of the learning assistant model and open source tutorials. *Physical Review Special Topics - Physics Education Research, 7*(2).

Grissom, R. J., & Kim, J. J. (2005). *Effect sizes for research: A broad practical approach*. Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Hake, R. R. (1998). Interactive-engagement vs. traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64-74.

Hall, G. F., & Loucks, S. F. (1978). *Innovation configurations: Analyzing the adaptations of innovations*. Austin, TX: The University of Texas, Research and Development Center for Teacher Education.

Hall, G. E., Loucks, S. F., Rutherford, W. L., & Newlove, B. W. (1975). Levels of use of the innovation: A framework for analyzing innovation adoption. *Journal of teacher education*, *26*(1), 52-56.

Hall, G. E., & Rutherford, W. L. (1976). Concerns of teachers about implementing team teaching. *Educational Leadership*, *34*(3), 227-233.

[a] Halloun, I. A., & Hestenes, D. (1985). Common sense concepts about motion. *American Journal of Physics, 53*(11), 1056-1065.

[b]Halloun, I. A., & Hestenes, D. (1985). The initial knowledge state of college physics students. *American Journal of Physics, 53*(11), 1043-1055.

Harris, M. B. (1998). *Basic statistics for behavioral science research* (2nd ed.). Boston, MA: Allyn and Bacon.

Herreid, C. F., & Schiller, N. A. (2013). Case study: Case studies and the flipped classroom. *Journal of College Science Teaching, 42*(5), 62-67.

Hestenes, D., & Wells, M. (1992). A mechanics baseline test. *Physics Teacher, 30*(3), 159.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *Physics Teacher, 30*, 141-158.

Higdon, J., & Topaz, C. (2009). Blogs and wikis as instructional tools: A social software adaptation of just-in-time teaching. *College Teaching, 57*(2), 105-110.

Howard, J. R. (2004). Just-in-time teaching in sociology or how I convinced my students to actually read the assignment. *Teaching Sociology*, *32*, 385-390.

IUPUI. (2015). *About IUPUI: Rankings & Campus Statistics*. Retrieved from http://www.iupui.edu/about/rankings-statistics.html.

Knight, R. D. (2004). *Five easy lessons: Strategies for successful physics teaching*. San Francisco, CA: Addison Wesley.

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60-70.

Linneman, S., & Plake, T. (2006). Searching for the difference: A controlled test of just-in-time teaching for large-enrollment introductory geology courses. *Journal of Geoscience Education*, *54*(1), 18-24.

Maloney, D. P., O'Kuma, T. L., Hieggelke, C. J., & Van Heuvelen, A. (2001). Surveying students' conceptual knowledge of electricity and magnetism. *American Journal of Physics, 69*(7), S12.

Mason, G. S., Shuman, T. R., & Cook, K. E. (2013). Comparing the effectiveness of an inverted classroom to a traditional classroom in an upper-division engineering course. *IEEE Transactions on Education*, *56*(4), 430-435.

Mazur, E. (1997). *Peer instruction*. Upper Saddle River, NJ: Prentice-Hall.

McDermott, L. C. (2001). Oersted medal lecture 2001: "Physics Education Research – the key to student learning". *American Journal of Physics*, *69*(11), 1127-1137.

McKeachie, W. J., & Svinicki, M. (2006). *McKeachie's teaching tips: Strategies, research, and theory for college and university teachers* (12th edition). New York, NY: Houghton Mifflin Company.

Nakamura, C. (2012). The pathway active learning environment: An interactive Wen-based tool for physics education (Doctoral dissertation). Kansas State University, Manhattan, KS.

National Research Council (NRC). (2013). *Adapting to a changing world – Challenges and opportunities in undergraduate physics education*. Washington, D.C.: National Academy of Sciences.

Novak, G. M. (2011). Just-in-time teaching. In W. Buskist & J. E. Groccia (Eds.), *Evidenced-based teaching* (pp. 63-73). Hoboken, NJ: Wiley & Sons, Inc.

Novak, G. M., & Patterson, E.T. (1998). *Just-in-time teaching: Active learner pedagogy with WWW*. Paper presented at the IASTED International Conference on Computers and Advanced Technology in Education, Cancun, Mexico.

Novak, G. M., Patterson, E. T., Gavrin, A. D., & Christian, W. (1999). *Just-in-time teaching: Blending active learning with web technology*. Upper Saddle River, NJ: Prentice-Hall, Inc.

O'Donnell, C. L. (2007). *Fidelity of implementation to instructional strategies as a moderator of curriculum unit effectiveness in a large-scale middle school science quasi-experiment* (Doctoral dissertation). The George Washington University, Washington, D.C.

O'Donnell, C. L. (2008). Defining, conceptualizing, and measuring fidelity of implementation and its relationship to outcomes in K–12 curriculum intervention research. *Review of Educational Research*, *78*(1), 33-84.

Perkins, K. K., Adams, W. K., Pollock, S. J., Finkelstein, N. D., & Wieman, C. E. (2005). Correlating student beliefs with student learning using the Colorado Learning Attitudes about Science Survey. *Proceedings of the AIP Conference, 790*, p. 61.

Planinic, M. (2006). Assessment of difficulties of some conceptual areas from electricity and magnetism using the conceptual survey of electricity and magnetism. *American Journal of Physics, 74*, 1143-1148.

Pryce, G. and Garcia-Granero, M. (2002). *Breusch-Pagan & Koenker test macro*. Retrieved from http://www.spsstools.net/Syntax/RegressionRepeatedMeasure/Breusch PaganAndKoenkerTest.txt

[a]QSR International. (n.d.). *Automatic coding using existing coding patterns*. Retrieved from http://help-nv10.qsrinternational.com/desktop/procedures/automatic_coding_using_existing_coding_patterns.htm

[b]QSR International. (n.d.). *Run a coding comparison query*. Retrieved from http://help-nv9-en.qsrinternational.com/nv9_help.htm#procedures/run_a_coding_comparison_query.htm

Rebello, N. S. (2007). Proceedings from NARST 2007 Annual Meeting: *Consolidating traditional and contemporary perspectives of transfer of learning: A framework and implications*. New Orleans, LA.

Redish, E. F., Saul, J. M., & Steinberg, R. N. (1998). Student expectations in introductory physics. *American Journal of Physics*, *66 (3)*, 212-224.

Redish, E. F., Steinberg, R. N., & Saul, J. M. (1997). The distribution and change of student expectations in introductory physics. *Proceedings of the AIP Conference*, *399*, p. 689.

Robertson, Stuart. (2014, January 23). Experiment with pattern-based auto coding. (Web log article.) Retrieved from http://blog.qsrinternational.com/experiment-with-pattern-based-auto-coding/

Rogers, E. (1995). *Diffusion of innovations* (3rd Edition). New York, NY: The Free Press.

Saldaña, J. (2013). *The coding manual for qualitative researchers* (2nd Edition). Los Angeles, CA: SAGE Publications Inc.

Scharff, L., Rolf, J., Novotny, S. A., & Lee, M. R. (2010). *Factors impacting completion of pre-class assignments in physics, math, and behavioural sciences.* Paper presented at the ISSoTL in Liverpool, UK.

Shaffer, P. S., & McDermott, L. C. (1992). Research as a guide for curriculum development: An example from introductory electricity. Part II: Design of instructional strategies. *American Journal of Physics*, *60*, 1003-1003.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Singley, M. K., & Anderson, J. R. (1989). *The transfer of cognitive skill*. Cambridge, MA: Harvard University Press.

Stelzer, T., Gladding, G., Mestre, J. P., & Brookes, D. T. (2009). Comparing the efficacy of multimedia modules with traditional textbooks for learning introductory physics content. *American Journal of Physics, 77*(2), 184-190. doi:10.1119/1.3028204

Stelzer, T., Brookes, D. T., Gladding, G., & Mestre, J. P. (2010). Impact of multimedia learning modules on an introductory course on electricity and magnetism. *American Journal of Physics, 78*(7), 755-759. doi:10.1119/1.3369920

Stewart, D. W., Shamdasani, P. N., & Rook, D. W. (2009). *Focus groups: Theory and practice* (2nd Edition). Thousand Oaks, CA: SAGE Publications, Inc.

Strayer, J. F. (2012). How learning in an inverted classroom influences cooperation, innovation and task orientation. *Learning Environments Research, 15*(2), 171-193.

Taylor, E. F. (1992). Guest comment: Only the student knows. *American Journal of Physics, 60*(3), 201-202.

U.S. Air Force Academy. (2014). *U.S. News and World Report*. Retrieved from http://colleges.usnews.rankingsandreviews.com/best-colleges/air-force-academy-1369.

Üstün, U. and Eryilmaz, A. (2014). A research methodology to conduct effect research synthesis: Meta-Analysis. *Education and Science*. *39*(174), 1-32. doi: 10.15390/EB.20143379.

Appendix A - Example Preflight Assignments From Fall 2014

Physics 215 (Regular)

Lesson 13: Capacitors & Energy in Electric Fields

Reading	23.2, 23.3
Example	Journal, 23.1
Pre-Class Problem	In Journal
Homework Problems	(1 pt) 23.18, 23.21, MP, MP
	(2 pts) 23.46, MP

Learning Objectives

[Obj 27] Explain capacitance relating charge, voltage , electric field, and energy stored. Describe how configuration changes affect these quantities.

[Obj 28] Interpret the time dependence of the current, charge and voltage of a capacitor in an R-C circuit.

[Obj 29] Explain how capacitors work and what effect a capacitor has in a circuit including common uses of capacitors in technology.

Preflight Questions

1. What topic from the lesson would you like to discuss during class?

2. T/F? A dielectric is a conducting material placed between the plates of a capacitor.

3. What units are used to measure capacitance?

a) Volts

b) Coulombs

c) Farads

d) None of the above

4. Where is the energy stored in a capacitor? Why is it necessary to hook a capacitor up to a source of EMF (like a battery) in order for it to become charged? When answering, think back to the lesson on electrostatic energy.

Physics 215H (Honors)

Lesson 13: Energy Stored in Capacitors

Learning Objectives	23, 26, 27, 28
Reading	23.2, 23.3 (thru Example 23.2)
Pre-Class Problem	23.18
Homework Problems	MP, 23.43, 23.55, (22.41)
YouTube Videos (optional)	Doc Physics – Intro to Capacitors [10 min] Doc Physics – Potential Energy Stored in a Capacitor [9 min]

Preflight Questions

1. The Worked Example(s)…
   a) Totally made sense, helped a lot – I could definitely solve that problem on my own now
   b) Sort of made sense, but I'd probably struggle if asked to solve that problem on my own
   c) Didn't do much for me – tried to follow it, didn't get very far
   d) Pretty much did nothing for me– I either didn't look at it or it made no sense

2. The Pre-Class Problem…
   a) I nailed it… made sense, got the right answer, could do it again
   b) A little rough… eventually got it, but would struggle if I had to do it again without help
   c) Really rough… I knew where to start but didn't get far before getting stuck
   d) No clue… either didn't know where to start or didn't try it

3. [1 pt] For a given parallel-plate capacitor, how will its capacitance be affected if you double the area of the plates and halve the distance between the plates?

   a) It will be unchanged.
   b) It will be doubled.
   c) It will be halved.
   d) It will go up by a factor of 4.
   e) It will go down by a factor of 4.

4. [1 pt] Skim the short article found here: http://www.slate.com/articles/health_and_science/alternative_energy/2013/03/graphene_supercapacitors_small_cheap_energy_dense_replacements_for_batteries.html. After reading the article, what do you think are the advantages and disadvantages with using capacitors as a source of electrical energy?

Physics 110 (Regular)

Lesson 14: Forces and Newton's Laws of Motion

Reading	Review Chap 4 & 5
Examples	4.1-4.5, 5.1-5.4, 5.10-5.11
Homework Problems	5.30, 5.44, 5.52

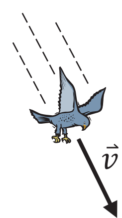
Learning Objectives

[Obj 16] Explain the difference between mass and weight.
[Obj 17] Construct free-body diagrams using vectors to represent individual forces acting on an object, and evaluate the net force using vector addition.
[Obj 18] Use Newton's laws of motion to solve problems involving multiple forces acting on a single object.
[Obj 21] Use Newton's laws of motion to solve problems involving multiple objects.
[Obj 19] Differentiate between the forces of static and kinetic friction and solve problems involving both types of friction.

Preflight Questions

1. What topic from the lesson would you like to discuss during class?

2. A falcon is in a dive at a constant speed v. Including the force of air resistance, what is the direction of the net force on the falcon?
   a) in the direction of the dive.
   b) in the direction of gravity.
   c) in the direction of air resistance
   d) There is no net force.



3. A Jeep is pushing a truck that has a dead battery. The mass of the truck is greater than the mass of the Jeep. Which of the following statements is true?

   a. The Jeep exerts a force on the truck, but the truck doesn't exert a force on the Jeep.
   b. The Jeep exerts a larger force on the truck than the truck exerts on the Jeep.
   c. The Jeep exerts the same amount of force on the truck as the truck exerts on the Jeep.
   d. The truck exerts a larger force on the Jeep than the Jeep exerts on the truck.
   e. The truck exerts a force on the Jeep, but the Jeep doesn't exert a force on the truck.

4. CRITICAL THINKING: For the worked example, what is the minimum coefficient of friction, μ, needed for the 50-kg to remain stationary on the ramp when released? HINT: Look at the calculations already done.

Physics 110H (Honors)

Lesson 12: Newton's Laws with Friction

Reading	5.4, 5.5
Examples	5.9, 5.10, 5.11
Homework Problems	5.31, 5.43, 5.47, 5.50, 5.57, MP

Learning Objectives

[Obj 23] Differentiate between the forces of static and kinetic friction and solve problems involving both types of friction.

[Obj 24] Describe drag forces qualitatively and quantitatively.

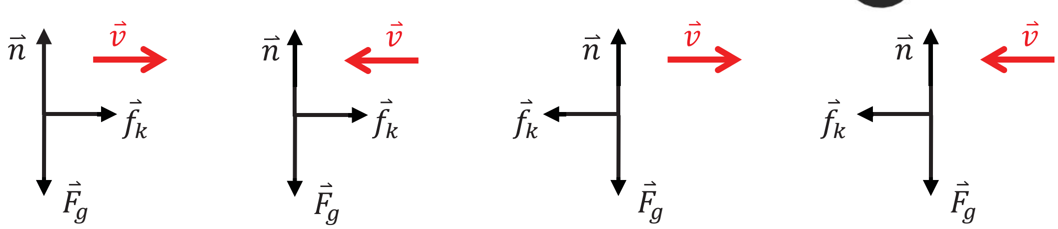
Preflight Questions

1. What topic from the lesson would you like to discuss during class?

2. Which statement concerning friction is true?

   a) Static friction is always opposite the direction of motion.
   b) Kinetic friction is always opposite the direction of motion.
   c) Both static and kinetic friction are always opposite the direction of motion.
   d) Neither is always opposite the direction of motion.

3. A box is at rest on the flat bed of a moving truck. Dawn applies the brakes abruptly and the box begins to slide. Which free-body diagram correctly depicts the forces acting on the box and its resulting motion?



a) b) c) d)

4. CRITICAL THINKING: How can the coefficient of friction be determined (or measured) experimentally? Explain how this could be done for both static and kinetic friction.

Meteorology 320

Lesson 10: Fog and Cloud Identification

Reading	**MT** Ch. 5 pp. 115–134
	AW None

Learning Objectives

1. Describe the formation processes of dew, frost, and haze.
2. Describe the conditions that produce various types of fog.
3. List and describe the four major cloud groups and the ten main types of clouds.
4. Be able to identify cloud types from photographs.

Preflight Questions

1. What topic or concept from the reading do you want to talk about in class today?

2. Dew forms when Earth's surface cools due to __________ and air in contact with the ground cools due to __________.
   a) conduction; convection
   b) radiation; conduction
   c) advection; evaporation
   d) latent heat release; radiation

3. Frost forms when
   a) air near the ground is cooled to the dew point.
   b) the dew point is less than the freezing temperature.
   c) deposition occurs.
   d) All of the above are correct.

4. Identify the cloud type in the image below.

5. Identify the cloud type in the image below.

Physics 370

Lesson 10: Fields and Currents

Reading	Knipp 4.2

Preflights

1. What topic or concept from the reading do you want to talk about in class?

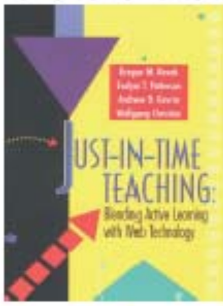
2. What are the units of volume current density? These units fit nicely with a physical quantity we defined recently in class. Can you think what it is?

3. Consider the currents that flow during space weather storms. Do you suppose these would usually be thought of as volume, sheet, or line currents? Why?

Appendix B - How Much Pre-Class Work Counts Toward Student Grade

Course	Journal Work (points)	Journal Proportion of Grade (%)	Preflights (points)	Preflights Proportion of Grade (%)	Total Pre-Class Work (points)	Total Pre-Class Work Proportion of Grade (%)
Regular E&M	54	5.4%	64	6.4%	118	**11.8%**
Honors E&M	60	6%	60	6%	120	**12%**
Regular Mechanics	49	4.9%	70	7%	119	**11.9%**
Honors Mechanics	66	6.6%	70	7%	136	**13.6%**
Introduction to Meteorology	N/A	N/A	99	9.9%	99	**9.9%**
Upper Atmospheric and Geo-Space Physics	N/A	N/A	80	8%	80	**8%**

Appendix C - Faculty Research Advertisement



TEACH PHYSICS OR METEOROLOGY?

YOU CAN PARTICIPATE IN

CAPT DWYER'S

DOCTORAL RESEARCH!

Come visit me in Lt Col Anderson's office (2A45)

YOU DON'T HAVE TO USE JUST-IN-TIME TEACHING TO PARTICIPATE IN THE STUDY

Even if you've chosen <u>not</u> to incorporate the JiTT pedagogy into your physics or meteorology class—or use a different form of JiTT—I am interested in learning more from you. Please see the "WAYS YOU CAN HELP" section below.

Who am I? (In case you haven't met me yet.)

I'm a Jersey girl who thought she would be a high school science teacher as an undergraduate student at a small liberal arts college, but then I got the bright idea to join the Air Force instead. I was thrilled at the opportunity to PCS to USAFA where I could serve *and* teach at the same time. Now I am in the USAFA faculty pipeline program and am a doctoral candidate at Kansas State University where I'm studying physics education.

Why am I here?

The K-State department of physics doesn't use JiTT—also called preflights. JiTT is engrained in USAFA core physics, which serves as an ideal test bed for my research interests. Additionally, the boring drive from Manhattan, KS to Colorado Springs, CO wasn't enough to deter me from coming back and infiltrating DFP.

What is the goal of my research?

When I taught core physics, I do not feel that I implemented JiTT effectively into my lessons, and several factors contributed to this failure on my part. Therefore, I want to see how other instructors integrate the teaching tool into their classes as well as what their thoughts are about the pedagogy. I want to know if there are ways to better educate and prepare faculty to implement JiTT into their classes.

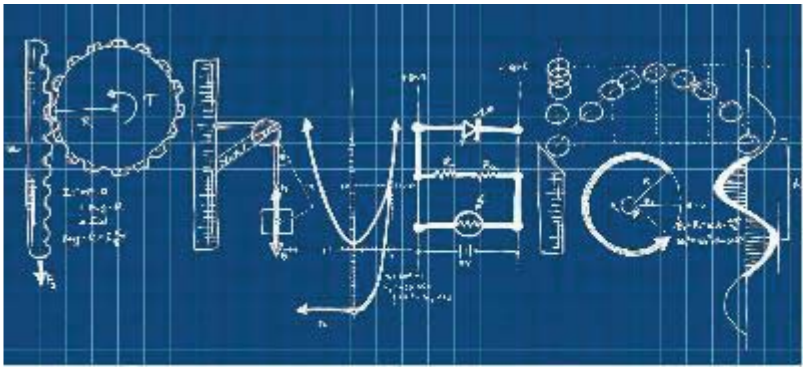
WAYS YOU CAN HELP

1. Complete a 20-minute online faculty questionnaire about instructional strategies in undergraduate physics (and meteorology)
    - This addresses *many* research-based pedagogies like Peer Instruction, collaborative learning, clickers, etc.
    - I will email all teaching faculty a link to the questionnaire.
1. Allow Capt Dwyer to observe your lessons (3 observations)
2. Meet with Capt Dwyer one-on-one to discuss your JiTT experiences and thoughts/perceptions about the pedagogy
    - Refreshments provided!
    - Interview will last approximately 20-30 minutes
    - Questions provided in advance
4. If you are an instructor who uses JiTT, <u>please</u> encourage your cadets to participate in the study as well.
    - Cadets can complete a 5-minute online questionnaire.
    - Cadets can partake in a 30-minute focus group interview (refreshments provided).

Appendix D - Instructional Strategies in Undergraduate Physics Questionnaire

Fall 2014 | USAFA | Instructional Strategies in Undergraduate Physics - Copy

Q1



Q2 This questionnaire supports the significant work physics education researchers carry out as part of their commitment to help faculty educate the next generation of physicists and scientifically literate citizens. Your honest responses to this questionnaire regarding your instructional practices will help us to better understand how we educate the students enrolled in our USAFA physics courses. Your participation in this questionnaire is entirely voluntary, and all of your responses will be kept confidential. You may return to this questionnaire after starting to complete remaining questions. This questionnaire takes approximately 20 minutes to complete. Thank you in advance for your involvement in this important project. Your time is greatly appreciated! NOTE: Do not use your browser's back button to revisit a question. Use instead the purple arrow at the bottom of each page of questions.

Q3 Selecting option #1 below signifies your consent to complete the questionnaire.

- 1. I agree to participate. (1)
- 2. I don't wish to participate. (2)

If 2. I don't wish to participate... Is Selected, Then Skip To End of Survey

Q4 From the drop down list below, please select the undergraduate physics or meteorology course you have taught most recently. If you taught more than one undergraduate physics or meteorology course simultaneously, please select one response option and complete the remainder of the questionnaire.

- I have never taught an undergraduate physics or meteorology course. (1)
- PHYS 110 - General Physics I (Mechanics) (2)
- PHYS 215 - General Physics II (E&M) (3)
- PHYS 246 - Modern Physics (4)
- PHYS 310 - Principles of Nuclear Engineering (5)
- PHYS 315 - Combat Aviation Physics (6)
- PHYS 341 - Laboratory Techniques (7)
- PHYS 355 - Classical Mechanics (8)
- PHYS 356 - Computational Physics (9)
- PHYS 361 - Electromagnetic Theory I (10)
- PHYS 362 - Electromagnetic Theory II (11)
- PHYS 370 - Upper Atmospheric & Geo-Space Physics (12)
- PHYS 371 - Astronomy (13)
- PHYS 375 - Physics of Space Situational Awareness (16)
- PHYS 391 - Introduction to Optics & Lasers (17)
- PHYS 393 - Solid State Physics (18)
- PHYS 421 - Thermal & Statistical Physics (19)
- PHYS 451 - Plasma Physics (20)
- PHYS 465 - Quantum Mechanics (21)
- PHYS 468 - Atomic & Nuclear Physics (22)
- PHYS 482 - Laser Physics & Modern Physics (23)
- PHYS 486 - Astrophysics (24)
- PHYS 495 - Special Topics (25)
- METEOR XXX (26)

If I have never taught or TA'd... Is Selected, Then Skip To You do not meet the criteria to complete this survey...

Answer If From the drop down list below, please select the undergraduate physics or meteorology course you have taught most recently. If you taught more than one undergraduate physics or meteorology course s... PHYS 495 - Special Topics Is Selected Or From the drop down list below, please select the undergraduate physics or meteorology course you have taught most recently. If you taught more than one undergraduate physics or meteorology course s... METEOR XXX Is Selected

Q5 Please list either the Physics Special Topic or Meteorology course you teach/taught below.

Q6 When did you last teach ${q://QID3/ChoiceGroup/SelectedChoices} or a similar course?

- Last semester (1)
- Last year (2)
- Within the last 5 years (3)
- I have not taught ${q://QID3/ChoiceGroup/SelectedChoices} within the last 5 years (4)

If I have not taught ${q://QID... Is Selected, Then Skip To You do not meet the criteria to compl...

Q7 In what type of environment did you primarily teach ${q://QID3/ChoiceGroup/SelectedChoices}?

- Lecture (1)
- Laboratory (2)

Q8 Section 1This section addresses your general beliefs about learning undergraduate physics. Please indicate the degree to which to agree or disagree with each of the following statements.

	Strongly Disagree (1)	Disagree (2)	Neither Agree Nor Disagree (3)	Agree (4)	Strongly Agree (5)
a. Lecturing is the best use of limited undergraduate physics class time. (1)	❍	❍	❍	❍	❍
b. Students learn undergraduate physics better when an instructor or teaching assistant is available while they are working on problems. (8)	❍	❍	❍	❍	❍
c. The most effective learning in undergraduate physics happens when students listen to a well-prepared lecture. (11)	❍	❍	❍	❍	❍
d.The most effective learning in undergraduate physics happens when students solve problems. (16)	❍	❍	❍	❍	❍
e. A formal lecture is necessary before students can effectively solve undergraduate physics problems. (18)	❍	❍	❍	❍	❍
f. Students learn undergraduate physics better when they work on problems together than when they work on problems alone. (22)	❍	❍	❍	❍	❍
g. When students talk to each other during an undergraduate physics class, it distracts them from learning. (25)	❍	❍	❍	❍	❍

Q9 Section 2 This section addresses the ${q://QID3/ChoiceGroup/SelectedChoices} course you've taught most recently. Please indicate what percentage of time on average your students spent/spend on each of the following 16 activities during class time. NOTE: Your response is not expected to total exactly 100%.

______ 1. Watch, listen and/or take notes on a lecture. (1)

______ 2. Discuss a problem in pairs or groups. (2)

______ 3. Answer multiple-choice conceptual questions with distracters (incorrect responses) that reflect common student misconceptions. (3)

______ 4. Spent time discussing pre-class assignments which helped you re-evaluate student learning and adjust your lecture "just in time" for class. (4)

______ 5. Work on projects inspired by problems or situations from real physics practice. (16)

______ 6. Provide the answer(s) to a posed problem or question before the class session can proceed. (5)

______ 7. Work on problem sets or projects in pairs or small groups. (6)

______ 8. Use clickers or similar means to "vote" on the correct answer of a multiple choice question. (7)

______ 9. Use means other than clickers to "vote" on the correct answer of a multiple choice question. (18)

______ 10. Complete specially designed activities to learn course concepts on their own without being explicitly told. (9)

______ 11. Participate in group work for which they earn the same score as every other member of the group. (10)

______ 12. Participate in group work for which the assessments are designed so that individuals may earn different scores for their work on the assignment. (20)

______ 13. Report their group's findings to the entire class (formally or informally). (22)

______ 14. Work on problems or projects that require students to seek out new information not previously covered in class. (11)

______ 15. Watch lectures online so that class time can be used for other activities. (25)

______ 16. Participate in activities that engage them with course content through reflection and/or interaction with their peers (other than watching, listening and/or taking notes). (12)

Q13 Section 3 This section addresses research based instructional strategies you may have used in any undergraduate physics courses you've taught recently. Please indicate your level of use and knowledge of each strategy presented.

	I currently use it (1)	I have used it in the past (2)	I have used something like it, but did not know the name (3)	I am familiar with it, but have never used it (4)	I have heard name, but know little else about it (5)	I have never heard of it (6)
1. Active Learning. A very general term describing anything course-related that all students in a class session are called upon to do other than passively watch, listen and take notes. (4)	❍	❍	❍	❍	❍	❍

If I have never heard of it Is Selected, Then Skip To Section 3 (continued) Please indicate...If I have heard name, but know... Is Selected, Then Skip To Section 3 (continued) Please indicate...If I am familiar with it, but ... Is Selected, Then Skip To Section 3 (continued) Please indicate...

Answer If Section 3 This section addresses research based instructional strategies you may have used in any undergraduate physics courses you've taught recently. Please indicate your level of use and k... - I currently use it Is Selected Or Section 3 This section addresses research based instructional strategies you may have used in any undergraduate physics courses you've taught recently. Please indicate your level of use and k... - I have used it in the past Is Selected Or Section 3 This section addresses research based instructional strategies you may have used in any undergraduate physics courses you've taught recently. Please indicate your level of use and k... - I have used something like it, but did not know the name Is Selected

Q14 Please describe the active learning methods you use(d) in your class(es).

Q15 Section 3 (continued) Please indicate your level of use and awareness of the teaching strategy below.

	I currently use it (1)	I have used it in the past (2)	I have used something like it, but did not know the name (3)	I am familiar with it, but have never used it (4)	I have heard name, but know little else about it (5)	I have never heard of it (6)
2. Just-in-Time Teaching. Asking students to individually complete homework assignments a few hours before class, reading through their answers before class and adjusting the plan for the class accordingly. (1)	❍	❍	❍	❍	❍	❍

If I have never heard of it Is Selected, Then Skip To Section 3 (continued) Please indicate...If I have heard name, but know... Is Selected, Then Skip To Section 3 (continued) Please indicate...If I am familiar with it, but ... Is Selected, Then Skip To Section 3 (continued) Please indicate...

Q16 How long have/did you use(d) Just-in-Time Teaching?

- ❍ Less than one semester or term (1)
- ❍ One complete semester or term (2)
- ❍ More than one complete semester or term (3)

Q17 How did you first hear about this teaching strategy?

- ❍ Read article or book about it (1)
- ❍ Presentation or workshop at my professional society conference (e.g., APS, AIP, SPS, AAS, AGU) (2)
- ❍ Presentation or workshop at a physics education conference (e.g., AAPT, AERA) (3)
- ❍ Presentation or workshop on my campus (4)
- ❍ Workshop at another location (e.g., NSF-sponsored) (5)
- ❍ Colleague (word of mouth) (6)
- ❍ Do not recall (7)
- ❍ Other (Please specify how you first heard about the teaching strategy.) (8) ____________________

Q18 Please select any of the factors below that seriously discourage any potential plans for using this particular teaching strategy in the future. Please select all response options that apply.

- ❑ Lack of evidence to support the efficacy of this instructional strategy (1)
- ❑ Too much advanced preparation time required (2)
- ❑ Takes up too much class time to let me cover the syllabus (3)
- ❑ Students would not react positively (4)
- ❑ My department and administration would not value it (5)
- ❑ My department does not have the resources to support implementation. (Please explain.) (6) ____________________
- ❑ Other (Please list.) (7) ____________________

Q19 Section 3 (continued) Please indicate your level of use and awareness of the teaching strategy below.

	I currently use it (1)	I have used it in the past (2)	I have used something like it, but did not know the name (3)	I am familiar with it, but have never used it (4)	I have heard name, but know little else about it (5)	I have never heard of it (6)
3. Think-Pair-Share. Posing a problem or question, having students work on it individually for a short time and then forming pairs and reconciling their solutions. After that, calling on students to share their responses. (1)	❍	❍	❍	❍	❍	❍

If I have never heard of it Is Selected, Then Skip To Section 3 (continued) Please indicate...If I have heard name, but know... Is Selected, Then Skip To Section 3 (continued) Please indica...If I am familiar with it, but ... Is Selected, Then Skip To Section 3 (continued) Please indicate...

Q20 How long have/did you use(d) Think-Pair-Share?

- ❍ Less than one semester or term (1)
- ❍ One complete semester or term (2)
- ❍ More than one complete semester or term (3)

Q21 How did you first hear about this teaching strategy?

- ❍ Read article or book about it (1)
- ❍ Presentation or workshop at my professional society conference (e.g., APS, AIP, SPS, AAS, AGU) (2)
- ❍ Presentation or workshop at a physics education conference (e.g., AAPT, AERA) (3)
- ❍ Presentation or workshop on my campus (4)
- ❍ Workshop at another location (e.g., NSF-sponsored) (5)
- ❍ Colleague (word of mouth) (6)
- ❍ Do not recall (7)
- ❍ Other (Please specify how you first heard about the teaching strategy.) (8) ____________________

Q22 Please select any of the factors below that seriously discourage any potential plans for using this particular teaching strategy in the future. Please select all response options that apply.

- ❑ Lack of evidence to support the efficacy of this instructional strategy (1)
- ❑ Too much advanced preparation time required (2)
- ❑ Takes up too much class time to let me cover the syllabus (3)
- ❑ Students would not react positively (4)
- ❑ My department and administration would not value it (5)
- ❑ My department does not have the resources to support implementation. (Please explain.) (6) ____________________
- ❑ Other (Please list.) (7) ____________________

Q23 Section 3 (continued) Please indicate your level of use and awareness of the teaching strategy below.

	I currently use it (1)	I have used it in the past (2)	I have used something like it, but did not know the name (3)	I am familiar with it, but have never used it (4)	I have heard name, but know little else about it (5)	I have never heard of it (6)
4. Concept Tests. Asking multiple-choice conceptual questions with distracters (incorrect responses) that reflect common student misconceptions. (2)	❍	❍	❍	❍	❍	❍

If I have never heard of it Is Selected, Then Skip To Section 3 (continued) Please indica...If I have heard name, but know... Is Selected, Then Skip To Section 3 (continued) Please indica...If I am familiar with it, but ... Is Selected, Then Skip To Section 3 (continued) Please indica...

Q24 How long have/did you use(d) Concept Tests?

- ❍ Less than one semester or term (1)
- ❍ One complete semester or term (2)
- ❍ More than one complete semester or term (3)

Q25 How did you first hear about this teaching strategy?

- ❍ Read article or book about it (1)
- ❍ Presentation or workshop at my professional society conference (e.g., APS, AIP, SPS, AAS, AGU) (2)
- ❍ Presentation or workshop at a physics education conference (e.g., AAPT, AERA) (3)
- ❍ Presentation or workshop on my campus (4)
- ❍ Workshop at another location (e.g., NSF-sponsored) (5)
- ❍ Colleague (word of mouth) (6)
- ❍ Do not recall (7)
- ❍ Other (Please specify how you first heard about the teaching strategy.) (8) ____________________

Q26 Please select any of the factors below that seriously discourage any potential plans for using this particular teaching strategy in the future. Please select all response options that apply.

- ❑ Lack of evidence to support the efficacy of this instructional strategy (1)
- ❑ Too much advanced preparation time required (2)
- ❑ Takes up too much class time to let me cover the syllabus (3)
- ❑ Students would not react positively (4)
- ❑ My department and administration would not value it (5)
- ❑ My department does not have the resources to support implementation. (Please explain.) (6) ____________________
- ❑ Other (Please list.) (7) ____________________

Q27 Section 3 (continued) Please indicate your level of use and awareness of the teaching strategy below.

	I currently use it (1)	I have used it in the past (2)	I have used something like it, but did not know the name (3)	I am familiar with it, but have never used it (4)	I have heard name, but know little else about it (5)	I have never heard of it (6)
5. Peer Instruction. The instructor poses a conceptual question in class, asks students to respond individually (possibly using a classroom response system or "clickers"), and then shares the distribution of responses with the class. Students form pairs, discuss their answers, and then vote again. (1)	❍	❍	❍	❍	❍	❍

If I have never heard of it Is Selected, Then Skip To Section 3 (continued) Please indicate...If I have heard name, but know... Is Selected, Then Skip To Section 3 (continued) Please indicate...If I am familiar with it, but ... Is Selected, Then Skip To Section 3 (continued) Please indicate...

Q28 How long have/did you use(d) Peer Instruction?

- ❍ Less than one semester or term (1)
- ❍ One complete semester or term (2)
- ❍ More than one complete semester or term (3)

Q29 How did you first hear about this teaching strategy?

- ❍ Read article or book about it (1)
- ❍ Presentation or workshop at my professional society conference (e.g., APS, AIP, SPS, AAS, AGU) (2)
- ❍ Presentation or workshop at a physics education conference (e.g., AAPT, AERA) (3)
- ❍ Presentation or workshop on my campus (4)
- ❍ Workshop at another location (e.g., NSF-sponsored) (5)
- ❍ Colleague (word of mouth) (6)
- ❍ Do not recall (7)
- ❍ Other (Please specify how you first heard about the teaching strategy.) (8) ____________________

Q30 Please select any of the factors below that seriously discourage any potential plans for using this particular teaching strategy in the future. Please select all response options that apply.

- ❑ Lack of evidence to support the efficacy of this instructional strategy (1)
- ❑ Too much advanced preparation time required (2)
- ❑ Takes up too much class time to let me cover the syllabus (3)
- ❑ Students would not react positively (4)
- ❑ My department and administration would not value it (5)
- ❑ My department does not have the resources to support implementation. (Please explain.) (6) ____________________
- ❑ Other (Please list.) (7) ____________________

Q31 Section 3 (continued) Please indicate your level of use and awareness of the teaching strategy below.

	I currently use it (1)	I have used it in the past (2)	I have used something like it, but did not know the name (3)	I am familiar with it, but have never used it (4)	I have heard name, but know little else about it (5)	I have never heard of it (6)
6. Collaborative Learning. Asking students to work on a common task in small groups. (1)	❍	❍	❍	❍	❍	❍

If I have never heard of it Is Selected, Then Skip To Section 3 (continued) Please indica...If I have heard name, but know... Is Selected, Then Skip To Section 3 (continued) Please indica...If I am familiar with it, but ... Is Selected, Then Skip To Section 3 (continued) Please indica...

Q32 How long have/did you use(d) Collaborative Learning?

❍ Less than one semester or term (1)
❍ One complete semester or term (2)
❍ More than one complete semester or term (3)

Q33 How did you first hear about this teaching strategy?

❍ Read article or book about it (1)
❍ Presentation or workshop at my professional society conference (e.g., APS, AIP, SPS, AAS, AGU) (2)
❍ Presentation or workshop at a physics education conference (e.g., AAPT, AERA) (3)
❍ Presentation or workshop on my campus (4)
❍ Workshop at another location (e.g., NSF-sponsored) (5)
❍ Colleague (word of mouth) (6)
❍ Do not recall (7)
❍ Other (Please specify how you first heard about the teaching strategy.) (8) ____________________

Q34 Please select any of the factors below that seriously discourage any potential plans for using this particular teaching strategy in the future. Please select all response options that apply.

❑ Lack of evidence to support the efficacy of this instructional strategy (1)
❑ Too much advanced preparation time required (2)
❑ Takes up too much class time to let me cover the syllabus (3)
❑ Students would not react positively (4)
❑ My department and administration would not value it (5)
❑ My department does not have the resources to support implementation. (Please explain.) (6) ____________________
❑ Other (Please list.) (7) ____________________

Q35 Section 3 (continued) Please indicate your level of use and awareness of the teaching strategy below.

	I currently use it (1)	I have used it in the past (2)	I have used something like it, but did not know the name (3)	I am familiar with it, but have never used it (4)	I have heard name, but know little else about it (5)	I have never heard of it (6)
7. Cooperative Learning. A structured form of group work in which faculty help students develop team skills, assess both individual learning as well as overall group results, and structure assignments to strengthen interactions between team members. (1)	❍	❍	❍	❍	❍	❍

If I have never heard of it Is Selected, Then Skip To Section 3 (continued) Please indicate...If I have heard name, but know... Is Selected, Then Skip To Section 3 (continued) Please indicate...If I am familiar with it, but ... Is Selected, Then Skip To Section 3 (continued) Please indicate...

Q36 How long have/did you use(d) Cooperative Learning?

- ❍ Less than one semester or term (1)
- ❍ One complete semester or term (2)
- ❍ More than one complete semester or term (3)

Q37 How did you first hear about this teaching strategy?

- ❍ Read article or book about it (1)
- ❍ Presentation or workshop at my professional society conference (e.g., APS, AIP, SPS, AAS, AGU) (2)
- ❍ Presentation or workshop at a physics education conference (e.g., AAPT, AERA) (3)
- ❍ Presentation or workshop on my campus (4)
- ❍ Workshop at another location (e.g., NSF-sponsored) (5)
- ❍ Colleague (word of mouth) (6)
- ❍ Do not recall (7)
- ❍ Other (Please specify how you first heard about the teaching strategy.) (8) ____________________

Q38 Please select any of the factors below that seriously discourage any potential plans for using this particular teaching strategy in the future. Please select all response options that apply.

- ❑ Lack of evidence to support the efficacy of this instructional strategy (1)
- ❑ Too much advanced preparation time required (2)
- ❑ Takes up too much class time to let me cover the syllabus (3)
- ❑ Students would not react positively (4)
- ❑ My department and administration would not value it (5)
- ❑ My department does not have the resources to support implementation. (Please explain.) (6) ____________________
- ❑ Other (Please list.) (7) ____________________

Q39 Section 3 (continued) Please indicate your level of use and awareness of the teaching strategy below.

	I currently use it (1)	I have used it in the past (2)	I have used something like it, but did not know the name (3)	I am familiar with it, but have never used it (4)	I have heard name, but know little else about it (5)	I have never heard of it (6)
8. Inquiry Learning. Presenting students with questions, problems or a set of observations and using this to drive the desired learning. (2)	❍	❍	❍	❍	❍	❍

If I have never heard of it Is Selected, Then Skip To Section 3 (continued) Please indicate...If I have heard name, but know... Is Selected, Then Skip To Section 3 (continued) Please indicate...If I am familiar with it, but ... Is Selected, Then Skip To Section 3 (continued) Please indicate...

Q40 How long have/did you use(d) Inquiry Learning?

- ❍ Less than one semester or term (1)
- ❍ One complete semester or term (2)
- ❍ More than one complete semester or term (3)

Q41 How did you first hear about this teaching strategy?

- ❍ Read article or book about it (1)
- ❍ Presentation or workshop at my professional society conference (e.g., APS, AIP, SPS, AAS, AGU) (2)
- ❍ Presentation or workshop at a physics education conference (e.g., AAPT, AERA) (3)
- ❍ Presentation or workshop on my campus (4)
- ❍ Workshop at another location (e.g., NSF-sponsored) (5)
- ❍ Colleague (word of mouth) (6)
- ❍ Do not recall (7)
- ❍ Other (Please specify how you first heard about the teaching strategy.) (8) ____________________

Q42 Please select any of the factors below that seriously discourage any potential plans for using this particular teaching strategy in the future. Please select all response options that apply.

- ❑ Lack of evidence to support the efficacy of this instructional strategy (1)
- ❑ Too much advanced preparation time required (2)
- ❑ Takes up too much class time to let me cover the syllabus (3)
- ❑ Students would not react positively (4)
- ❑ My department and administration would not value it (5)
- ❑ My department does not have the resources to support implementation. (Please explain.) (6) ____________________
- ❑ Other (Please list.) (7) ____________________

Q43 Section 3 (continued) Please indicate your level of use and awareness of the teaching strategy below.

	I currently use it (1)	I have used it in the past (2)	I have used something like it, but did not know the name (3)	I am familiar with it, but have never used it (4)	I have heard name, but know little else about it (5)	I have never heard of it (6)
9. Problem-Based Learning. Acting primarily as a facilitator and placing students in self-directed teams to solve open-ended problems that require significant learning of new course material. (3)	❍	❍	❍	❍	❍	❍

If I have never heard of it Is Selected, Then Skip To Section 3 (continued) Please indicate...If I have heard name, but know... Is Selected, Then Skip To Section 3 (continued) Please indicate...If I am familiar with it, but ... Is Selected, Then Skip To Section 3 (continued) Please indicate...

Q44 How long have/did you use(d) Problem-Based Learning?

❍ Less than one semester or term (1)
❍ One complete semester or term (2)
❍ More than one complete semester or term (3)

Q45 How did you first hear about this teaching strategy?

❍ Read article or book about it (1)
❍ Presentation or workshop at my professional society conference (e.g., APS, AIP, SPS, AAS, AGU) (2)
❍ Presentation or workshop at a physics education conference (e.g., AAPT, AERA) (3)
❍ Presentation or workshop on my campus (4)
❍ Workshop at another location (e.g., NSF-sponsored) (5)
❍ Colleague (word of mouth) (6)
❍ Do not recall (7)
❍ Other (Please specify how you first heard about the teaching strategy.) (8) ____________________

Q46 Please select any of the factors below that seriously discourage any potential plans for using this particular teaching strategy in the future. Please select all response options that apply.

❑ Lack of evidence to support the efficacy of this instructional strategy (1)
❑ Too much advanced preparation time required (2)
❑ Takes up too much class time to let me cover the syllabus (3)
❑ Students would not react positively (4)
❑ My department and administration would not value it (5)
❑ My department does not have the resources to support implementation. (Please explain.) (6) ____________________
❑ Other (Please list.) (7) ____________________

Q47 Section 3 (continued) Please indicate your level of use and awareness of the teaching strategy below.

	I currently use it (1)	I have used it in the past (2)	I have used something like it, but did not know the name (3)	I am familiar with it, but have never used it (4)	I have heard name, but know little else about it (5)	I have never heard of it (6)
10. Physics Concept Inventory. Assessing students' mastery of conceptual ideas in physics using this multiple choice test. (3)	❍	❍	❍	❍	❍	❍

If I have never heard of it Is Selected, Then Skip To Please comment on any additional fact...If I have heard name, but know... Is Selected, Then Skip To Please comment on any additional fact...If I am familiar with it, but ... Is Selected, Then Skip To Please comment on any additional fact...

Q48 How long have/did you use(d) Physics Concept Inventories?

- ❍ Less than one semester or term (1)
- ❍ One complete semester or term (2)
- ❍ More than one complete semester or term (3)

Q49 How did you first hear about this teaching strategy?

- ❍ Read article or book about it (1)
- ❍ Presentation or workshop at my professional society conference (e.g., APS, AIP, SPS, AAS, AGU) (2)
- ❍ Presentation or workshop at a physics education conference (e.g., AAPT, AERA) (3)
- ❍ Presentation or workshop on my campus (4)
- ❍ Workshop at another location (e.g., NSF-sponsored) (5)
- ❍ Colleague (word of mouth) (6)
- ❍ Do not recall (7)
- ❍ Other (Please specify how you first heard about the teaching strategy.) (8) ____________________

Q50 Please select any of the factors below that seriously discourage any potential plans for using this particular teaching strategy in the future. Please select all response options that apply.

- ❑ Lack of evidence to support the efficacy of this instructional strategy (1)
- ❑ Too much advanced preparation time required (2)
- ❑ Takes up too much class time to let me cover the syllabus (3)
- ❑ Students would not react positively (4)
- ❑ My department and administration would not value it (5)
- ❑ My department does not have the resources to support implementation. (Please explain.) (6) ____________________
- ❑ Other (Please list.) (7) ____________________

Q51 Please comment on any additional factors that might prevent you from using more of the instructional strategies addressed in this survey in the future.

Q52 Section 4 This section addresses your teaching and other professional responsibilities.

Q53 On average, approximately how many students were in the class section(s) the last time you taught ${q://QID3/ChoiceGroup/SelectedChoices}? Please type your response in the box below.
Average # Students Per Section (1)

Q54 Please select the response option that best describes your current job responsibilities.

- ❍ Primarily teaching (1)
- ❍ Teaching accounts for more than half of my responsibilities (2)
- ❍ Teaching accounts for about half my responsibilities (3)
- ❍ Teaching accounts for less than half of my responsibilities (4)

Q55 How often did you talk to or correspond with your colleagues or other physics professors about teaching over the past two years?

- ❍ Never (1)
- ❍ Once or twice per semester or term (2)
- ❍ Several times per semester or term (3)
- ❍ Weekly (4)
- ❍ Nearly every day (5)

Q56 Approximately how many talks or workshops on teaching methods or other physics education topics have you attended in the past two years (at professional meetings, on campus, or at other venues)?

- ❍ None (1)
- ❍ 1-3 (2)
- ❍ 4-9 (3)
- ❍ 10 or more (4)

Q57 How many total years of experience do you have teaching undergraduate students? Please type your response in the box below.

Q58 What is your current academic rank?

- ❍ Instructor (1)
- ❍ Assistant Professor (2)
- ❍ Associate Professor (3)
- ❍ Full Professor (4)
- ❍ Emeritus Professor (5)
- ❍ Visiting Scholar (11)
- ❍ Other (Please list.) (6) ____________________

Q59 What is your gender?

- ❍ Female (1)
- ❍ Male (2)

Q60 In which department or program is your faculty or teaching appointment?

- Physics (1)
- Mathematics (2)
- Chemistry (3)
- Engineering (Please specify type.) (5) ____________________
- Other (Please specify.) (6) ____________________

Answer If From the drop down list below, please select the undergraduate course you have taught or TA'd most recently. If you taught more than one undergraduate physics course simultaneously, please select o... I have never taught or TA'd an undergraduate physics course. Is Selected Or When did you last teach ${q://QID3/ChoiceGroup/SelectedChoices} or a similar course? I have not taught ${q://QID3/ChoiceGroup/SelectedChoices} within the last 5 years Is Selected

Q61 Thank you for your interest in helping our research; however, you do not meet the criteria to complete this survey. Please advance to the next screen in order to exit out of the survey.

Appendix E - Faculty Interview Protocols

Version A: For JiTT Users

1. What kind of training did you receive on Just-in-Time Teaching?
   a. How adequate was the training experience?
   b. Did you feel prepared to implement it in your lessons at the start of your first semester using it?

2. What do you think the purpose of preflight assignments is?
   a. Tell me your thoughts on whether that is a worthy reason to complete the assignments?
   b. How are preflights a useful (or not) learning tool?

3. Please walk me through your typical routine for reviewing preflight questions.
   a. When?
   b. Depth?
   c. Time spent per section?

4. Please walk me through your typical routine for tailoring your lessons based on preflight responses.

5. In what ways do preflights help prepare students for future learning during class?

6. How do you explain to individual students or entire classes your expectations for students when they complete their preflights?

7. What do you have to say about the way preflights are graded (i.e., number of points, correctness vs. effort)?
   a. How is it fair/unfair?
   b. Too many/few points?

8. What can be done to improve the way preflights are administered?
   a. Online?
   b. During class?

Is there anything else you would like share with me today regarding your thoughts on preflights or how you incorporate them in class?

Version B: For Non-JiTT Users

1. What is your understanding or interpretation of why preflights are used in this department?
    a. Do you believe we meet that expectation in our classes that use JiTT?

2. In what ways do you believe JiTT either has or does not have the potential to be a useful pedagogical tool in a physics course?
    a. How can preflights be modified in a way that would make them more effective?

3. If you used preflights in the past, please walk me through how you integrated the assignment into your class.
    a. Why do you believe preflights helped or did not help prepare students to learn new physics concepts in your class?

4. If you used preflights in the past, what discouraged you from continuing to use them?

5. What do you believe motivates students to come prepared to class and why? (Where preparation means being familiar with and/or having read course materials prior to a lesson.)

Is there anything else you would like to share with me today?

Appendix F - Classroom Observation Protocol

I. BACKGROUND INFORMATION
Date:_________________ Class Period:__________ Lesson #: _________
Name of instructor:_____________________________ Announced Observation? Yes No
Course observed: __________________________

II. CLASS ACTIVITIES
PF#1
□ Clearly Referenced?
□ Responses displayed to class. PowerPoint Server Clicker Other Anonymous
□ Preflight concept directly connected/transferred to a new situation/scenario.
□ Students engage in discussion about preflight question. Peer Instruction Think Pair Share Other
□ Students appear satisfied with preflight clarification(s).
Notes:

Scored after the observation using this system:

Criteria Anonymous Yes No N/A	**No** **0**	**Yes** **1**
Clearly referenced.		
Responses displayed to class. **Method**:		
Preflight concept directly connected/transferred to a new situation/scenario.		
Students engage in discussion about preflight question. **Method**:		
Students appear satisfied with preflight clarification(s).		
Total		

PF#2
□ Clearly Referenced?
□ Responses displayed to class. PowerPoint Server Clicker Other Anonymous
□ Preflight concept directly connected/transferred to a new situation/scenario.
□ Students engage in discussion about preflight question. Peer Instruction Think Pair Share Other
□ Students appear satisfied with preflight clarification(s).
Notes:

Scored after the observation using this system:

Criteria Anonymous Yes No N/A	**No** **0**	**Yes** **1**
Clearly referenced.		
Responses displayed to class. **Method**:		
Preflight concept directly connected/transferred to a new situation/scenario.		
Students engage in discussion about preflight question. **Method**:		
Students appear satisfied with preflight clarification(s).		
Total		

PF#3
□ Clearly Referenced?

□ Responses displayed to class. PowerPoint Server Clicker Other Anonymous
□ Preflight concept directly connected/transferred to a new situation/scenario.
□ Students engage in discussion about preflight question. Peer Instruction Think Pair Share Other
□ Students appear satisfied with preflight clarification(s).
Notes:

Scored after the observation using this system:

Criteria Anonymous Yes No N/A	**No** **0**	**Yes** **1**
Clearly referenced.		
Responses displayed to class. **Method**:		
Preflight concept directly connected/transferred to a new situation/scenario.		
Students engage in discussion about preflight question. **Method**:		
Students appear satisfied with preflight clarification(s).		
Total		

PF#4

□ Clearly Referenced?
□ Responses displayed to class. PowerPoint Server Clicker Other Anonymous
□ Preflight concept directly connected/transferred to a new situation/scenario.
□ Students engage in discussion about preflight question. Peer Instruction Think Pair Share Other
□ Students appear satisfied with preflight clarification(s).
Notes:

Scored after the observation using this system:

Criteria Anonymous Yes No N/A	**No** **0**	**Yes** **1**
Clearly referenced.		
Responses displayed to class. **Method**:		
Preflight concept directly connected/transferred to a new situation/scenario.		
Students engage in discussion about preflight question. **Method**:		
Students appear satisfied with preflight clarification(s).		
Total		

Appendix G - Student Preflight Questionnaire

Example taken from Physics 215 (Regular Electricity & Magnetism) Course.

Q1 Thank you for completing this short questionnaire. Your time is greatly appreciated! When answering the following questions, please use the “BACK”; button at the bottom of the screen (not your browser’s back button) to revisit previous questions. If you receive a webpage error (not a questionnaire error), refresh the screen.

Q2 On average, please indicate how much time you spend on a preflight for a single lesson?

______ Minutes (1)

Q3 When do you typically complete your preflight assignments?

- ❍ During the second hour of class (EI). (1)
- ❍ The morning that they are due. (2)
- ❍ During ACQ. (3)
- ❍ Other. (Please list.) (4) ____________________

Q4 With whom do you usually work on preflights? (Select all that apply.)

- ❑ A physics classmate. (1)
- ❑ Another member of my squadron. (2)
- ❑ Individually (by myself). (3)
- ❑ My instructor. (4)
- ❑ A physics tutor. (5)
- ❑ Other. (Please list.) (6) ____________________

Q5 For the following 3 questions, on a scale of 1-6, please indicate how much you agree with the statements.

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
I complete physics preflights because it's necessary to read course material to be prepared for class. (1)	❍	❍	❍	❍	❍	❍
Preflights prepare me to learn new physics concepts during class. (2)	❍	❍	❍	❍	❍	❍
Physics preflights are worth my time. (4)	❍	❍	❍	❍	❍	❍

Q6 For the following 4 questions, on a scale of 1-6, please indicate how much you agree with the statements.

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
I take physics preflights seriously. (1)	❍	❍	❍	❍	❍	❍
I would complete physics preflights even if they were not worth any points toward my grade. (2)	❍	❍	❍	❍	❍	❍
Our preflight answers clearly guide what we cover in class. (3)	❍	❍	❍	❍	❍	❍
It is evident that my physics instructor reads all preflight responses before class starts. (4)	❍	❍	❍	❍	❍	❍

Please complete the following sentence with the single most appropriate statement:

Q7 *My physics instructor references preflight assignments during* ______________________.

- ❍ every class. (1)
- ❍ most classes. (2)
- ❍ some classes. (3)
- ❍ no classes. (4)

Q8 *In general, when my physics instructor reviews a preflight assignment during class, she/he explains* _________________ *in depth.*

- ❍ only the preflight questions that gave my class the most difficulty (1)
- ❍ all preflight questions (2)
- ❍ most preflight questions (3)
- ❍ some preflight questions (4)
- ❍ no preflight questions (5)

Q9 How obvious is it when your physics instructor connects a preflight question to a discussion about other related problems or examples?

- ❍ It is always obvious when she/he makes a connection between a concept covered in a preflight and another problem or example. (1)
- ❍ It is sometimes obvious when she/he makes a connection between a concept covered in a preflight and another problem or example. (2)
- ❍ It is never obvious when she/he makes a connection between a concept covered in a preflight and another problem or example. (3)
- ❍ N/A (she/he never reviews preflights during class). (4)

Q10 Please complete the following sentence: (Select all that apply.)

Preflight questions help prepare me for ________________________.

- ❑ Mastering Physics problems. (1)
- ❑ multiple choice questions on Graded Reviews. (2)
- ❑ multiple choice questions on quizzes. (3)
- ❑ workout problems on Graded Reviews. (6)
- ❑ workout problems on quizzes. (4)
- ❑ none of the above. (5)

Q11 Your answer to the following and final question will provide important information that will help improve how preflights are used in future physics classes.

Q12 In the space below, please indicate how preflight assignments could be improved to increase your preparation for future learning in physics class. (i.e., length of assignments, types of questions asked, etc.)

Q13 If you wish to participate in a 30-minute student focus group with Capt Dwyer during the second hour of your physics class (EI), please indicate your interest below. She will kindly serve light refreshments to all participants. If you are not interested, please click "NEXT" to submit your responses.

❍ Yes, please sign me up! (Please enter your cadet email below.) (1)

Appendix H - Student Focus Group Interview Protocol

1. What purpose or theory did your instructor explain as the reason for assigning preflights?

2. Please explain your routine for completing preflight assignments (i.e., time of day, length of time, location, on paper, etc.).

3. In what ways do you think preflights help prepare you for class?

4. Please explain how your instructor integrates preflights into your lessons (i.e., not at all, verbally, with clickers, anonymous answers, etc.).

5. In what ways does your teacher tailor her/his lessons based on your preflight responses?

6. What are some suggestions for ways to improve how preflights are administered?

7. In what ways do you believe preflights are a useful learning tool?

8. What motivates you to complete preflights?

9. What do you have to say about the way preflights are graded?

10. Is there anything else you would like to share with me today regarding your thoughts on preflights or how they are incorporated in class?

Appendix I - Modified Colorado Learning Attitudes about Science Survey (CLASS)

General Physics I and II Worked Example Questionnaire

Below are statements that may or may not describe your beliefs about learning physics. Fill in the entire circle that corresponds to the choice that best expresses your feelings about the statement. This questionnaire is optional, and you are not required to answer any of the questions. The information we gather from this questionnaire will not affect your grade in the class and will not be shared with your instructor. Thank you!

SSN

Worked Example Questionnaire	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1. A significant problem in learning physics is being able to memorize all the information I need to know.	○	○	○	○	○
2. When I am solving a physics problem, I try to decide what would be a reasonable value for the answer.	○	○	○	○	○
3. After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.	○	○	○	○	○
4. When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.	○	○	○	○	○
5. There is usually only one correct approach to solving a physics problem.	○	○	○	○	○
6. I cannot learn physics if the teacher does not explain things well in class.	○	○	○	○	○
7. I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.	○	○	○	○	○
8. I study physics to learn knowledge that will be useful in my life outside of school.	○	○	○	○	○
9. I do not spend more than five minutes stuck on a physics problem before giving up or seeking help from someone else.	○	○	○	○	○
10. If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.	○	○	○	○	○
11. In physics, it is important for me to make sense out of formulas before I can use them correctly.	○	○	○	○	○
12. In physics, mathematical formulas express meaningful relationships among measurable quantities.	○	○	○	○	○
13. Learning physics changes my ideas about how the world works.	○	○	○	○	○
14. I find carefully analyzing only a few problems in detail is a good way for me to learn physics.	○	○	○	○	○
15. I can usually figure out a way to solve physics problems.	○	○	○	○	○
16. The subject of physics has little relation to what I experience in the real world.	○	○	○	○	○
17. To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.	○	○	○	○	○
18. I am confident in my abilities to solve physics problems.	○	○	○	○	○
19. I am afraid to ask questions in physics class.	○	○	○	○	○
20. I am always worried about being called on in physics class.	○	○	○	○	○

Appendix J - Student Focus Group Schedule Flyer

PREFLIGHT FOCUS GROUP SCHEDULE & LOCATIONS

*If you don't know where to find the specified room, ask your instructor for directions.

	M-Day Monday 15 Sep 14	T-Day Tuesday 16 Sep 14
Period 1		
Period 2	2B11	2B11
Period 3		
Period 4	Physics Small Conference Room	2B11
Period 5		
Period 6		
Period 7	2B11	2B11

POC:
JESSICA H. DWYER, Captain, USAF
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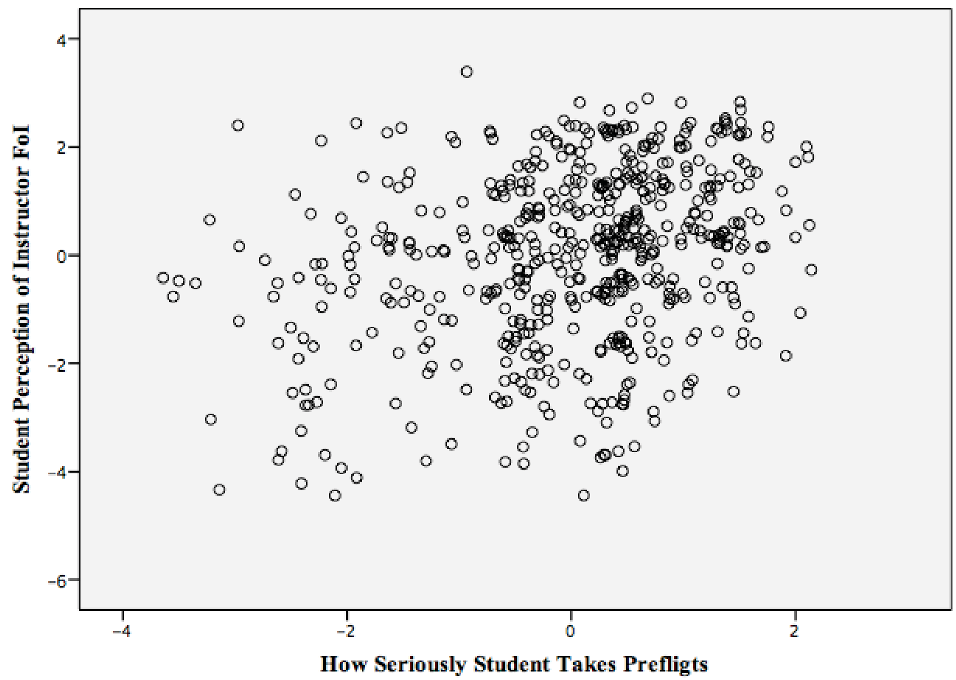
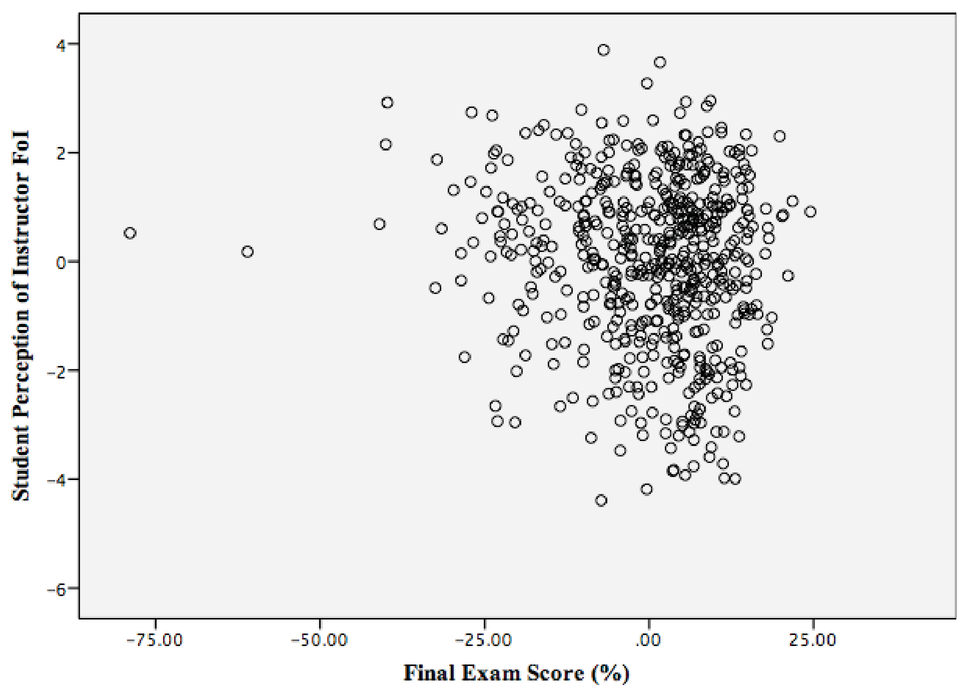
Appendix K - Partial Regression Scatterplots and Correlation Table

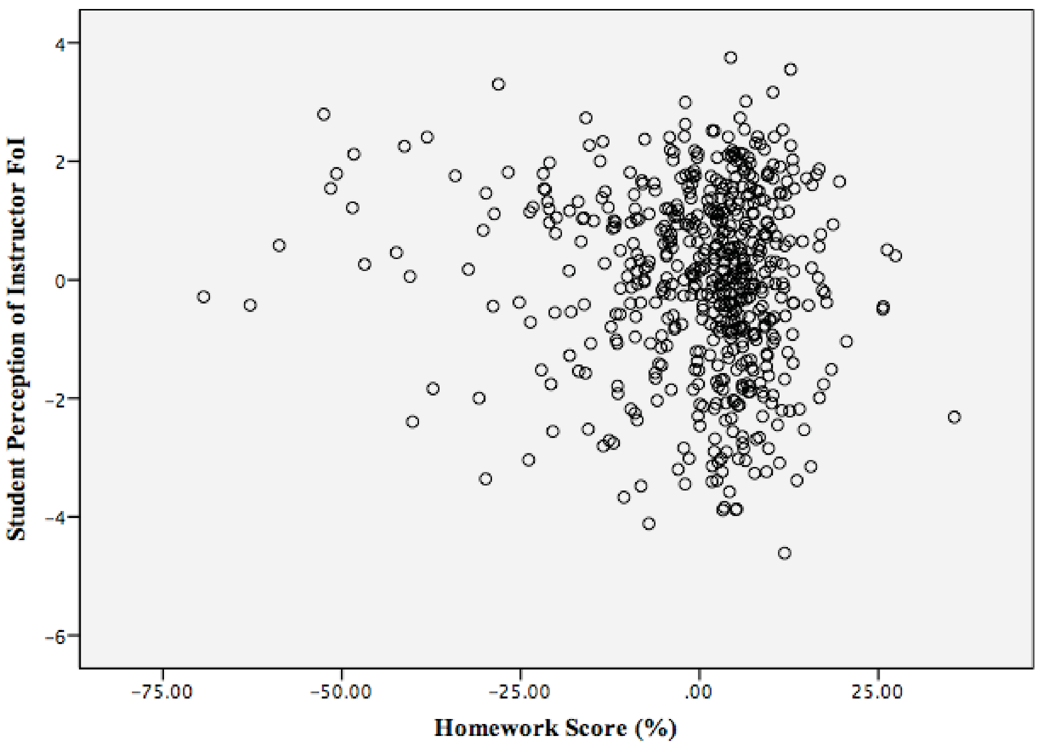
Partial Regression Plot: Outcome vs. Preflight Seriousness



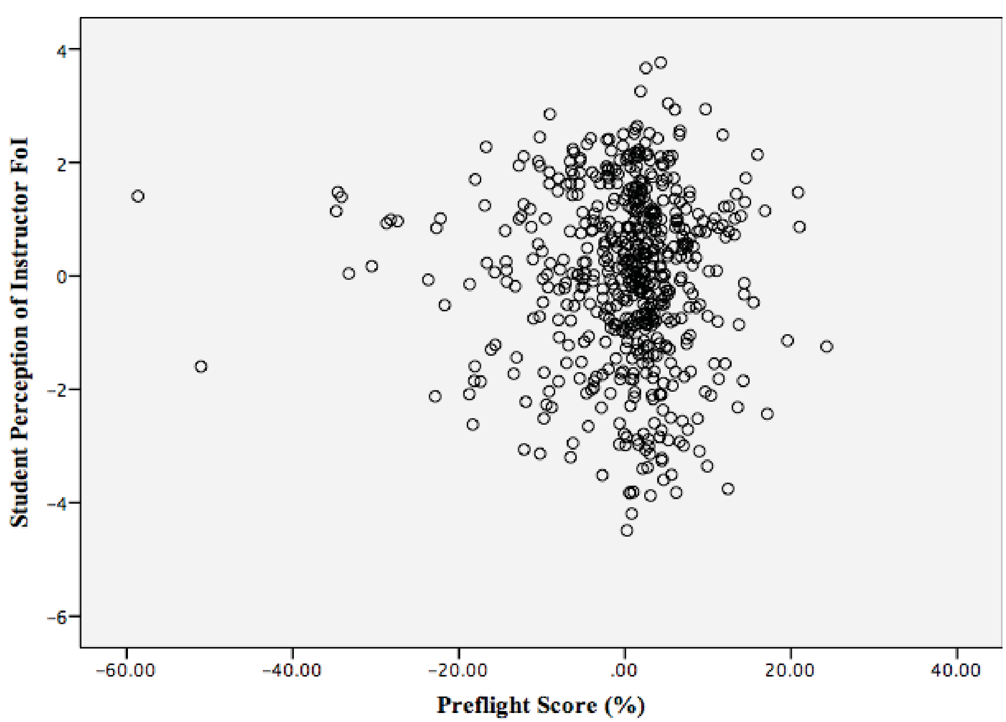
Partial Regression Plot: Outcome vs. Final Exam Score (%)



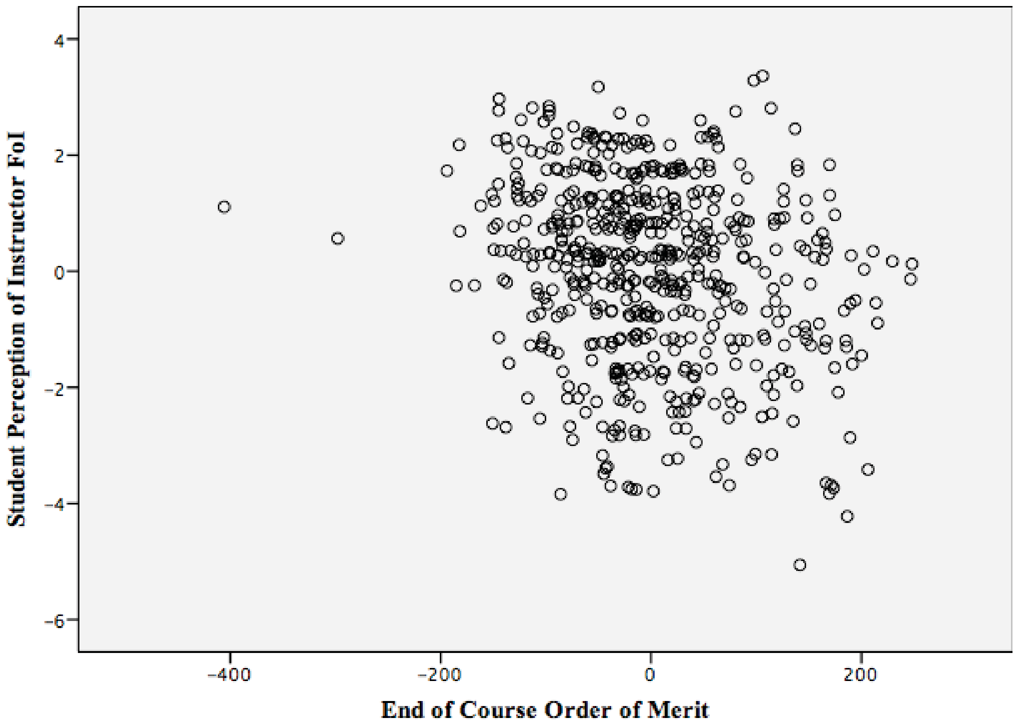
Partial Regression Plot: Outcome vs. Homework Score (%)



Partial Regression Plot: Outcome vs. Preflight Score (%)



Partial Regression Plot: Outcome vs. End of Course Order of Merit



Correlation Table for Independent Variables

		I take PF seriously	Final Order of Merit	Final Average (%)	Total Final Exam (%)	Total Homework (%)	Total points earned on PF (%)
I take PF seriously	Pearson Correlation	1	-.217**	.235**	.129**	.180**	.247**
	Sig. (2-tailed)		.000	.000	.002	.000	.000
	N	567	567	567	567	567	567
Final Order of Merit	Pearson Correlation	-.217**	1	-.768**	-.618**	-.222**	-.095*
	Sig. (2-tailed)	.000		.000	.000	.000	.024
	N	567	567	567	567	567	567
Final Average (%)	Pearson Correlation	.235**	-.768**	1	.833**	.374**	.233**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	567	567	567	567	567	567
Total Final Exam (%)	Pearson Correlation	.129**	-.618**	.833**	1	.124**	.015
	Sig. (2-tailed)	.002	.000	.000		.003	.720
	N	567	567	567	567	567	567
Total Homework (%)	Pearson Correlation	.180**	-.222**	.374**	.124**	1	.544**
	Sig. (2-tailed)	.000	.000	.000	.003		.000
	N	567	567	567	567	567	567
Total points earned on PF (%)	Pearson Correlation	.247**	-.095*	.233**	.015	.544**	1
	Sig. (2-tailed)	.000	.024	.000	.720	.000	
	N	567	567	567	567	567	567

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix L - CLASS Correlation Tables By Core Course

Physics 215

Regular Electricity & Magnetism

		SumStudentPerceptionFol	CLASS Pretest % Favorable	CLASS Posttest % Favorable	CLASS Normalized Gain
SumStudentPerceptionFol	Pearson Correlation	1	.007	.152*	.104
	Sig. (2-tailed)		.909	.019	.107
	N	240	240	240	240
CLASS Pretest % Favorable	Pearson Correlation	.007	1	-.011	-.472**
	Sig. (2-tailed)	.909		.870	.000
	N	240	240	240	240
CLASS Posttest % Favorable	Pearson Correlation	.152*	-.011	1	.735**
	Sig. (2-tailed)	.019	.870		.000
	N	240	240	240	240
CLASS Normalized Gain	Pearson Correlation	.104	-.472**	.735**	1
	Sig. (2-tailed)	.107	.000	.000	
	N	240	240	240	240

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Physics 215H

Honors Electricity & Magnetism

		SumStudentPerceptionFol	CLASS Pretest % Favorable	CLASS Posttest % Favorable	CLASS Normalized Gain
SumStudentPerceptionFol	Pearson Correlation	1	-.017	.075	.065
	Sig. (2-tailed)		.846	.393	.463
	N	130	130	130	130
CLASS Pretest % Favorable	Pearson Correlation	-.017	1	.027	-.370**
	Sig. (2-tailed)	.846		.762	.000
	N	130	130	130	130
CLASS Posttest % Favorable	Pearson Correlation	.075	.027	1	.882**
	Sig. (2-tailed)	.393	.762		.000
	N	130	130	130	130
CLASS Normalized Gain	Pearson Correlation	.065	-.370**	.882**	1
	Sig. (2-tailed)	.463	.000	.000	
	N	130	130	130	130

**. Correlation is significant at the 0.01 level (2-tailed).

Physics 110

Regular Mechanics

		SumStudentPerceptionFol	CLASS Pretest % Favorable	CLASS Posttest % Favorable	CLASS Normalized Gain
SumStudentPerceptionFol	Pearson Correlation	1	-.123	.066	.135
	Sig. (2-tailed)		.259	.547	.214
	N	86	86	86	86
CLASS Pretest % Favorable	Pearson Correlation	-.123	1	.148	-.341**
	Sig. (2-tailed)	.259		.173	.001
	N	86	86	86	86
CLASS Posttest % Favorable	Pearson Correlation	.066	.148	1	.837**
	Sig. (2-tailed)	.547	.173		.000
	N	86	86	86	86
CLASS Normalized Gain	Pearson Correlation	.135	-.341**	.837**	1
	Sig. (2-tailed)	.214	.001	.000	
	N	86	86	86	86

**. Correlation is significant at the 0.01 level (2-tailed).

Physics 110H

Honors Mechanics

		SumStudentPerceptionFol	CLASS Pretest % Favorable	CLASS Posttest % Favorable	CLASS Normalized Gain
SumStudentPerceptionFol	Pearson Correlation	1	-.084	.042	.034
	Sig. (2-tailed)		.437	.697	.751
	N	89	89	89	89
CLASS Pretest % Favorable	Pearson Correlation	-.084	1	-.154	-.403**
	Sig. (2-tailed)	.437		.149	.000
	N	89	89	89	89
CLASS Posttest % Favorable	Pearson Correlation	.042	-.154	1	.950**
	Sig. (2-tailed)	.697	.149		.000
	N	89	89	89	89
CLASS Normalized Gain	Pearson Correlation	.034	-.403**	.950**	1
	Sig. (2-tailed)	.751	.000	.000	
	N	89	89	89	89

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix M - Definitions of Qualitative Faculty Codes

Code	Definitions of Faculty Data Codes	
1	**JiTT Implementation**	Instructor mentions or researcher observes any aspect of instructor’s use of preflights from initial access to integration during a lesson.
2	**Sharing Student Questions & Answers**	Instructor mentions or researcher observes instructor share student responses to preflight questions. This includes multiple choice and open-ended preflight questions.
3	**Anonymous**	When instructor shares student answers, they are anonymous.
4	**Projected**	When instructor shares student answers, they are projected for the students to see (i.e., uses Power Point or the JiTT server).
5	**Lesson Guide**	Instructor mentions or researcher observes instructor use preflight responses to guide what is covered during a lesson.
6	**First Preflight Question**	Instructor uses responses to the first preflight question (*What do you want to cover in class?*), in particular, to guide a lesson.
7	**Time**	Instructor mentions that time is a factor in their JiTT use.
8	**In-Class**	Instructor mentions or implies how JiTT impacts their use of time during class.
9	**Preparation**	Instructor mentions or implies how JiTT impacts their use of time during preparation for class.

Appendix N - Definitions of Qualitative Student Codes

Code	Definitions of Student Data Codes	
1	**Class Preparation**	Student mentions how preflights influence their ability to a) learn physics concepts or mathematical calculations during class or b) perform on future graded assessments.
2	**Preflights Help**	Student mentions something about whether preflights are helpful in their learning.
3	**Yes, helps**	Student believes preflights help them learn new physics topics.
4	**No, doesn't help**	Student does not believe preflights help them learn new physics topics
5	**Students Read Textbook**	Student mentions or implies something about reading their physics textbook.
6	**Yes, reads**	Student indicates or implies that they read their textbook.
7	**No, doesn't read**	Student indicates or implies that they do not read their textbook.

Appendix O - Inter-Rater Reliability

IRR with NVivo Automatic Coding Comparison

Faculty

Node	Source	Agreement (%)	A and B (%)	Not A and Not B (%)	Disagreement (%)	A and Not B (%)	B and Not A (%)
Implementation\Lesson Guide	All	87.41	0.80	86.61	12.59	0.68	11.92
Implementation\Sharing questions and answers	All	82.69	2.67	80.03	17.31	0.39	16.93
Implementation\Sharing questions and answers\Anonymous	All	86.55	0.66	85.89	13.45	0.00	13.45
Implementation\Sharing questions and answers\Project on board	All	84.92	1.85	83.08	15.08	0.05	15.03
Implementation\Sharing questions and answers\Project on board\No	All	99.86	0.00	99.86	0.15	0.15	0.00
Implementation\Sharing questions and answers\Some answers	All	89.64	0.62	89.02	10.37	0.05	10.32
Implementation\Sharing questions and answers\All answers	All	94.17	0.54	93.64	5.83	0.10	5.73
Prep Routine\Prep Time	All	85.52	1.08	84.44	14.49	0.75	13.74
Implementation\Sharing questions and answers\Out of Time	All	93.04	0.47	92.57	6.97	0.00	6.97

Students

Node	Source	Agreement (%)	A and B (%)	Not A and Not B (%)	Disagreement (%)	A and Not B (%)	B and Not A (%)
PFL	All	98.38	0.00	98.38	1.62	1.62	0.00
PFL\Doesn't Help	All	99.27	0.00	99.27	0.73	0.73	0.00
PFL\Helps	All	99.37	0.00	99.37	0.63	0.63	0.00
Reading	All	97.79	0.00	97.79	2.21	2.20	0.01
Reading\No	All	99.31	0.00	99.31	0.69	0.68	0.01

IRR with Physics Education Researcher

	Source	Agreement	Disagreement	J not F	F Not J
Faculty (all codes)	Interview Transcript	90%	10%	0	4
Students (all codes)	Questionnaire Narrative Responses	98.1%	1.9%	0	0

Appendix P - Examples of Coded Faculty Data: JiTT Implementation

Sharing Student Preflight Questions and Answers

Almost every observed instructor posted quoted student feedback from the first preflight question into a PowerPoint slide and displayed it early in the lesson.

All posted responses were anonymous. One instructor posted names of students who did not submit a preflight.

About half of the instructors created a PowerPoint slide for each multiple choice preflight question and provided the answer to it. Some also share the percentage of students in the section who answered the question correctly.

Instructor 15: "*The nice thing about [reviewing preflights] as clickers is that if you have a bit of a discussion first, you can put it up and say, "Okay, you guys [answered] sixty percent [correctly] online. Let's see if we can improve."*

Instructor 21: *"I try and pick a variety of things that allow us to chat about this stuff…I leave it anonymous… I want everybody to see their responses at one point or another. Otherwise, they might get the impression, 'Well, [my instructor]'s not reading mine.' Or 'Mine aren't worthy of noting.' Kind of mindful of that."*

Using Preflights as a Lesson Guide

Instructor 6 especially used the first preflight question to guide lesson planning. They said they sometimes used the first JiTT question to start a lesson or integrated preflight questions later during the lesson.

Instructor 7 used JiTT to make class more conversational and to drive what is covered.

Instructor 18 felt the first JiTT question is the most important question for guiding class.

Instructor 21: *"I haven't found a case where the students overwhelmingly understand the pre-flight, 'Wow! We don't have to cover this today.' I have not found that to be true. Maybe that means that I'm hitting the right level of difficulty with the pre-flight."*

Instructor 22 would like to eventually utilize a second screen in classroom to have first preflight question displayed throughout entire class to reference as needed.

Time Required to Implement JiTT

Preparatory

Instructor 6 spent about 20-30 minutes (depending on experience with the course) preparing her/his lesson with JiTT feedback.

Instructor 7 first looks at preflight responses a few hours before class and integrates more descriptive questions into the lesson.

Instructor 15: "*They close [preflights] out generally at 7. It used to be classes started at 7:15, now classes start at 7:30. I usually get in…about 6:30. About an hour before, because you have to you. You need at least 45 minutes to do that. Then, you have to gather stuff up and get to your classroom and do all the other things you need to prep."*

Instructor 18 takes about 15 minutes to paste student responses into a PowerPoint slide to display in class.

In-Class

In about half of the observed core and non-core lessons, instructors did not have enough time to review all of the pre-class work, to include preflights. Most often the final preflight question or "critical thinking exercise" in the core classes was neglected, and the Worked Examples worksheets in the core journal were not explicitly covered or covered in their entirety.

"[There is a] [l]imited amount of time for finding and balancing the [pedagogical] approaches that seem to work best for the particular students you have in the classroom."

"[Teaching] strategy overload--you can't do them all (even if they each have merit)." [Referencing multiple instructional strategies.]

"It's all about time... can't do it all when you have 53 minutes, 2-3x per week. Given unlimited time, I'd probably use them all at some point or another during the semester." [Referencing multiple instructional strategies.]

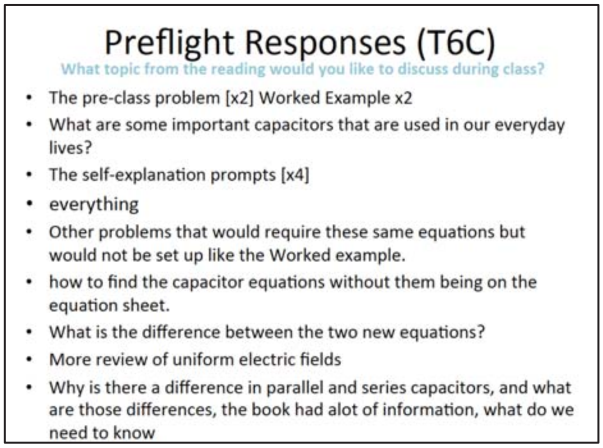
Instructor 7 addressed each concern raised by students in the first preflight question one-by-one. It took about 12 minutes of class time to do this during the beginning of class.

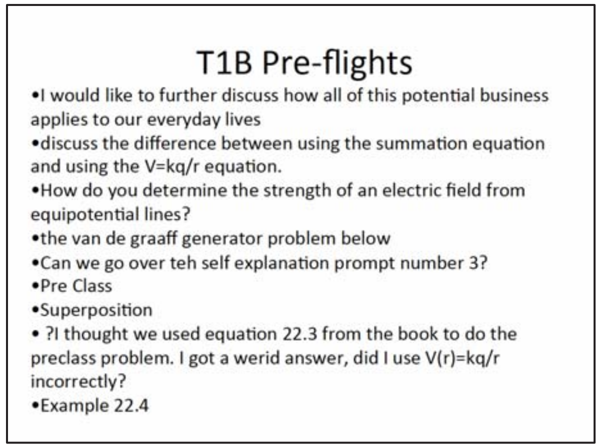
Instructor 15: *"I'd give them a couple minutes to discuss it amongst themselves and then they'd go up [to explain the preflight and Worked Example answers in front of the class]. It took anywhere from about 10 or 15 minutes to get through all the preflights and all the [Worked Example] self-explanation prompts that way. It's obviously much faster to just tell them 'this is the answer.' I go back and forth on whether or not it worked, because all I have is anecdotal evidence."*

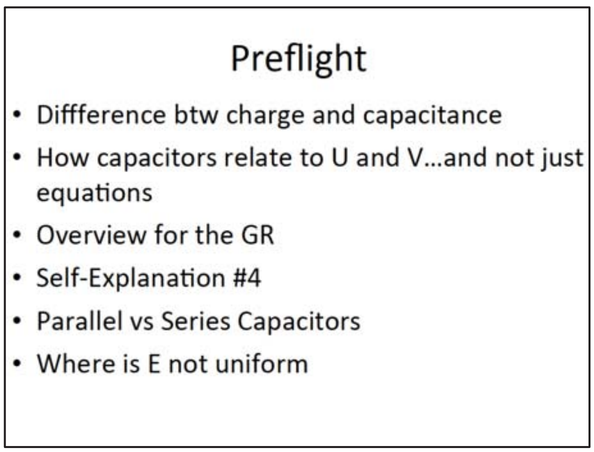
Instructor 22 addressed each concern raised by students in the first preflight question one-by-one at the start of class. It took about 8 minutes of class time to do this

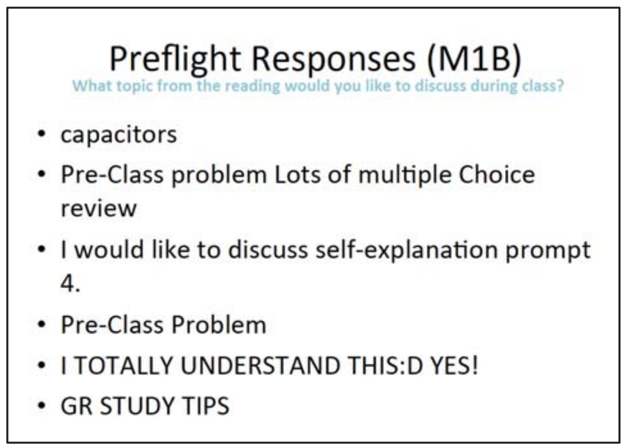
Appendix Q - Sample Displays of First Preflight Question

Electricity & Magnetism Classes









Preflight Responses (M6D)

What topic from the reading would you like to discuss during class?

- I was confused about the relationship between U and V and point charges affecting them in a space.
- Pre-Class Problem. Seriously, how does it work out?
- what is "a" representative of in the equation on pate 390
- Go over electrostatic vs electric V

Lesson 10 Pre-flights

- Some questions on this lesson:
  - I am not sure if I got question 2 right, can we go over it in class?
  - I would like to discuss question 2 in depth
  - Can we talk about the three different current shapes and examples of each
  - I'm a little confused about line currents

Preflight Responses (M6B)

What topic from the reading would you like to discuss during class?

- Whats a farad?
- Farads and that C looking greek symbol
- Preclass problem!
- Can you elaborate more on working voltage?
- I don't understand the visual representation in the Worked example
- When would the internal elecitric field not be unifrom, if the 2 plates are the saem area.

Lesson 13 Pre-flight review

PF #1

- Electrostatic shenanigans, I'm lost
- the square preflight problem
- The work equation
- The formula was confusing.
- Journal 1

PF #2: **b** *(60% correct)*

PF #3: **a** *(80% correct)*

PF#4: Water molecules

- Dissociate the molecules. Use energy to break them apart.
- Put an electric current through the water and the hydrogen will be attracted to the negative pole of the battery or whatever you use.

Mechanics Classes

Preflight Responses (T1B)

What topic from the reading would you like to discuss during class?

- Why does the coefficient of friction play no factor in the Pre-Class problem even though you still have to push against that total force of block 2.
- Solving problems with kinetic friction and static friction.
- I would still like to practice working with breaking force problems into x and y components. Specifically knowing when to.
- How not to get confused on multiple choice questions.
- A refresher on how to distinguish the difference between mass and weight.
- Objects exerting force on each other.
- Regarding when to add or subtract forces.
- how friction adds into the sum of the forcesWhy is friction not relevant to solving the pre class problem?

Preflight Responses (M1A)

What topic from the reading would you like to discuss during class?

- Pre-Class Problem x14
- Pre-flights
- force exerted from one object to another.
- Worked Example
- I need more help and examples of problems with projectile motion. From lessons 6-8. Also, I need help recognizing our known and unknowns in a prompt that is given for a question
- how to draw the FBD x2
- Friction and how it ties into the equations.
- I would discuss third law pair problems and strategies to solve these problems.
- I would like to review some of the equations in lesson 9

Preflight Responses T1B

- Terminal Speed- How can the net force of an object be equal to zero while it is still falling because of gravity? Is this a result of Newtons third law?
- Differnce between the two coefficeints of friction
- The main difference between static friction and kinetic frictions. I am almost positive there will be a question asking the difference on a GR and the question will be written in a manner that no man will have any idea what the question is asking. I would like to be prepared.
- how friction affects motion
- I would like to discuss example 5.9 and how to incorporate the steering wheel.

Pre-flights

- Normal forces and magnitudes like example two in the preflight; I would like to go over normal forces and how to use them correctly in problems.
- How Netwon's Laws can work in 2-dimensions
- What is the most common mistake made when solving problem in two dimensions?
- More about the angles
- The "got it>" 5.1 question. Also (in the y-direction), If tension on a rope is greater than a the weight of a block block (m*g), does that mean the rope is pulling up the block??
- Pre-class Problem (x3); Pre-Class Problem and another example where we find the acceleration of something tilted; How to solve rope tension problems.
- Is a rolling sphere calculated differently than a frictionless sliding rectangle?
- The Mastering Physics question asking how no force can move a heavy trunk when the force was angled (50 degrees) and when the static friction coefficient was 0.84; Mastering physics problem 3 for lesson 10. I get the idea but I don't know how to prove it using equations.
- More practice with free-body diagrams of objects that are slanted.
- Other examples aside from the book
- I don't know how much more of Newton's Laws I can take.

Non-Core Classes

Lesson 10 Pre-flights

- Some questions on this lesson:
  - I am not sure if I got question 2 right, can we go over it in class?
  - I would like to discuss question 2 in depth
  - Can we talk about the three different current shapes and examples of each
  - I'm a little confused about line currents

Something interesting about HAARP?

- I think its interesting that people are allowed on site with no security clearance
- It would be expensive to make the site compliant with the Clean Air Act, so the Air Force is considering shutting it down
- Found that low frequency radio waves can be generated by modulated heating of the auroral electrojet, useful because generating VLF waves ordinarily requires gigantic antennas
- The Ionospheric Research Instrument is used to temporarily excite a limited area of the ionosphere
- One of the things that I found interesting is that this program is partly funded by the US Air Force and Navy!
- I found it fascinating that people think we could significantly modify the weather to the extent of causing earthquakes. The premise of HAARP is very interesting as well, that we could use the Ionosphere to improve our communication signals.

Lesson 13 Pre-flights

- Some questions on this lesson:
  - why do active regions form?
  - Can you explain why the poles of the sun switch?
  - Could we go over the Butterfly diagram in a little more detail? Some of the terminology for me is confusing.
  - What is Joy's Sunspot Tilt Law? (confused by the reading)
  - How did Hale come up with his law?

What topic or concept from the reading do you want to talk about in class today?

Usually I don't have anything really desired to talk about in class, is it okay if I leave this blank unless I don't understand something? I would like to know if I'm losing points. Thank you!

Is there anything else special that happens when the dew point drops below freezing besides the formation of frozen dew.

I barely see the difference between haze and fog

Condensation Nuclei

Why is upslope fog more prevalent on the east side of the Rockies than the west side?

What is the type of fog that forms after a summer rain? Usually in the evening

identifying between the different clouds in pictures

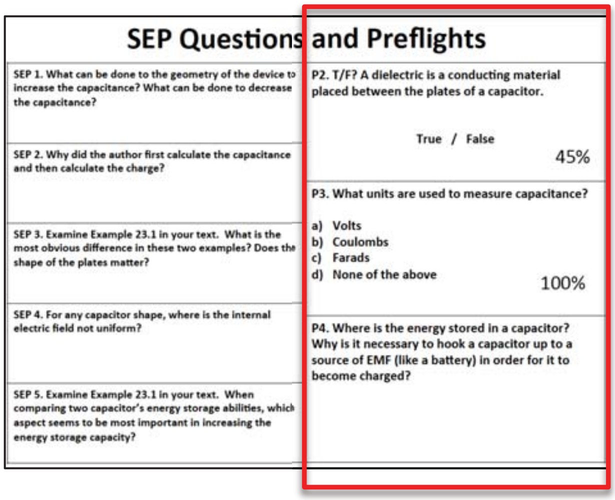
Why are there different types of clouds

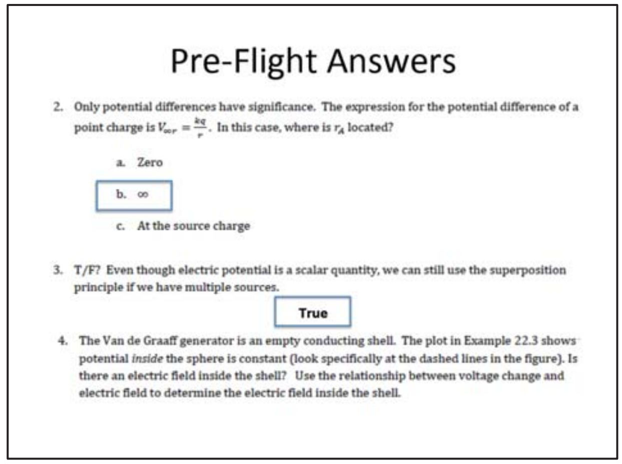
What causes the different types of clouds to form and why at different altitudes

the variables used in the formula on page 124

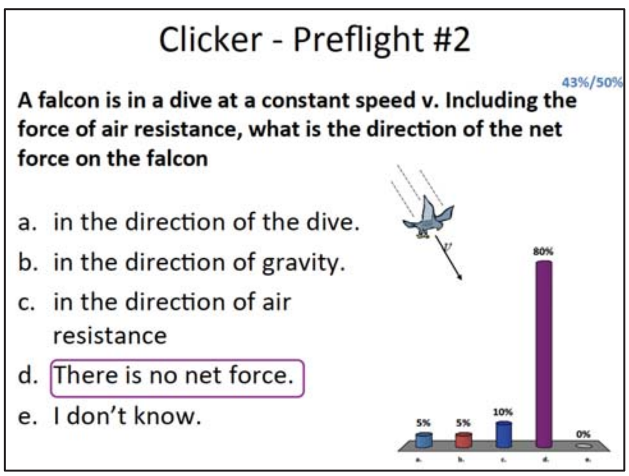
Appendix R - Sample Displays of Other Preflight Questions

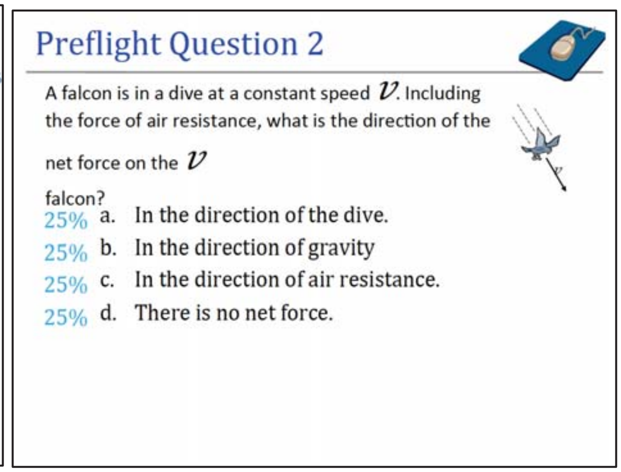
Electricity & Magnetism Classes

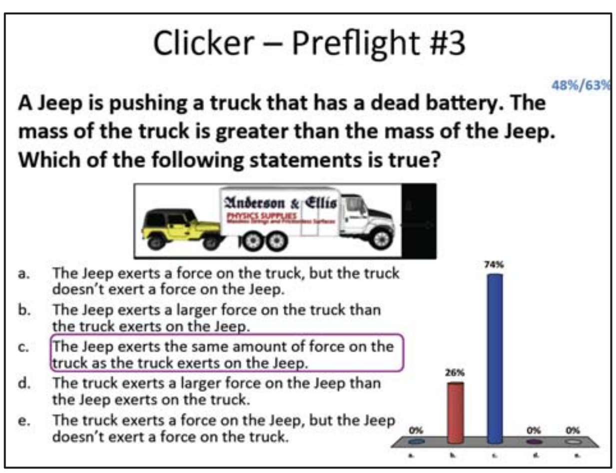


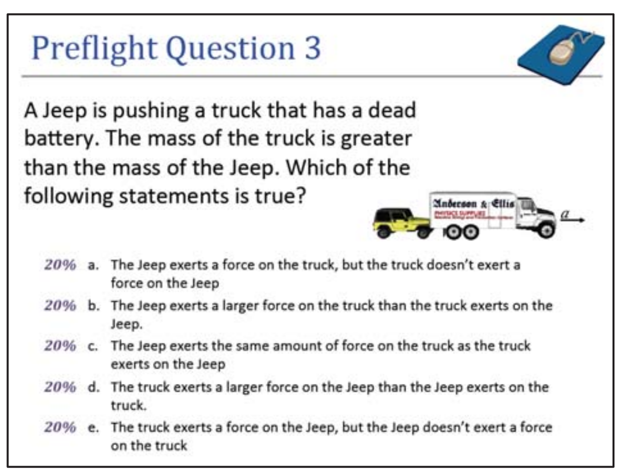


Mechanics Classes









Lesson 10 Pre-flights

- Question 2: Consider the currents that flow during space weather storms. Do you suppose these would usually be thought of as volume, sheet, or line currents? Why?
- Line currents; the volume is not constant
- Sheet:
  - They explode outward with a cross-sectional area but not much depth.
  - It is similar to a sheet expanding from the sun
- Volume:
  - First of all, you always calculate J. Second of all plasma in the atmosphere has 3 dimensions.
  - "currents in space flow in ill-defined structures".
  - Charge can flow in all three during a space weather storm

Lesson 13 Pre-flights

- Question 2: Briefly describe the features of the magnetic "butterfly diagram".

  Your answers:
  - The Butterfly diagram maps the position, time, and magnetic strength of different sun spots.
  - Date vs. latitude, with colors indicating the strength and direction of the magnetic field at that point. Dark curves indicate the path of sunspot drifts.
  - The diagram shows magnetic field strength of the sun over long intervals, which shows the solar cycle and the shifting polarity of the sun

Preflight Questions

2. Dew forms when Earth's surface cools due to ________ and air in contact with the ground cools due to ________

25% a. conduction; convection

25% b. radiation; conduction

25% c. advection; evaporation

25% d. latent heat release; radiation

Preflight Questions

3. Frost forms when

25% a. air near the ground is cooled to the dew

25% b. the dew point is less than the freezing te

25% c. deposition occurs.

25% d. All of the above are correct.

Appendix S - Examples of Coded Student Data: Class Preparation

Preflights Help

"They definitely help me feel better prepared than in other classes that don't use preflights."

"I do think that they are really helpful, especially for concept questions on [test]s, quizzes, etc."

"I think the preflight questions combined with the pre-class problem(s) are an adequate amount of preparation for class."

"The first question which asks what we would like to discuss is always helpful because I can put down any question I have before class and my teacher will most likely go over it in class."

"[P]reflights really just get you prepared for the lesson material in the next physics class."

"[Preflights] help you focus on the concepts to be talked about next class."

"Honestly, preflights help me a lot with my physics learning experience…I genuinely feel that preflights help me understand more during class."

"I personally find Preflight pretty helpful as a recap."

"Honestly I find that the few basic concepts in the few questions is a good way to conduct preflights. I am able to dip into the concept without having to fully understand it. This shows me what I need to ask my instructor during class and what concepts do not make sense to me naturally."

"They generally are fairly good as an indicator of students' knowledge, especially if a number of students get a preflight wrong; it gives the instructor feedback on how/what they should teach."

"I believe that pre-flights are a good way for a teacher to see if their students understand the topic or not."

"I think the preflight assignments are helpful. I enjoy the fact that the preflight questions aren't too specific in Meteorology 320. They make sure you understand the concepts from your reading."

Preflights Do Not Help

"The preflight questions are good conceptually, but since there is no math involved, the help towards being able to solve that type of problem is minimal."

"The preflight assignments are just too easy for the material that is covered in class. If they covered ideas relating to the same topic but were more difficult conceptually they would be more helpful."

"Questions 2 and 3 are usually too easy (conceptual)."

"I just can't see them as that important or helpful to my general understanding of Physics."

"My first physics teacher never went over them so I never got anything out of them."

"Pre-flights for physics are not conductive [sic] to my learning behavior but that does not mean it doesn't help other people more than me."

"To be honest I do not find them helpful. To be fair the poor preflight though, it is not entirely its fault for being so

useless. The fact that it is based off probably the worst textbook I have ever been forced to use definitely does not help."

"The online preflight isn't much value either. I focus on the [Worked] [E]xample and [back-of the chapter] problem."

"The questions asked as well as our preclass homework is either way too easy like V=Er or extremely difficult. They don't help me with of the [multiple choice] questions. I wish we could go over the problems in depth."

"[T]he questions they ask are often too simple or too deep to warrant much attention."

Students Read Textbook

"Preflights are usually helpful in the aspect that they give me an idea if I am understanding general concepts of what I just read."

"I think the preflight system is effective in accomplishing it's goal of encouraging students to do their readings and homework questions."

"[T]hey are really hard to do when you have no idea about the material and have actually tried to read and learn it."

"[T]he readings are typically very confusing and normally leave me more confused or not sure where to start on a problem."

"I seem to struggle with them most of the time because I have trouble reading the textbook and producing answers."

"I rarely understand the concepts from reading the book, and just end up being confused."

"Put the reading from the textbook in simpler terms. I don't understand the reading so it's hard to understand the pre-flight."

"I think preflights are beneficial to learning the concepts, because they guide what I look for in the reading."

"I'd say it depends on how well you teach yourself the material from the reading or how well it sticks with you after the initial revealing. If you don't know what the book is talking about, the pre-class problem seem impossible, and if you do then it's too easy."

"Sometimes the pre-class reading does not follow the preflight very well because usually the reading goes into more depth than the preflight."

"Reading the book can sometimes guide me in the right direction but not always."

"[E]very time after I read the book I would ask [the tutor] for clarification."

Students Do Not Read Course Materials

"As it is now, we can guess and get it right without doing the reading."

"The book is very hard to read and often misguides me. I don't like to sit down and try to understand it before class because I might come to a wrong conclusion about something."

Appendix T - Examples of Coded Student Data: Views of Instructor Implementation of JiTT

Favorable Implementation Feedback

"The first question which asks what we would like to discuss is always helpful because I can put down any question I have before class and my teacher will most likely go over it in class."

"I learned from [preflights], but only after my teacher explained it."

"My physics 215 teacher goes over each question and explains them."

"Most of these preflights focus on asking us how we handled the preclass work, which is great. Then the teacher knows what to focus on."

"I believe my teacher does an excellent job with the preflights and discussing them in class."

"It is usually in class, when my instructor explains the problem and shows examples, that I understand the concepts."

"My teacher tries to base the class off of pre-flight responses. The first question, here is what you would like to go over in class? [She/he] makes that mandatory."

"[Displaying student responses] is good because then you can see the different ones that you relate to and you know that you're not the only one struggling with that."

"[M]y instructor does an awesome job. I'll say this guy, he goes and posts up some of the comments, some of the key things from the pre-flights and I think that's awesome for that. We usually say, 'Okay, we're going to go over this,' but I know I've had instructor in the past where you know they've looked at it, or they've got a printed out sheet of it. They're walking around, 'Oh, so you understand this now?' It's not as genuine as having the actual connect feedback up there back up there on the board. I really like that."

Unfavorable Implementation Feedback

"Encourage the instructors to read over pre-flight responses in order to tailor the lesson to what the students don't understand from the reading."

"If the teacher went over the questions more, then I would be less confused."

"Well, in my case, I feel like I do the preflights but my teacher just scans over my physics journal quick enough to see if I did it so I really don't know if I am right or not and a lot of them are concept questions where the answers are written out and I am not sure if I understand even after he goes over worked out problems on the board."

"The only essential thing about the preflight is where we can 'anonymously' let our teacher know we are having difficulty with something."

"It would be more beneficial if the teachers spent more time incorporating them into the lesson and going over the correct answers."

"My physics 215 teacher goes over each question and explains them. If we are going to be forced to do them every night then I would like to go over them in class every day."

"Some teachers only [know] how the preclass stuff and no other types of problems in class. It makes it very hard to learn."

"[A]lthough your questions ask if my teacher is actually talking about and using the preflight, she/he does NOT use it in a way that is helpful."

"The set up of the preflight could be incredibly helpful if the teacher would actually review the questions in class. Right now, there is no way for me to know if I got the questions correct and if my explanations were correct because my teacher doesn't review them in class."

"[I]t would be good if [the critical thinking preflight exercise] was either easier or the instructor worked through it with the students."

"We don't really go over stuff when we have labs. Normally [my instructor] is really good about going over it, but I know there have been, like the first lab we did. I messed something up in my pre-flight. I was lost the entire lab, and I had no idea what was going on because everybody else took control in the group. I was like, 'I have no idea what's going on.' We didn't go over [the pre-flight] and I didn't know what I did wrong."

Preflight Connections to Lessons Topics and/or Readings

"The preflight questions could be more connected to the textbook."

"The preflights would be more useful if they were more clearly connected to what was taught in the book."

"[E]very once in a while there will be something seemingly somewhat unconnected questions."

"Just make them more related to the material. Sometimes it's hard to figure out the connections by myself."

"Preflight questions could be improved by making them a couple questions longer to connect more to the reading."

"[Preflights] often make seemingly vague connections."

"Primarily, a focus more on connecting the factual data (formulas, procedures, etc) and their conceptual counterparts (this problem requires solution X)."

"I do the preflight assignments however often go into the next class and do not feel a connection between the two. I have questions about the lesson going in from doing the preflight, but often end the class with the same questions."

"Sometimes the pre-flight questions seem to be a little out of the blue and not all that related to the specific learning objectives."

"If the instructor brought up a direct correlation to how they apply to our next lesson."

"My instructor will then go over the preflight questions in class but not explain other types of problems on the same subject matter."

"Ensure that the preflights actually relate, particularly to the pre-class problems, as sometimes those are totally different and unhelpful in trying to solve them."

"In some instances, the preflight questions do not even seem to be related to what we are doing."

Appendix U - Concept Inventory Scores for Core Courses

Conceptual Survey of Electricity & Magnetism

Physics 215: Regular Electricity & Magnetism

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Points earned on Concept Inventory Pretest	177	1	12	6.16	2.350	5.520
Concept Inventory Pretest (%)	177	3	38	19.24	7.342	53.909
Points earned on Concept Inventory Posttest	172	0	11	5.91	2.222	4.939
Concept Inventory Posttest (%)	172	0	34	18.46	6.945	48.229
Valid N (listwise)	158					

Conceptual Survey of Electricity & Magnetism

Physics 215H: Honors Electricity & Magnetism

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Points earned on Concept Inventory Pretest	82	1	12	6.51	2.420	5.858
Concept Inventory Pretest (%)	82	4	38	20.73	7.227	52.234
Points earned on Concept Inventory Posttest	81	2	12	6.12	2.204	4.860
Concept Inventory Posttest (%)	81	6	38	19.14	6.889	47.457
Valid N (listwise)	79					

Force Concept Inventory

Physics 110: Regular Mechanics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Points earned on Concept Inventory Pretest	53	3	21	10.25	4.000	15.996
Concept Inventory Pretest (%)	53	10	70	34.15	13.332	177.737
Points earned on Concept Inventory Posttest	51	5	24	13.45	4.536	20.573
Concept Inventory Posttest (%)	51	17	80	44.84	15.119	228.584
Valid N (listwise)	50					

Force Concept Inventory

Physics 110H: Honors Mechanics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Points earned on Concept Inventory Pretest	53	6	30	18.70	6.716	45.099
Concept Inventory Pretest (%)	53	20	100	62.33	22.385	501.105
Points earned on Concept Inventory Posttest	55	11	30	23.89	4.744	22.506
Concept Inventory Posttest (%)	55	37	100	79.64	15.814	250.071
Valid N (listwise)	53					