HIGH SCHOOL STUDENTS' PHYSICS EPISTEMOLOGICAL BELIEFS

by

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DEDICATION

I dedicate this to my husband, Dr. Brian Mark Schwab, for putting up with all the long nights with class online, the weekends away when I had to travel, and all of the events I had to miss. Without your support and encouragement, this would not have been possible. Thank you and I love you.

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Under the direction of KAREN W. SWANSON, Ed.D.

This study was conducted to examine the extent to which high school students' physics epistemological beliefs varied from the beginning of the semester where they had no physics instruction and after 11 weeks of high school physics instruction. A correlational study was conducted in the fall of 2017 at an urban high school in southeastern Pennsylvania. Fifty-two students completed the Colorado Learning Attitudes about Science Survey (CLASS) before any physics instruction. The CLASS was also completed by the same students after 11 weeks of high school physics instruction. Scores were evaluated on a 1 to 5 scale, ranking students' physics epistemological beliefs on a novice-to-expert continuum.

Data was analyzed with a repeated measures ANOVA. A statistical significance was found between the overall pretest and posttest scores. All of the mean scores for the posttests were higher than the pretests, showing that physics epistemological beliefs became more expert-like with more physics instruction. Overall, none of the controlling factors were influential. In terms of the controlling variables, gender, grade level, and GPA had no statistical significance on any category of the CLASS. Ethnicity was statistically significant in the Personal Interest category and socioeconomic status statistically impacted the Problem Solving Sophistication category. Small to medium effect sizes were observed throughout the study. Results from this study demonstrated that high school students' physics epistemological beliefs can become more expert-like in high school after traditional physics instruction. However, further study on high school students' physics epistemological beliefs is necessary.

CHAPTER 1

INTRODUCTION TO THE STUDY

"Good physics education is the backbone of a first-class workforce in science, technology, engineering, and mathematics," said Toufiq Hakim (American Institute of Physics, 2007). Society, as well as students' futures, are dependent on a good physics education. A good physics education begins the moment students enter their first physics course due to the instruction they experience. While physics educators have disagreed as to what the focus of high school physics instruction should be, they have agreed that physics should not just be about memorizing formula and solving problems (Otero & Meltzer, 2016). During to students' first formal physics class in high school, students will develop beliefs regarding physics due to their experiences. It is important to determine what those beliefs are and how they change during and after physics instruction.

Since its inception into the high school curriculum in the mid-1800s, high school physics has evolved. While it was initially added to the high school curriculum to provide information about everyday things, it has transformed throughout time. During certain periods, high school physics curricula had a stronger mathematical focus; during other times, it was more relevant, relating to everyday life. Ultimately, the focus of high school physics curricula has changed over time, due to current events or different groups' intentions. Although the focus of high school physics has changed, what has not changed is the perception about physics: difficult and abstract (Adeyemo, 2010).

Beliefs are conclusions that people draw from their perceptions and their experiences (Furinghetti & Pehkonen, 2002). The beliefs people have can change when people are presented with conflicting experiences. People's beliefs are important because they influence motivation and behaviors. In addition, people make choices based on the beliefs they have constructed from their experiences.

While people have many beliefs, this study focused specifically the beliefs students construct based on their experiences relating to knowledge. These beliefs are called epistemological beliefs. Epistemological beliefs are beliefs about knowledge and knowing (Hofer, 2004). According to Muis, Bendixen, and Haerle (2006), students' beliefs about knowledge and knowing can be general, domain-general, and domain specific. General epistemological beliefs are broad beliefs students have about knowledge and knowing. In contrast, students also construct beliefs about particular content areas, like science, which are called domain-general epistemological beliefs. More specifically, within content areas, students also form domain-specific epistemological beliefs. According to Whitmire (2003), "the connection between various background characteristics, such as gender, socioeconomic status, and disciplinary differences, and epistemological beliefs are useful avenues for further exploration" (p.140). Therefore, this research study examined the domain-specific epistemological beliefs of students relating to physics when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA.

These domain-specific epistemological beliefs are called physics epistemological beliefs. Physics epistemological beliefs are beliefs that students construct about what knowledge is and how knowledge is formed in physics (Kortemeyer, 2001). Hammer

(1994) breaks down physics epistemological beliefs into three categories: structure of physics knowledge, physics content knowledge, and the process of learning physics. Furthermore, physics epistemological beliefs are differentiated on a continuum from novice to expert-like. Physics epistemological beliefs are important because they describe how students perceive knowledge and knowing in physics. As students acquire more knowledge through experiences, their epistemological beliefs tend to become more sophisticated. Thus, physics education needs to include experiences that will assist in fostering the development of physics epistemological beliefs with the ultimate goal being epistemological sophistication.

Conceptual Underpinnings of the Study

Epistemological beliefs have been the focus of many studies over the last few decades. Because of the importance of epistemological beliefs, many researchers have developed epistemological belief models. Some models were based on overall epistemological beliefs, stating there were no contextual or content differences. However, more recent models acknowledge contextual and content differences. For example, Hofer and Pintrich's (1997) model focuses on the nature of knowledge and sources of knowing while acknowledging content and contextual differences. They categorized epistemological beliefs into four different areas: certainty of knowledge, simplicity of knowledge, the sources of knowing, and the justification of knowledge.

As more knowledge was acquired about epistemological beliefs, researchers determined that in addition to general epistemological beliefs, there are domain-general and domain-specific epistemological beliefs. Domain-general epistemological beliefs are categorized by their content area. For example, sciences were defined as hard and applied whereas social sciences were described and being soft and pure (Jehng, Johnson, & Anderson, 1993; Paulsen & Wells, 1998). Those researchers both surmised that students' epistemological beliefs in hard fields tended to be more fixed and novice-like as compared with soft fields where epistemological beliefs were more expert-like.

Besides domain general epistemological beliefs, there are also domain-specific epistemological beliefs (Kienhues, Bromme, & Stahl, 2008). These are beliefs that individuals form about particular subject areas. Domain-specific epistemological beliefs have more variability due to the context (Gill, Ashton, & Algina, 2004). Because the context is different for each subject, students develop different epistemological beliefs in different subject areas.

Physics epistemological beliefs are domain-specific epistemological beliefs relating to physics knowledge and how physics knowledge is constructed. Hammer (1994) categorized these beliefs into three categories: the structure of physics knowledge, the content of physics knowledge, and the process of learning physics. Students can have physics epistemological beliefs that range on a continuum from novice to expert. Novices view knowledge as fragmented and incoherent whereas experts perceive knowledge as related and coherent (Gray, Adams, Wieman, & Perkins, 2008; Larkin, McDermott, Simon, & Simon, 1980; Larkin, 1983). In order to determine physics epistemological beliefs, typically interviews or surveys are used.

Many different surveys have been developed to measure general, domain-general, and domain-specific epistemological beliefs. For example, the Schommer Epistemological Beliefs Questionnaire (EBQ) measures general epistemological beliefs, the Views about Science Survey (VASS) measures domain general epistemological beliefs, and the

Maryland Physics Expectations Survey (MPEX) measures physics epistemological beliefs. Most recently, however, the Colorado Learning Attitudes about Science Survey (CLASS) was developed to measure physics epistemological beliefs. It has a wider applicability as well as more generalized statements relating to physics, as compared with previous surveys.

The Colorado Learning Attitudes about Science Survey has been administered in hundreds of classes at the collegiate level. Many researchers found that with traditional instruction, physics epistemological beliefs declined over the course of the semester, becoming more novice-like. However, other researchers determined, with reformed pedagogies, college students' epistemological beliefs became more expert-like. Other researchers detected no shifts in physics epistemological beliefs after a semester of physics instruction.

There are only two studies done on physics epistemological beliefs of high school students. However, Zhang and Ding (2013) examined Chinese students in grades 8 through 12 and found results like those in college; with traditional instruction, students' physics epistemological beliefs became more novice-like after a semester of instruction. Marusic and Slisko's (2012) results also corroborated collegiate studies regarding reformed pedagogies; with reformed pedagogies, students had more expert-like physics epistemological beliefs. Neither of these studies began at the beginning of the school year. In addition, neither of these studies examined how socioeconomic status, ethnicity, or GPA were factors. Although these studies did utilize the CLASS to examine high school students' physics epistemological beliefs, these studies did not examine all the covariates nor the timeframe in which the researchers conducted this study. Both high school studies will be discussed in detail in Chapter 2.

Statement of the Problem

The knowledge acquired from studying physics in useful in many contexts. Not only is the physics content knowledge important, but so are the skills that students form during their physics studies. According to the National Alliance of Black School Educators (2012),

> Physics is a gateway course for post-secondary study in science, medicine, and engineering, as well as an essential component in the formation of students' scientific literacy. Physics classes hone thinking skills and help to polish the skills needed to score well on the SAT and ACT. Knowledge of physics is helpful for understanding the arts, politics, history, and culture (para. 1).

Therefore, the content and skills learned in physics becomes crucial to many students' futures. While physics content is important, the beliefs and skills that students form during their study of physics become useful in the future, regardless of their college major or career.

The good news, according to American Institute of Physics, is that "nearly 40% of high-school students take physics" (White & Tesfaye, 2014). However, the bad news is after that first physics course, "only around 3% of students who take that first course go on to take another class" (Orzel, 2015). This means that over 1/3 of students take physics in high school but when given the choice, they will not take another physics course. Slaughter, Bates, and Galloway (2011) suggested a reason for the decline in enrollment: negative beliefs formed in high school towards a subject many times predict that students will not pursue that field of study. Thus, the experiences students have in high school physics cause them to form certain beliefs. However, other factors, such as gender, grade/age, ethnicity, socioeconomic status, and GPA may also influence the choice to continue in physics. Because students' choices are influenced by prior experiences and beliefs, it is important to know what beliefs students form regarding physics.

Physics epistemological beliefs are beliefs students form about physics knowledge and how it is acquired. Previous studies have shown that over the course of a semester, physics epistemological beliefs change. While some studies have shown more expert-like beliefs after a semester of physics instruction, other studies have shown more novice-like beliefs. Better understanding students' epistemological beliefs is important because they influence students' motivation and behavior (Buehl & Alexander, 2001; Garner & Alexander, 1994). While these beliefs are not the only factors that will predict students' future course selection and possible college major, they are significant.

Zhang and Ding (2013) acknowledged there is little data about physics epistemological beliefs prior to college. Thus, there is little information as to what beliefs students form during or after their first high school physics class. Physics majors form their expert-like epistemological beliefs during their K-12 education (Madsen, McKagan, & Sayre, 2015). Therefore, physics epistemological beliefs of high school students, and the factors that could affect them are important and require more research.

Purpose of the Study

The purpose of this study was to determine the extent to which high schoolers' physics epistemological beliefs varied from the beginning of high school physics and after 11 weeks of high school physics instruction. This study also provided information about the influence of gender, grade/age, ethnicity, socioeconomic status, and GPA on those shifts in high school students' physics epistemological beliefs. Because domain-specific epistemological beliefs start developing in secondary and postsecondary education, the determination of the beliefs of high school physics students, as well as if certain factors influence them, becomes important (Muis, Trevors, Duffy, Ranellucci, & Foy, 2016).

Because this study determined that physics epistemological beliefs of high school students become more expert-like, then the type of instruction utilized in this high school physics course should be studied in other high school physics courses. Additionally, this study provided information as to regarding gender, grade/age, ethnicity, socioeconomic status, or GPA and their association with physics epistemological beliefs. While these results may not be broadly generalizable, they may provide areas for further study in terms of high school students' physics epistemological beliefs and the factors that influence them.

Research Questions

There were nine research questions for this study. The first research question addressed the significance between the overall scores of the CLASS from the beginning of the semester to the end of the semester when controlling for gender. grade/age, ethnicity, socioeconomic status, and GPA. Each subsequent question related to the different sections of the CLASS comparing the scores at the beginning of the semester and after 11 weeks of physics instruction when controlling for gender. grade/age, ethnicity, socioeconomic status, and GPA. The research questions were:

1. To what extent do overall pretest/posttest scores differ as measured by the CLASS when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
2. To what extent do pretest/posttest scores in the Real World Connections category of the CLASS differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
3. To what extent do the pretest/posttest scores in the Sense Making/Effort category of the CLASS differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
4. To what extent do the pretest/posttest scores in the Personal Interest category of the CLASS differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
5. To what extent do the pretest/posttest scores in the Conceptual Understanding category of the CLASS differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
6. To what extent do the pretest/posttest scores in the Applied Conceptual Understanding category of the CLASS differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
7. To what extent do the pretest/posttest scores in the Problem Solving General category of the CLASS differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?

8. To what extent do the pretest/posttest scores in the Problem Solving Confidence category of the CLASS differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
9. To what extent do the pretest/posttest scores in the Problem Solving Sophistication category of the CLASS differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?

Effect Size

For each of the research questions listed above, the researcher predicted a medium effect size. The researcher made these predictions based on previous studies as well as the sample size. With a medium effect size, the researcher believed that a correlation would be observed between the covariates of gender, grade level/age, socioeconomic status, ethnicity, and GPA and high school students physics epistemological beliefs.

Limitations

The focus of this study was to compare physics epistemological beliefs of high school students from the beginning of the course and after 11 weeks of high school physics instruction. Physics epistemological beliefs in this study were measured by using the CLASS; one limitation of this study due to its predetermined questions and categories. The researcher chose students at an urban high school in southeastern Pennsylvania because they were a convenient sample, which meant that results may not be the same in different settings. Another limitation of this study was the students signed up for physics during the 2017-2018 school year, thus limiting the sample size initially, limiting the generalizability. Additionally, because standardized tests commenced in December, this limited the amount of time for the study, which could have influenced results. This correlational study examined the statistical relationships between physics epistemological beliefs and the covariates of gender, grade level/age, socioeconomic status, ethnicity, and GPA, all factors the researchers believed could be related to physics epistemological beliefs. Furthermore, threats to internal validity for a correlational study include: history, maturation, and testing effects. All of these are limitations because they could have influenced students' physics epistemological beliefs.

Delimitations

Although students typically are exposed to physics concepts prior to high school, students' first formal experience with physics typically occurs in high school. From that experience, students refine their beliefs about physics. These beliefs influence students' future choices. Therefore, the beliefs that students form during that first experience are important. Furthermore, students have other factors that could influence those beliefs. Thus, this study examined high school students' physics epistemological beliefs utilizing the CLASS when controlling for factors such as gender, grade/age, ethnicity, socioeconomic status, and GPA

The current study was confined to physics epistemological beliefs of high school juniors and seniors in an urban high school in southeastern Pennsylvania. While students do have domain general epistemological beliefs about science, and other domains within science, those beliefs were not examined in this study.

Assumptions

It was assumed that students who participated in this study will have not had a full year of high school physics instruction prior to this class, due to the scope and sequence of science in this southeastern Pennsylvania school district. It is also assumed, due to following the Pennsylvania State Standards for Science and having the same teacher, that students will receive the same instruction, and thus similar experiences in high school physics (Pennsylvania Department of Education, 2002). It is assumed that students will not receive any other formal instruction in physics outside of the high school physics classroom because of the structure of high school students' schedules.

To measure students' physics epistemological beliefs, students who took physics in the fall 2017 were administered the CLASS. Because the CLASS is a Likert-scale survey, it was assumed that students will answer truthfully since it was given anonymously through the computer.

Possible threats to internal validity could have existed if students talked with each other while answering survey questions on the CLASS. Therefore, the survey was administered during the school day, and on the same school day, to all students taking high school physics. Furthermore, students were monitored during the administration to ensure their focus was on answering the survey questions to the best of their ability. Students were given as much time as needed to answer the questions and did not speak with the physics teacher during this time.

Ethics

The researcher's role in this study was to compile and analyze the data. The research was conducted at the high school where the researcher teaches. Because the initial data collection was prior to any formal physics instruction, the researcher expected initial physics epistemological beliefs to be novice-like. However, after a semester of physics instruction, the researcher hypothesized that physics epistemological beliefs would become more expert-like. Additionally, the researcher believed that the covariates of gender, grade level/age, socioeconomic status, ethnicity, and/or GPA could be correlated to physics epistemological beliefs; however, the researcher was unsure how these factors would influence physics epistemological beliefs of high school students.

Researcher Bias

The researcher has been teaching physics since 2002 at the high school where the study was conducted. While the researcher has made observations about students' beliefs regarding physics, the researcher has not conducted formal research regarding high school students' physic epistemological beliefs. The researcher has chosen to quantitatively determine if the covariates of gender, grade level/age, socioeconomic status, ethnicity, and GPA are correlated to physics epistemological beliefs. Although only quantitative data was examined, the researcher's potential bias could have been interjected. However, by using a survey that the students answered anonymously online, the researcher cannot identify students' responses. It was assumed that no one was singled out for answering truthfully, and thus, scores best reflected students' physics epistemological beliefs.

Design Controls

The hypothesis was that after a semester of high school physics instruction, students' physics epistemological beliefs would become more expert-like. All students received the same physics instruction during high school physics due to the requirements set forth in Pennsylvania State Science Standards (Pennsylvania Department of Education, 2002). High school students' physics epistemological beliefs were measured in relation to the covariates of gender, grade level/age, socioeconomic status, ethnicity, and GPA.

Data was collected as students enter physics in the fall 2017, in the form of a Likert scale survey called the Colorado Learning Attitudes about Science Survey (CLASS). After 11 weeks of high school physics instruction, data was collected again using the CLASS. To test the statistical significance between the beginning of the semester and the end of the semester scores, repeated measures ANOVA was conducted. The repeated measures ANOVA was used to compare overall CLASS scores as well as overall scores in each category of the CLASS controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA. Ancillary results were also conducted to determine what combinations of covariates provide a statistical significance relating to physics epistemological beliefs as measured overall and in each category of the CLASS as well as interactions.

The sample consisted of 52 students taking the first physics course at an urban high school in southeastern Pennsylvania in the fall of 2017. These students chose to take either College Physics or AP Physics 1 offered at this high school. Students received physics instruction from the same instructor based on the Pennsylvania State Standards for Science (Pennsylvania Department of Education, 2002).

Definition of Key Terms

The following terms were deemed important because they related to epistemological beliefs and to the study design used to test the research questions.

1. beliefs- conclusions people form based on perceptions and experiences (Furinghetti & Pehkonen, 2002).

2. general epistemological beliefs- "beliefs about the definition of knowledge, how knowledge is constructed, how knowledge is evaluated, where knowledge resides and how knowing occurs" (Hofer, 2004, p.355)
3. domains- overarching content areas (Alexander, 2002)
4. domain-general epistemological beliefs- beliefs students form about content areas, such as science (Buehl & Alexander, 2001)
5. domain-specific epistemological beliefs- beliefs relating to specific contexts that develop during schooling, particularly in secondary and post-secondary years (Muis et al., 2016)
6. physics epistemological beliefs- beliefs about what knowledge is and how knowledge is acquired in physics (Kortemeyer, 2001)
7. college physics- a heterogeneous group of students that are studying a more conceptual based physics
8. AP Physics 1 - a heterogeneous group of students studying Advanced Placement physics following the requirements set forth by the College Board

Summary

Because epistemological beliefs are influential in students' decisions, it is important to know what they are. Epistemological beliefs can be general, domain-general, or domain-specific. Epistemological beliefs tend to be determined through interviews or survey. This study focused specifically on domain-specific physics epistemological beliefs. The physics epistemological beliefs of high school students were measured by the CLASS. These physics epistemological beliefs that students form due to their physics instruction are important because they affect students' future course selection, major, and ultimately career path. While most previous studies have examined physics epistemological beliefs of college students, this study examined the physics epistemological beliefs that students developed during their first physics course, which tends to be in high school, while controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Beliefs are conclusions that people draw from their perceptions and their experiences (Furinghetti & Pehkonen, 2002). Beliefs are not fixed, but can change when situations cause people to question their existing beliefs. People make decisions based on the beliefs they construct from perceptions and experiences. Thus, because beliefs influence students' behavior, motivation, processing of information, and ultimately learning, they are important to understand and identify (Buehl & Alexander, 2001; Garner & Alexander, 1994).

While students have beliefs about many things, this study will focus on epistemological beliefs. Epistemological beliefs are defined as beliefs about knowledge and knowing (Kortemeyer, 2007). Students possess general epistemological beliefs, domain-general epistemological beliefs, and domain-specific epistemological beliefs concurrently (Muis et al., 2006). General epistemological beliefs are broad beliefs students construct about knowledge and learning. In contrast, domain-general epistemological beliefs relate to academic domains, such as science or history. More specifically, beliefs that are related to a specific subject area, such as physics, are domain-specific epistemological beliefs.

Students acquire knowledge both formally, in school, and informally, outside of school. Students' science knowledge acquisition, and belief development, starts when they begin exploring at a young age. However, students' formal science instruction begins when they first start schooling. During their early years, science tends to be integrated, providing students some information regarding all three domains of science: life science, earth and space science, or physical science. Throughout the early years of instruction, students form general and domain-general epistemological beliefs. However, once students enter high school, science instruction tends to become specialized and it is during these years that domain-specific epistemological beliefs begin to develop. Typically, this is when students encounter their first introductory course in physics.

Physics has been a part of the high school curriculum since the 1800s. Through the decades, however, the focus of physics has changed. What has not changed is the perception of physics. Many students perceive physics as difficult and not relevant because of its abstract nature (Adeyemo, 2010). Students' perceptions of physics have large implications. Students' beliefs that physics is a difficult subject has affected the enrollment and performance of students in physics (Bamidele, 2004). Therefore, it is important to determine what beliefs students construct regarding physics.

While students' first course in physics tends to be in high school, students form beliefs about physics even prior to having their first formal physics course in high school. Therefore, students enter high school physics with domain-specific epistemological beliefs. Kortemeyer (2007) defined these domain-specific epistemological beliefs as physics epistemological beliefs. Physics epistemological beliefs are related to what physics knowledge is and how it is acquired. Students' physics epistemological beliefs can influence learning, motivation, and behaviors and therefore, are important.

To examine high school students' physics epistemological beliefs, the researcher will utilize the Colorado Learning Attitudes about Science Survey (CLASS). The

CLASS is a Likert-scale survey where students' self-report their physics epistemological beliefs. The CLASS has been used with many students prior to this study. While most of the administrations of the CLASS have been in collegiate settings, a few studies outside of the United States have utilized the CLASS in high school settings to determine physics epistemological beliefs.

History of Physics Education

The first version of physics in high schools was natural philosophy. The purpose for its integration into the high school curriculum was to provide factual information about everyday things. This pedagogical goal, of accumulating factual knowledge, continued into the 1860-1870s. Physics instruction during that time involved primarily lectures and textbooks

During the 1880s, the purpose for physics changed from learning the facts to training the mind to think different ways. To do this, instruction became more laboratory-based and inductive in nature. That type of pedagogy was favored because it was believed to foster observational skills and reasoning. Laboratory focused instruction continued through the 1890s. In 1893, the Committee of Ten concurred that laboratory was the best means of physics instruction, because they believed through that type of physics instruction, students also obtained mental fortitude and moral rectitude (Rudolph & Meshoulan, 2014).

In the early 1900s, physicists got involved with high school physics because they claimed that physics instruction was not up-to-par. They declared changes needed to be made to improve the quality of physics instruction. Due to their intervention, physics instruction became formalized and was highly mathematical. Textbooks changed to include more quantitative problem solving and abstract conceptual learning to increase the rigor of physics. Laboratory experiments were still conducted but they were prescribed and procedural. The goal for physics was no longer to be relevant, but increase academic rigor.

By 1906, the increase quantitative perspective was waning and the return to a more qualitative, relevant focus increased. The New Movement Among Physics Teachers convened to discuss making physics more interesting and inspiring at the elementary level. Discussion like this occurred in 1908-1909 about high school physics. The outcome of these meetings was a transition back to making physics relevant and interesting. During this transition, the project method also emerged to relate physics to students' lives. These goals were reiterated by the National Education Association (NEA) Commission on the Reorganization of Secondary Education in 1918. They stated the goal for science was to produce scientifically literate citizens, because it was necessary for national strength and economic and intellectual well-being. They declared that high school physics classes needed to inspire students through experimentation, and through that type of instruction, lives would be transformed.

Between the 1920s and the 1940s, physicists disappeared from discussions about high school curriculum. This allowed high school science teachers to take ownership of physics curricula. Teachers deemed practical physics important for students. Textbooks and curricula were written with a focus on uses and applications of physics in everyday life. Furthermore, the scientific method was the designated way for students to learn about physics (Otero & Meltzer, 2016).

As early as 1951, there were concerns about high school physics due to its practical focus. With the launching of Sputnik in 1957, these concerns were pushed to the forefront. Physics instruction changed drastically after Russians launched Sputnik. Not only were federal funds directed into math and science, but again, university physicists got involved with high school physics. They provided training and curriculum development that heavily focused on physics content. “New curricula focused on in-depth conceptual reasoning, investigation, reasoning from evidence, and fundamental unifying principles” (Meltzer & Otero, 2015, p. 452). During this time, the Physical Science Study Committee (PSSC) convened to promote the importance of physics knowledge and reasons why changing the focus of science was important to society. The PSSC concurred with others that physics must focus on teaching fundamental physics principles. Thus, the goal of high school physics during that time was to teach basic, unifying principles.

The content and fundamental approach waned during the 1960s and 1970s. The Harvard Physics Project (HPP) was more humanistic and less technical. The goal of the HPP was to incorporate historical aspects with a humanistic approach while discussing physics concepts. During the 1970s, the goal for physics education was to be more accessible. This became a problem for high school teachers, once again, to solve as money from previous decades disappeared and scientists moved back into their laboratories. Teachers believed that physics needed to incorporate technological and social issues. Teaching methodology during this time allowed for student-choice and decision-making.

During the last twenty years, the diversity of physics courses, such as conceptual physics, Physics First, and Advanced Placement Physics, led to increased physics enrollments. During this time, conceptual physics courses were developed that focused more on concepts and less on math. In addition, Physics First emerged to introduce students to physics concepts earlier in their academic career. Advanced Placement classes were also helping to increase enrollments.

Throughout history, the focus of physics has changed many times. However, there is still dissatisfaction and disagreement as to what should be the focus. However, there is still no consensus as to the best way to teach high school physics. Furthermore, research within the last twenty years suggests that beliefs are influential in learning and motivation. In particular, students' epistemological beliefs, beliefs about knowledge and knowing, affect students' learning in physics.

Epistemological Beliefs

Epistemological beliefs are "beliefs about the definition of knowledge, how knowledge is constructed, how knowledge is evaluated, where knowledge resides and how knowing occurs" (Hofer, 2004, p.355). Epistemological beliefs are not fixed; as the individual gains more knowledge, the beliefs can change. These personalized beliefs about knowledge and knowing can affect an individual's motivations, behaviors, and choices (Vahedi & Yari, 2014). Since epistemological beliefs indirectly influence behavior, it is important to examine students' epistemological beliefs.

Many different models have been developed to describe epistemological beliefs. These models have different applicability as well as stages. Context and content also are also important in some of the models whereas in other models, they are not significant.

Below, in Table 1, is a list of different models including their scope, stages, role of context, and role of content. Epistemological Development Models focus on development of knowledge and the reasoning associated with each stage (Perry, 1970; Belenky, Clinchy, Goldberger, & Tarule, 1986; Baxter Magolda, 1987; King & Kitchener, 2002; Kuhn & Weinstock, 2002). These models do not examine domain differences. In contrast, the System of Beliefs models do acknowledge domain-specific beliefs (Schommer-Aikins, 2002; Buehl &Alexander, 2001). Furthermore, their focus is on "describing the nature, features, and structure of epistemological beliefs from a static viewpoint" (Limon, 2006, p.14). The Personal Epistemological Models are models about epistemological beliefs as being dynamic, based on context and domain (Hofer & Pintrich, 1997; Hammer & Elby, 2002).

Table 1

General Epistemological Beliefs Models

Model Name	Scope	Stages	Role of context	Role of Content
Intellectual and ethical development. Perry (1970)	-how male college students make meaning of their college experiences	1. Dualism 2. Multiplicity 3. Relativism 4. Commitment within relativism	-how students responded differentially to intellectual and social environments in college	-does not consider domain differences
Women's ways of knowing	-interviewed women in colleges or human services agencies	1. Silence 2. Received Knowledge	-discussed education but also personal experiences-	-does not consider domain differences

Table 1 - continued

Belenky et al. (1986)		3. Procedural knowledge- either connected or separate	different questions based on the situation	
		4. Constructed knowledge		
Development of epistemological reflection Baxter Magolda (1987)	-applies to academic learning sphere- specifically college	1. Absolute knowing 2. Transitional knowing 3. Independent knowing 4. Contextual knowing	-linked to personal experiences of learning and instruction	-does not consider domain differences
The reflective judgement model King and Kitchener (2002).	-discusses reflective reasoning from late adolescence to adulthood-not only applicable in academic areas but others also	1. Pre-reflective thinking 2. Quasi-reflective thinking 3. Reflective thinking	-does not consider differences	-does not consider domain differences
Development of epistemological understanding Kuhn and Weinstock (2002)	-valid in different areas-not just academic -epistemological understanding from child to adult	1. Realist 2. Absolutist 3. Multiplist 4. Evaluativist	-does not consider contextual differences	-possible differences with domains relating to personal preference
Epistemological belief system Schommer-Aikins, (2002)	-independent beliefs about knowledge and learning	-no specific stages-beliefs asynchronous	-just general epistemological beliefs	-general measure-not specific to learning context

Table 1 - continued		-mature beliefs lead to higher order thinking	-beliefs independent of each other and difficult to change	
Beliefs about academic knowledge Buehl and Alexander (2001)	-individuals beliefs relating to knowledge and learning in academic settings	-different stages due to different domains	-domain general and domain specific beliefs exist	-multilayered so potentially context dependent
Personal epistemology Hofer and Pintrich (1997)	-how individuals perceive knowledge and knowing- not just academic	-develops over time 4 areas 1. Certainty of knowledge 2. simplicity of knowledge 3. source of knowledge 4. Justification of knowledge	-knowledge and knowing is contextual and activated certain ways	-depends on discipline- both domain general and domain specific
Epistemological resources Hammer and Elby (2002)	-applies to science learning- academic contexts	-not stages-novices and experts -resources required to move to expert	-different contexts different epistemological beliefs	-domains academic disciplines then content dependent also

Summary of General Epistemological Belief Models

Various frameworks describing epistemological beliefs have been developed. The Perry (1968, 1970) scheme examined male university students' ideas about knowledge and learning, and how they changed with more education. The women's ways of knowing framework examined the perspectives of women from diverse backgrounds. Building upon prior frameworks, Belenky, Clinchy, Goldberger, and Tarule (1986), differentiated two orientations within procedural knowledge. In the Epistemological Reflection Model, Baxter Magolda (2002) examined different genders' epistemological beliefs and found while both genders had similar developmental patterns, males and females had different ways of knowing. The Reflective Judgement framework examined intellectual tasks during open-ended problem solving. King and Kitchener (1994) described stages that develop during reflection. In Schommer-Aikins's (2002) epistemological beliefs system, there are not distinct stages and beliefs are not context specific. Most of these models have distinct stages individuals traverse through during their lives. However, these models do not acknowledge domain differences and how or if they influence beliefs differently.

In contrast, other models profess that there are domain differences. Kuhn and Weinstock's (2002) epistemological framework described how epistemological beliefs are theories-in-action. These theories-in-action originate from personal preferences, which are domain dependent. Buehl and Alexander (2001) stated domain general and domain specific beliefs do exist. Furthermore, people can be in different stages at different times due to particular contexts. Hofer and Pintrich (1997) also believed that epistemological beliefs depend on the discipline but they outline specific areas under which they categorize epistemological beliefs. Hammer and Elby (2002) developed the epistemological resources model specifically for science. Their model also does not define stages, but rather outlines the progression from novice to expert and is also context dependent. Although these differing models and frameworks varied in terms of participants and views, they led to some overarching conclusions about epistemological beliefs.

Epistemological beliefs change as individuals acquire more knowledge. Muis et al. (2006), claimed there are three specific types of epistemological beliefs: general, academic, and domain-specific epistemological beliefs. General epistemological beliefs, according to Muis et al. (2016), were beliefs individuals have about everyday life. In contrast, academic beliefs were related to school context but were generalized. Domain-specific beliefs, Muis et al., (2016), are defined as relating to specific contexts that develop during schooling, particularly during secondary and post-secondary education. Therefore, beliefs formed in high school are significant, specifically when examining particular domains.

As individuals' knowledge increases, it is assumed they traverse a continuum from novice to expert in all three epistemological belief areas: general, domain-general, and domain-specific. The novice stage is categorized by an objectivist, dualistic view of knowledge (Hofer, 2004). During this stage, knowledge comes from authorities, is either right or wrong, and is fixed (Muis et al., 2016). As individuals acquire knowledge, they transition towards more expert-like beliefs. During this transition, individuals believe multiple perspectives may be in conflict (Muis et al., 2016). Upon reaching expert status, in terms of epistemological beliefs, individuals believe that "knowledge is actively constructed by the knower and knowing is coordinated with justification" (Hofer, 2004, p. 359).

Personal Epistemological Beliefs

Hofer and Pintrich (1997) divided epistemological beliefs into two categories: the nature of knowledge and the nature or process of knowing. The first category, the nature of knowledge, is defined as what one believes knowledge is at any given point. This category is divided into the certainty of knowledge and the simplicity of knowledge. The certainty of knowledge ranges from absolute truth at the lower levels to tentative truth at higher levels. The simplicity of knowledge describes knowledge as an accumulation of facts at the lower end of the continuum to knowledge being relative and contextual at the upper end. The second category, called the nature or process of knowing, describes how one comes to know. Under this category are sources of knowing and the justification for knowing. Sources for knowing range from authority at the lower end to oneself at the higher end. Justification of knowing ranges from authority or observations at the lower levels to inquiry and personal evaluation at the higher level. As individuals acquire knowledge, they progress through the different dimensions of general epistemological beliefs.

Academic Domain Epistemological Beliefs

According to Buehl and Alexander (2001), knowledge is multidimensional and multilayered. This means, in addition to general epistemological beliefs, individuals have more specific beliefs regarding particular domains. Domains, as defined by Alexander (1992), are overarching content areas, such as science, history or mathematics. Because context and content is different in different domains, epistemological beliefs vary by domains. Furthermore, since there are different views of knowledge based on academic domains, they must be examined separately (Buehl & Alexander, 2001).

Many studies have demonstrated that students have different epistemological beliefs towards different academic domains. For example, Marra and Palmer (2008) did a study employing grounded theory first with college science and engineering majors, and then another with liberal arts majors. In both grounded theory studies, the college students described their epistemological beliefs in the humanities more complex than in science. They determined that students can have contrasting epistemological beliefs when examining different domains. They also stated that while individual courses and experiences are not the only factors that determine epistemological beliefs, these factors can be influential.

Jehng, Johnson, and Anderson (1993) examined 386 university students' epistemological beliefs. The researchers defined hard fields as engineering or business and soft as humanities or social science. The researchers found that in soft fields, students perceive knowledge as changeable and students had beliefs that are more expert-like. In contrast, the students perceived hard fields having fixed knowledge coming from an authority figure and their beliefs were more naïve. Furthermore, the researchers stated that epistemological beliefs were based on five factors: certainty of knowledge, omniscient authority, orderly process, innate ability, and quick learning. When comparing undergraduates to graduates, the researchers found that graduate students were more expert-like in their beliefs about knowledge and the sources of knowledge as compared with undergraduates. They suggested that students' epistemological beliefs develop due to context, such as learning environment, and culture, in terms of perceptions.

Paulsen and Wells (1998) examined university students' epistemological beliefs and their correlation to academic domain. They grouped all majors into the following six domains: humanities and fine arts, social sciences, natural sciences, education, business and engineering. These domains were divided by hard/soft and pure/applied designations. The researchers used the classification that Biglan (1973) outlined to assign domains to hard/soft and pure/applied. Biglan (1973) characterized hard/soft dichotomy as the degree of paradigm development: hard has a single paradigm with consensus whereas soft has multiple paradigms with a lack of consensus. Biglan (1973) described that "applied fields as grounded in their related pure fields", meaning that applied fields typically value the application of knowledge acquired from pure fields (p.202). All majors were categorized both by the hard/soft and pure/applied distinctions. Thus, for Paulsen and Wells (1998), "humanities and fine arts as well as social sciences were soft and pure, natural sciences pure and hard, education soft and applied, business soft and applied and engineering as hard and applied" (p. 371).

Paulsen and Wells (1998) conducted a study consisting of 290 university students within six different majors. They examined their epistemological beliefs in terms of fixed ability, simple knowledge, quick learning, and certain knowledge. In the areas of simple knowledge, quick learning, and certain knowledge, the researchers discovered statistically significant results comparing domains. Soft and applied fields tended to have more naïve beliefs in simple knowledge. Students in hard and applied fields, like engineering, had more naïve beliefs in certain knowledge. The researchers found that in applied fields, such as engineering, students had more naïve beliefs about the simple knowledge, quick learning, and certainty of knowledge. Results for the hard/soft dualism showed students in soft fields have more expert-like beliefs as compared with students in hard fields. The results of their study corroborated what Jehng, Johnson, and Anderson (1993) had previous determined; students' epistemological beliefs differ by academic domains and their major influences their epistemological beliefs.

While these studies were conducted in college or university setting, similar studies were conducted on epistemological beliefs as early as elementary school. Stodolsky, Salk and Glaessner (1991) interviewed 60 fifth grade students and found that students believed math as fixed and unchangeable and social studies less rigid. Furthermore, the students described sources of authority as how they would acquire math knowledge as compared to social studies where in addition to authority, they stated they could also read about it. As early as elementary school, students have different beliefs about different domains, both about knowledge and sources of knowledge.

Kitchener's (1983) differentiation of domains may be one reason as to why different domains have different beliefs associated with them. He described domains as either well-structured or ill-structured. Well-structured domains tend to have agreed upon solutions. Examples of well-structured domains are mathematics and science. In contrast, ill-structured domains, such as history or English, are multidimensional and have flexible answers.

Besides the structure of the domain, the exposure to the domain can also influence epistemological beliefs. When students have limited exposure to domains, their beliefs tend to be fragmented and simplistic (Marra & Palmer, 2008). In contrast, the more courses that students have in particular domains, the more likely they will influence epistemological beliefs in that domain (Hart, Rickards, & Mentkowski, 1995).

Smith, Maclin, Houghton, and Hennessey (2000) also demonstrated that experiences influence epistemological beliefs. The researchers examined middle schoolers epistemological beliefs about science. They discovered that students' epistemological beliefs varied according to the type of instruction; more expert-like beliefs were associated with constructivist instruction whereas more novice beliefs were associated with traditional instruction.

Songer and Linn (1991) discovered that these novice or expert-like beliefs also related to understanding. They examined 153 eighth graders in a physical science course in California. Dynamic, the researchers defined as the belief that science can change and that understanding is important, is more expert-like. Static, in contrast, is the belief that science is fixed and learning it means memorizing, which represents more novice-like beliefs. The researchers found that "only 15% of students reported a dynamic view of science, whereas 63% viewed science as static" (p.773). Furthermore, their results demonstrated that students with dynamic beliefs have a greater understanding of physical science concepts as compared to their classmates with static beliefs relating to science.

Domain-Specific Epistemological Beliefs

Kienhues et al. (2008) determined people have epistemological beliefs about particular academic domains as well as domain-specific beliefs. They examined 58 students, with a variation of majors, at a German university. Two different instruments were used to measure epistemological beliefs: the Connotative Aspects of Epistemological Beliefs (CAEB) and the Domain–specific Epistemological Belief Questionnaire (DEBQ). With the CAEB, the researchers found that the naïve refutational group's beliefs became more sophisticated and the more sophisticated group's beliefs became more naïve after instruction. In contrast, with the DEBQ, the naïve group's beliefs remain stagnant, whereas the more sophisticated group's beliefs became more naïve. They surmised that changes in domain-specific epistemological beliefs only occur when instruction challenges preexisting epistemological beliefs of students.

Furthermore, Gill et al. (2004) suggested that domain-specific beliefs are more variable as compared with general beliefs. Due to the variability of domain-specific epistemological beliefs, the way knowledge is presented could be influential (Muis et al., 2006; Perry, 1970). Furthermore, when the same content was presented different ways, individuals' beliefs differed (Gottleib & Wineburg, 2012; Muis, Franco, & Gierus, 2011; Stahl, 2009). Hence, specific contexts affect educational experiences. These educational experiences lead to the variability of students' domain-specific epistemological beliefs.

Students develop epistemological beliefs relating to a specific discipline due to their instructional experiences. According to Muis et al., (2016), the domain-specific epistemological beliefs develop during secondary and postsecondary years. Therefore, the experiences students have due to high school physics instruction influences physics epistemological beliefs. The researcher is interested in studying physics epistemological beliefs because not only do they influence learning, but also motivation and behaviors.

Physics Epistemological Beliefs

Physics epistemological beliefs pertain to what is knowledge and how that knowledge is developed in physics (Kortemeyer, 2007). These beliefs have the potential to influence students' success in physics. Physics epistemological beliefs also affect learning, text comprehension and metacognition strategies relating to physics (Hofer & Pintrich, 2002). Thus, physics epistemological beliefs are an important factor in students' abilities to learn physics. Since epistemological beliefs are influential in students' ability to learn physics, and high school is the first time that students encounter physics, it is important that high school physics instruction foster the transition of students from novice to more expert-like in terms of epistemological beliefs.

Physics epistemological beliefs consist of beliefs about the structure of physics knowledge, physics content, and the process of learning physics (Hammer, 1994). The structure of physics knowledge is viewed on a continuum from being isolated to being coherent. At the lower end of the continuum, being isolated means physics is perceived as separate pieces of knowledge that are to be memorized, whereas being coherent, on the higher end, is perceived as physics knowledge being linked and able to be derived when necessary. The content of physics knowledge category consists of just formulas on the lower end of the continuum or concepts that underlie the formulas at the higher end. For those students who believe physics is just formulas to be solved, they do not understand the fundamental concepts that go with those symbols and formulas. Students at the higher end of the continuum view solving equations as not only a quantitative answer but also qualitative understanding. The belief about learning physics category also exists on a continuum from learning from authority at the lower end to self-realization at the higher end. Beliefs in this category are differentiated by receiving from authority, where learning is perceived as memorizing, or formed independently, where the student applies his/her own judgement to make sense of physics. Since epistemological beliefs are influential in students' ability to learn physics, and high school is the first time that students encounter physics, it is important that high school physics instruction foster the transition of students from novice to more expert-like in terms of epistemological beliefs in all three categories.

Novices, in terms of physics epistemological beliefs, tend to have fragmented, incoherent knowledge that is weakly organized (Larkin, 1983; Larkin et al., 1980). Novices believe knowledge is "an accumulation of discrete, concrete, knowable facts" (Schommer, Crouse, & Rhodes, 1992; Schommer 1990). Furthermore, novices believe physics is about manipulating formulas. Thus, novices tend to remain in the initial stages of epistemological belief development. Experts, in contrast, have a great ability to connect physics to the real world, solve physics problems, structure physics knowledge and in general, know how to learn physics (Gray et al., 2008). Besides focusing on physics content, high school physics instruction must also strive to assist students in achieving epistemological sophistication by encouraging the transition of epistemological beliefs from novice to more expert-like.

Epistemological sophistication means students have developed more expert-like views of physics. According to Sinatra and Pintrich (2003), "Epistemological sophistication is positively related to skills and attitudes important for learning" (p.257). The progression of students from novice to more expert-like beliefs is important, not just for knowledge acquisition. By developing instructional environments that foster epistemological growth, students' skills and attitudes regarding physics will also become more expert-like. In turn, by developing epistemological sophistication, students develop deep understanding of the content (Stathopoulou & Vosniadou, 2007).

Madsen et al. (2015) suggested the "many physics majors develop these expert-like views in their K-12 education" (p.12). Therefore, increasing epistemological sophistication needs to be a goal in high school physics instruction. Muis and Gierus (2014) suggested that in order to develop a view that is more expert-like, more time should be spent on conceptual knowledge, rather than just procedural knowledge. High school physics instruction, which tends to focus mainly on solving problems, may not provide the best structure necessary to foster expert-like beliefs. Therefore, high school physics instruction needs to incorporate dimensions that facilitate the development of conceptual knowledge in order to foster the development of positive epistemological beliefs. Madsen et al. (2015) suggest that more work needs to be done to examine physics epistemological beliefs in K-12 education as well as other factors that could potentially influence these beliefs.

Physics epistemological beliefs have been typically determined through interviews or surveys. Multiple surveys have been developed to measure general epistemological beliefs like the Schommer Epistemological Beliefs Questionnaire (EBQ), academic domain epistemological beliefs like the Views about Science Survey (VASS), and physics epistemological beliefs like Maryland Physics Expectations Survey (MPEX). However, this study is going to use the Colorado Learning Attitudes about Science Survey because it specifically measures physics epistemological beliefs and was developed to be used in a wide variety of settings.

Colorado Learning Attitudes about Science Survey (CLASS)

The Colorado Learning Attitudes about Science Survey (CLASS) was developed by researchers at the University of Colorado to measure students' attitudes and beliefs relating to physics. Furthermore, this survey also distinguishes experts from novices based on responses. The CLASS is a domain specific survey that focuses specifically on physics epistemological beliefs. According to Adams, Perkins, Podolefsky, Dubson, Finkelstein, and Wieman (2006), this survey was based on other attitude and epistemological surveys such as the Maryland Physics Expectations Survey (MPEX), Views about Science Survey (VASS), and Epistemological Beliefs Assessment for Physical Science (EBAPS). While the MPEX, VASS, and EBAPS all examine students' epistemological beliefs, the CLASS was written "to make the statements as clear and concise as possible and suitable for use in a wide variety of physics courses" (Adams, et al., 2005, p.1).

The CLASS consists of 42 Likert scale items from which students can choose options ranging from strongly agree to strongly disagree. The items fall into eight categories: Real World Connection, Personal Interest, Sense Making/Effort, Conceptual Connections, Applied Conceptual Understanding, Problem Solving General, Problem Solving Confidence, and Problem Solving Sophistication. There are at least four statements in the survey that fall under each category and many of the statements on the survey fall into multiple categories, meaning that the categories are not isolated (Douglas, Yale, Bennett, Haugan, & Bryan, 2014).

Categories of the CLASS

"Category names function as a way to summarize statements within a category" (Adams, et al., 2006, p.7). The Personal Interest category contains statements that connect what is learned in physics class to students' lives. Real World Connections is similar to Personal Interest but it relates physics to everyday lives, not just students' personal lives. Sense Making/Effort is another personal category that relates personal understanding to physics. In contrast, the Conceptual Connections category describes students' connections to physics and their ability to make connections between physics concepts. The Applied Conceptual Understanding category is similar but includes statements about physics knowledge and problem solving. The Problem Solving General category describes students' beliefs about solving physics problems. Similarly, Problem Solving Confidence also relates to students' problems solving but also includes statements regarding students' ability. Problem Solving Sophistication elaborates on the two previous categories by including statements about how one solves physics problems.

The eight categories in the CLASS align well with general epistemological beliefs as described by Hofer and Pintrich (1997) as well as domain-specific physics epistemological belief categories outlined by Hammer (1994). The correlations between the categories of the CLASS, the general epistemological beliefs, and physics epistemological beliefs are shown in Table 2, below.

Table 2

Categories of CLASS Aligned with Epistemological Beliefs

CLASS category	General Epistemological Beliefs (Hofer & Pintrich, 1997)	Domain-specific epistemological beliefs (Hammer, 1994)
Personal Interest	Nature of knowledge Justification for knowledge	Structure of knowledge Content of knowledge Beliefs about learning physics
Real World Connections	Nature of knowledge Justification for knowledge	Content of knowledge Beliefs about learning physics
Conceptual Connections	Simplicity of knowledge Sources of knowledge	Structure of knowledge
Applied Conceptual Understanding	Simplicity of knowledge Sources of knowledge	Structure of knowledge
Sense Making/Effort	Simplicity of knowledge Sources of knowledge	Content of knowledge Structure of knowledge
Problem Solving General	Simplicity of knowledge Sources of knowledge	Content of knowledge Structure of knowledge Beliefs about learning physics
Problem Solving Confidence	Sources of knowledge	Beliefs about learning physics
Problem Solving Sophistication	Simplicity of knowledge Sources of knowledge	Beliefs about learning physics

The CLASS is usually administered in a pretest/posttest format, with the first administration at the beginning of the course, and the second administration later in the semester. Scoring of the CLASS is done by calculating the percent favorable, where the student's response agrees with the expert, or percent unfavorable, where the student's response disagrees with the expert. These individual scores are then averaged to determine overall average percent favorable score. Typically, each category is also examined in terms of favorable scores to determine which areas demonstrate statistically significant results after instruction.

Due to the wide application of the CLASS, many researchers have used this survey to examine students' attitudes and beliefs about physics at the postsecondary level. Many times, researchers utilized the CLASS to assess curriculum reform or to determine the impact of a teaching strategy. The developers of the CLASS have administered it to over 7000 college students and over 60 college physics courses (Adams, et al., 2006). Their goal was to examine shifts that occurred in physics beliefs over a semester and to determine if specific teaching strategies had an impact. They found regardless of the major or the institution, students beliefs declined with traditional instruction. Furthermore, Perkins, Adams, Pollack, Finkelstein, and Wieman (2005) determined there was a positive correlation between students' attitudes, conceptual learning gains, and student retention. Thus, by evaluating students' attitudes and beliefs with the CLASS, predictions can be made about students' conceptual learning as well as retention of students in physics. *Figure 1*, below, shows the implementation of the CLASS with my study at the bottom.

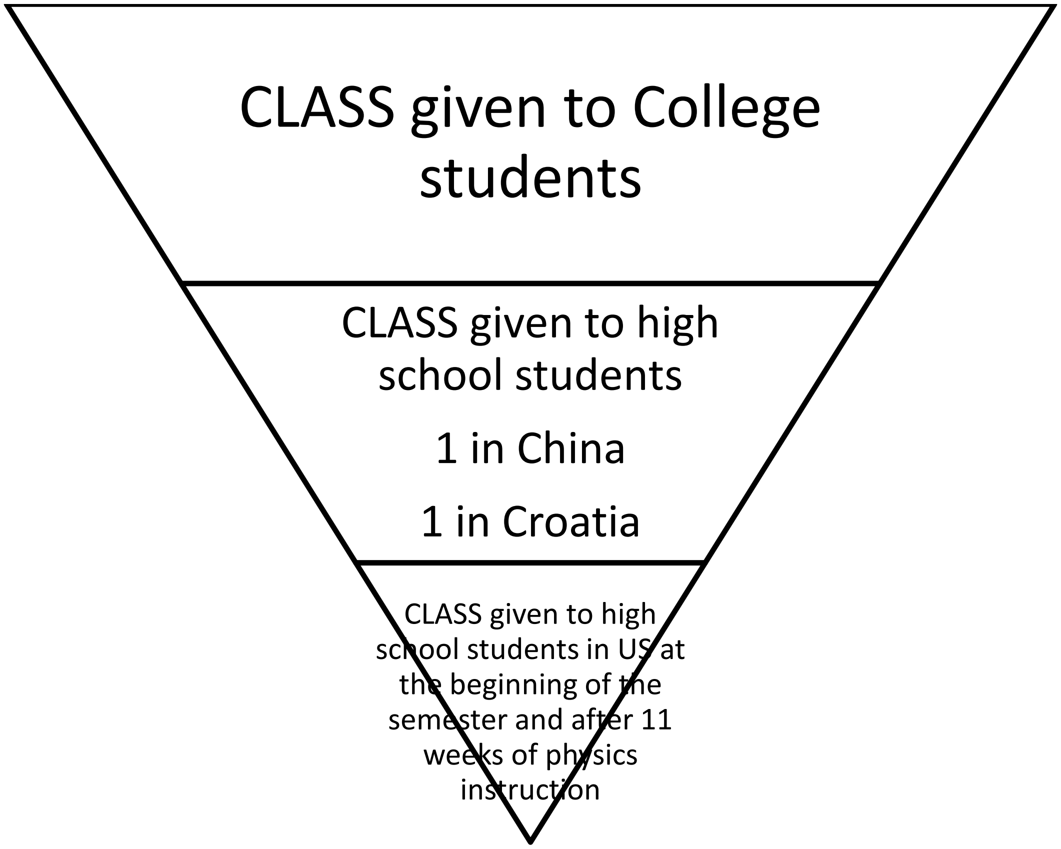

Figure 1. Studies which Utilized the CLASS

College Research Studies Which Utilized the CLASS

After a semester of college physics instruction, multiple researchers found beliefs became more novice-like, particularly in calculus-based physics courses (Madsen et al., 2015; Perkins, Gratney, Adams, Finkelstein, & Wieman, 2006). Perkins, et al., (2006) examined 391 college students in an introductory calculus-based physics course in fall 2004. They discovered that after a semester of instruction, students' beliefs became more novice-like. The researchers stated that this decrease in expert-like beliefs after a semester of physics instruction was due to the traditional instructional methods employed. Furthermore, they also correlated student interest in physics with beliefs. They found that students with more expert-like beliefs also had a higher interest in physics at the end of the semester. They determined that gender also plays a role in students' ideas of physics and learning physics. In their study, men typically had more expert-like beliefs as compared to women.

Slaughter et al. (2011) examined 304 first year college students, both physics majors and non-majors taking physics at the University of Edinburgh. In their study, physics majors began with more expert-like beliefs as compared with non-majors, but both experienced a decline in beliefs after a semester of traditional physics instruction. Specifically, physics majors and non-majors had statistically significant differences in the Sense Making/Effort categories as well as the Conceptual Understanding category. Furthermore, when examining gender, they found that females had a more significant drop in beliefs as compared with males. For females, the largest decrease was in the Real World Connection and Conceptual Understanding categories. Their data corroborated what others found; the trend towards more novice-like beliefs after tradition instruction.

Multiple studies using the CLASS showed no shift in beliefs. Gire, Jones, and Price (2009) administered the CLASS to 519 university students and found over the first three years of undergraduate study, beliefs remained consistent. Their results also determined physics majors had more expert-like views as compared to engineering majors. Bates, Galloway, Lopton and Slaughter (2011) collected data from 637 high school, undergraduate, postgraduate and university staff and found similar results in the United Kingdom; there was no shift in beliefs through the undergraduate years. However, they did find significant changes in beliefs between their final years in high school and college as well as their final year in college and their first year as a physics teacher.

Ding and Zheng (2016) conducted a longitudinal study with Chinese undergraduates who were studying to be physics teachers and first year high school physics teachers. Their results using the CLASS were comparable to other researchers; no shift in beliefs during undergraduate years but significant shifts in beliefs during their first year as high school physics teachers. Upon deeper investigation, while undergraduates' overall results stagnated, all three problem-solving categories showed significant decreases. In contrast, those students who were in the first year of teaching physics showed significant increases in the Problem Solving General, Problem Solving Confidence, and Sense Making/Effort categories. Ding and Zheng (2016) found that their grade/age made a difference; first year physics teachers had more expert-like physics epistemological beliefs as compared to undergraduates and second year teachers.

In contrast, many researchers found positive shifts in expert-like beliefs as measured by the CLASS. At the University of Toronto, Harlow, Landau, and Bailey (2014) administered the CLASS to non-science students with little prior physics experience in two different physics breadth courses during the spring and summer of 2013. They found that students who had interactive teaching techniques or hands-on approach had a positive shift in beliefs whereas students in the traditional lecture course had a slight negative shift in beliefs.

In Beijing, Zhang, Ding, and Mazur (2017) examined 441 first year science undergraduate majors' attitudes and beliefs using the CLASS in four different sections of the same physics course. Three sections taught with peer instruction and the fourth used traditional teaching methods. Their results substantiated previous researchers work; positive shifts in beliefs occurred when the primary method of instruction was peer instruction whereas with traditional instruction, beliefs shifted towards more novice-like. Furthermore, in the courses taught with peer instruction, statistically significant positive shifts were found in Personal Interest, Problem Solving General, and Real World Connection. Zhang et al. (2017) also determined that although females were less expert-like in their physics epistemological beliefs at the beginning of the course, after peer instruction, they exhibited more positive shifts. In contrast, with traditional instruction, both genders displayed negative shifts in physics epistemological beliefs.

Similar results also occurred at Canadian University in the fall of 2008 with an introductory calculus-based physics courses. Milner-Bolotin, Antimirova, Noack, and Petro (2011) discovered that in almost all categories, students moved to more expert-like beliefs over the course of a semester. The only statistically significant positive shift occurred in the Real World Connections category. However, in Problem Solving General and Sense Making/Effort, students did not move towards more expert-like beliefs. Although this study did not examine demographic data and its influence on physics epistemological beliefs, they did acknowledge that it could be a factor and may explain differences (Milner-Ballotin, Antimirova, Noack, & Petro, 2011).

Lindsey, Hsu, Sadaghiani, Taylor, and Cummings (2012) examined college students' physics attitudes and beliefs with the CLASS from five different colleges and universities in the United States before and after the implementation of Physics by Inquiry. The Physics by Inquiry teaching method was developed to help preservice and in-service K-12 teachers, as well as non-majors, learn physics content. In Physics by

Inquiry, students work in small groups to perform experiments and through experimentation, they answer questions and learn physics in an applicable way. After a semester of Physics by Inquiry, the researchers found large positive shifts in epistemological beliefs. There were statistically significant gains in Conceptual Understanding, Applied Conceptual Understanding, Problem Solving General, Problem Solving Confidence and Problem Solving Sophistication. This study demonstrated that even without a specific focus on epistemological beliefs, physics epistemological beliefs can shift towards more expert-like with certain types of instruction.

Another reform effort in college physics pedagogy was instituted at Florida International University during the 2007-2008 academic year. Brewe, Kramer, and O'Brien (2009) examined epistemological beliefs of 22 students in the fall and 23 students in the spring who took physics courses that used Modeling Instruction. Modeling Instruction utilizes student activities to explicitly address the nature of science in its curriculum. The CLASS was administered at the beginning and end of each semester. In the fall, significant shifts were found in the Problem Solving General and Conceptual Understanding categories. During the spring, only the Personal Interest category had a statistically significant positive shift. Sixteen of the students took both semesters and for them, all categories shifted to positive in terms of epistemological beliefs, except Real World Connections. According to Brewe et al. (2009), "A single semester is sufficient to significantly shift attitudes of students" (p.5).

Brewe, Traxler, de la Garza, and Kramer (2013) also used reformed pedagogies in their college level calculus-based mechanics classes from fall 2008-fall 2012. The researchers found Modeling Instruction produced positive shifts in beliefs. The research suggested that reformed pedagogies assist students in forming more expert-like beliefs. In contrast, with traditional instruction, students reverted towards more novice-like beliefs.

Beliefs are also influenced by previous physics experience. Students entering college having physics in grade 12 had more favorable and expert-like beliefs at the beginning of the semester (Harlow et al., 2014; Milner-Bolotin, Antimirova, Novak, & Petrov, 2011). Therefore, after having physics in grade 12, students have already formed attitudes and beliefs regarding physics. Thus, the beliefs formed by students' first exposure to physics are important.

The CLASS has also been utilized in studies with non-science majors. Otero and Gray (2008) administered to 182 students in Physics and Everyday Thinking (PET) classes and Physical Science and Everyday Thinking (PSET) classes to elementary teachers. These classes were inquiry-based and focused on the nature of science and the nature of science learning. Again, with interactive instructional methods, positive shifts were observed in the CLASS. Shifts were observed in all categories except Sense Making/Effort and Problem Solving. The highest shifts were in Personal Interest, Problem Solving Sophistication, Conceptual Understanding, and Applied Conceptual Understanding. According to Otero and Gray (2008), these categories are related to students' beliefs about the structure of knowledge and conceptual understanding. Otero and Gray (2008) also asked students about their interest in physics during the administration of the class and found that student interest increased by the end of the semester.

The CLASS has been administered in a wide variety of college physics classes with varying results. In some cases, physics epistemological beliefs became more expert-like after a semester of physics instruction, whereas in other cases, no change, or more novice-like shifts in physics epistemological beliefs were observed. However, to get a better indication of the practical significance of the different instruction methods' effect on physics epistemological beliefs, effect sizes were calculated using Cohen's *d*.

Effect Sizes in College Studies Which Utilized the CLASS

According to Huck (2012), the effect size is a measure of the "pure strength of the measured relationship (p. 163). In the studies below, the effect size is calculated by using Cohen's *d*. According to Cohen (1992), when $d = 0.20$, the effect size is small, when $d = 0.50$, the effect size is medium, and when $d = 0.80$, the effect size is large. The researchers calculated *d* by subtracting the mean overall percent favorable responses for pre- and -, and dividing by the pooled standard deviation for both sets (Brewe et al., 2013). The effect sizes calculated through this method in various college settings are shown below in Table 3. These studies illustrated a range of effect sizes; however, overall, there was a medium effect size.

Table 3

Previous College CLASS Studies Measured Effect Sizes

Authors	Pre/Post Shift	Average Effect Size
Brewe, Kramer, and O'Brien (2009)	9.0±2.7	0.71
de la Garza and Alarcon (2010)	3.1±2.2	0.21
Otero and Gray (2010)	8.8±1.1	0.59
Lindsey, Hsu, Sadaghiani, Taylor, and Cummings (2012)	8.6±0.7	0.52
Brewe, Traxler, de la Garza, and Kramer (2013)	6.9±1.1	0.45

As observed in the table 3, above, different studies had different effect sizes. A small effect size was calculated by de la Garza and Alarcon (2010) at a Mexican University in two mechanics courses that were utilizing modeling pedagogy. Medium effect sizes were calculated by multiple researchers in utilizing different instructional methods. Brewe et al. (2009) found medium-to-large effect sizes in students over the course of a year at Florida International University who had modeling instruction. These studies calculated effect sizes only on overall mean scores. Additionally, these studies with calculated effect sizes were conducted at the collegiate level; none were done at the high school level, although the CLASS has been administered to high school students.

High School Research Studies Which Utilized the CLASS

As noted above, the CLASS has been administered in many different college and university classrooms through the world in to determine physics epistemological beliefs. However, there is a lack of published studies where the CLASS was administered in high school settings. Although the CLASS has not been administered as frequently in high school settings, the CLASS can be administered there just as effectively, due to the clear and concise statements (Adams, et al., 2006).

High School Studies Utilizing the CLASS

Two high school studies conducted in other countries utilized the CLASS in similar ways to the aforementioned college studies. Marusic and Slisko (2012) examined physics epistemological beliefs of 176 physics students in 12th grade spring semester for 16 weeks in Croatia. Students were divided into two groups: one received ED (experimenting and discussion) pedagogy and the other received RPQ (reading, presenting and questioning) pedagogy. Like the other studies, the CLASS was administered prior to and after the intervention. Both the RPQ and ED groups had positive shifts in beliefs. "Students in the RPQ groups achieved a statistically significant positive shift in Personal Interest, Sense Making/Effort, Conceptual Understanding, Applied Conceptual Understanding, and Problem Solving Sophistication" (Marusic & Slisko, 2012, p. 8). The ED group also had statistically significant results in those categories as well as Real World Connection, Problem Solving General, and Problem Solving Confidence. The researchers confirmed that reformed pedagogies influenced students' shift in physics epistemological beliefs to more expert-like views. They also noted that with only one semester of teaching high school physics differently, physics epistemological beliefs could be altered. In terms of gender, Marusic and Slisko (2012) found that with the ED, both genders' physics epistemological beliefs improved whereas with the RPQ, males' physics epistemological beliefs became more expert-like but females' beliefs became more novice-like. Although the CLASS has widespread application and has been implemented in many collegiate classrooms, less research is available on the administration of the CLASS at the high school level.

Zhang and Ding (2013) acknowledged there is little data about physics epistemological beliefs prior to college. Therefore, they examined 1318 Chinese middle and high school students' physics epistemological beliefs. In China, physics is required in all grades 8-12. The researchers found that middle schoolers had more expert-like beliefs as compared to the high school students. The researchers also corroborated the results found in college that with traditional instruction, beliefs became less expert-like. The researchers also found that at grade 11, students had the lowest epistemological sophistication of beliefs, which they attested was due to the mathematical focus. However, the researchers observed positive shifts in physics epistemological beliefs from grade 8 to 9 and grade 11 to 12. Because of their results, Zhang and Ding (2013) "suggest the relationship between physics instruction and student epistemological beliefs to be complex and may include nonpedagogical factors and that begs for further study" (p.8). Both studies that utilized the CLASS to determine physics epistemological beliefs of high school students were outside of the United States; no published studies were conducted in the United States. In addition, both studies were commenced after some physics content was taught; no studies utilizing the CLASS identify high school students' physics epistemological beliefs at the beginning of their first physics course in high school. Both studies also examined only top tier students. The Croatian study did conduct a pretest/posttest design but only after a semester of instruction and both groups received reformed pedagogies but different content. In contrast, the Chinese study only administered the CLASS once. Hence, there is currently no high school study utilizing the CLASS to measure the physics epistemological beliefs of high school with a diverse group of students starting the beginning of the semester. Furthermore, while some college and high school studies have examined gender or grade/age, no studies have examined the influence of ethnicity, socioeconomic status, or GPA on high school students physics epistemological beliefs utilizing the CLASS. Below, in Table 3, is a summary of the studies previously mentioned and what factors they examined relating to the different categories of the CLASS.

Other Potential Factors Influencing Epistemological Beliefs

"Although it is clear that epistemological beliefs change over time, there may be personal factors that can facilitate or constrain development" (Conley, Pintrich, Vekiri, & Harrison, 2004, p.9). These various factors include grade/age, gender, and socioeconomic status (Paulsen & Wells, 1998; Schommer 1990, 1993a). Furthermore, because culture shapes beliefs, ethnicity also needs to be considered (Sternberg & Grigorenko, 2004). Therefore, these factors need to be examined in conjunction with shifts in physics epistemological beliefs in order to determine what factors are significant.

Multiple college studies, utilizing the CLASS, determined gender to be influential in physics epistemological beliefs. Adams et al. (2006) found men tended to be more expert-like with their physics epistemological beliefs as compared to women. Slaughter et al. (2011) found similar results with females' physics epistemological beliefs decreasing the most in the Real World Connection, Problem Solving Sophistication, and Conceptual Understanding categories. In contrast, Zhang et al. (2017) determined that although females started with more novice-like beliefs, after peer instruction, they had a greater positive shift in physics epistemological beliefs as compared with males.

However, in groups that received traditional instruction, their results confirmed others' results; females became more novice-like.

Less studies have been conducted examining grade/age and how it relates to physics epistemological beliefs with the CLASS. However, the study utilizing the CLASS with Chinese students in grades 8-12 examined how grade/age related to physics epistemological beliefs. Zhang and Ding (2013) observed that student in grades 8 and 11 had more novice-like beliefs as compared to students in grades 9 and 12. At the collegiate level, Ding and Zhang (2016) found that during undergraduate years, physics epistemological beliefs plateaued, but for first year physics teachers, physics epistemological beliefs became more expert-like. Table 4, below, depicts what studies, as well as what factors, researchers included when examining physics epistemological beliefs with the CLASS. The factors gender, grade/age, ethnicity, socioeconomic status (SES), and grade point average (GPA) were selected.

Table 4

Previous CLASS Studies and Other Influencing Factors

Study	Gender	Grade/Age	Ethnicity	SES	GPA
Adams, Perkins, Podolefsky, Dubson, Finkelstein, and Wieman (2006)	Yes	No	No	No	No
Perkins, Adams, Pollock, Finkelstein, and Wieman (2005, September)	No	No	No	No	No
Brewe, Traxler, de la Garza, and Kramer (2013)	No	No	No	No	No
Lindsey, Hsu, Sadaghiani, Taylor, and Cummings (2012)	No	No	No	No	No
Milner-Bolotin, Antimirova, Noack, and Petrov (2011)	No	No	No	No	No
Zhang, Ding, and Mazur (2017)	Yes	No	No	No	No
Ding and Zhang (2016)	No	Yes	No	No	No
Sawtelle, Brewe, and Kramer (2009)	No	No	No	No	No
Slaughter, Bates, and Galloway (2011)	Yes	No	No	No	No
Gire, Jones, and Price (2009)	No	No	No	No	No
Perkins, Gratny, Adams, Finkelstein, and Wieman (2006, February)	No	No	No	No	No
Madsen, McKagan, and Sayre (2015)	No	No	No	No	No
Harlow, Landau, and Bailey (2014)	No	No	No	No	No
Brewe, Kramer, and O’Brien (2009)	No	No	No	No	No
Otero and Gray (2008)	No	No	No	No	No
Marusic and Slisko (2012)	Yes	No	No	No	No
Zhang and Ding (2013)	No	Yes	No	No	No

Although no studies utilizing the CLASS have examined socioeconomic status, ethnicity, or GPA, other researchers have found these factors to be significantly related to general or domain-general epistemological beliefs. In fact, Pintrich (2002) validated the importance of examining ethnicity and socioeconomic status in relation to epistemological beliefs. Furthermore, Paulsen and Wells (1998) deemed GPA as a factor that influences epistemological beliefs.

Conley et al. (2004) examined 187 fifth grade students' general epistemological beliefs with a survey whose questions related to Hofer and Pintrich's (1997) four dimensions of epistemological beliefs. Their study differentiated socioeconomic status by those who received free and reduced lunch and those who did not. They found students having lower socioeconomic status had less sophisticated general epistemological beliefs.

Trautwein and Ludtke (2007) studies 2854 students in upper secondary school in Germany with a mean age of 19. In their study, epistemological beliefs in Hofer and Pintrich's (1997) certainty of knowledge dimension were measured with a questionnaire. On that survey, students were asked to self-report socioeconomic status in terms of parents' jobs. Within the certainty of knowledge dimensions, the researchers found that certainty epistemological beliefs correlated significantly and negatively with socioeconomic status. Their study corroborated Schommer's (1990) statement that with "more educated parents' children tend to have more sophisticated epistemological beliefs" (p. 503).

In contrast, other researchers found socioeconomic status not related to epistemological beliefs. Yilmaz-Tuzun and Topcu (2009) examined 941 Turkish students in grades 4 thru 8. They obtained data from the previous year regarding socioeconomic status. Their results demonstrated that there is no relationship between epistemological beliefs and socioeconomic status. Abedalaziz, Leng, and Song (2013) examined 719 Malaysian students and found similar results: socioeconomic status was not significant linked to epistemological beliefs.

Graham (1994) and Pollard (1993) stated that socioeconomic status and ethnicity must be separate in order to not confound variables. Conley et al., (2004) cited the paucity of studies that examined ethnicity as it related to epistemological beliefs as a reason for including it in their study. In order to determine ethnicity, they categorized students as White, African American, or Latino. They found no significant relationship between ethnicity and general epistemological beliefs.

In terms of grade point average, Schommer and Dunnell (1995) examined 69 gifted high school students in terms of general epistemological beliefs. They found that students with a lower GPA has more novice-like general epistemological beliefs. Schommer (1993b) administered a survey to measure epistemological beliefs to over 1000 high school students in the categories of simple knowledge, certainty of knowledge, fixed ability, and quick learning. She found that high school grade point average was positively correlated with sophisticated beliefs across four dimensions: quick learning, simple knowledge, certain knowledge and fixed ability. In contrast, King and Magun-Jackson (2009), examined undergraduate and graduate students' general epistemological beliefs using Schommer's Epistemological Questionnaire. They found that engineering students with above average GPA had more novice-like beliefs as compared with students with average GPAs. Although Marra, Palmer, and Litzinger (2000) also examined GPA and general epistemological beliefs of engineering students, their results differed. They did not find a significant relationship between GPA and general epistemological beliefs.

Madsen et al. (2015) stated that positive epistemological beliefs are formed in students' K-12 education. However, according to Gire, Jones, and Price (2007), "the factors shaping students' views about physics before they enter the university have not been established and are an important line of investigation" (p. 6). Due to the lack of information about physics epistemological beliefs prior to college, particularly in terms of gender, grade/age, socioeconomic status, ethnicity, and GPA, this study will not only utilize the CLASS to determine physics epistemological beliefs of high school students, but it will also determine if other factors are significantly related to them (Zhang & Ding, 2013). Therefore, it becomes important to examine the physics epistemological beliefs students have entering high school physics and the shifts in beliefs that form during high school physics instruction as well as the other factors that could influence physics epistemological beliefs.

Conclusion

The purpose of this study was to examine the extent to which students' physics epistemological beliefs varied from the beginning of their first introductory physics course in high school, and after 11 weeks of high school physics instruction, when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA. According to Slaughter et al. (2011), negative beliefs formed in high school towards a subject many times predicts that students will not pursue that field of study. Therefore, it is important to determine what physics epistemological beliefs students form in high school, as it may be an indicator of whether they pursue physics or not in the future. Additionally, the factors significantly impact their physics epistemological beliefs also become important.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

Because “student beliefs about physics play a substantial role in a student’s ability to learn physics”, it is important to know what these beliefs are (Gray et al., 2008). In particular, students form beliefs about the structure of physics knowledge, where the knowledge comes from, how to learn physics, and how to solve physics problems. These physics epistemological beliefs influence a student’s ability to succeed in physics. Therefore, because of the impact physics epistemological belief have on learning, it is important to know what physics epistemological beliefs students have at the before and after physics instruction.

Physics epistemological beliefs are measured on a continuum from novice-like to expert-like. Novices tend to have fragmented knowledge, coming from authority, as compared to experts, who create their own coherent knowledge. Experts tend to have more positive beliefs regarding physics as compared with novices. Students developed their expert-like views in K-12 education, however, the factors influencing them are not established (Madsen et al., 2015; Gire, Jones, & Price, 2007). Therefore, the beliefs that students construct during their first high school physics courses become important, as well as the factors influencing them. This study employed a quantitative methodology in order to examine high school students’ physics epistemological beliefs when controlling for gender, grade/age, socioeconomic status, ethnicity, and GPA.

Setting and Participants

This study was conducted at an urban high school in southeastern Pennsylvania. The high school consisted of grades 10-12 and there are approximately 1000 students. The high school is 58% economically disadvantaged and 52% non-White. One hundred and five students were registered for their first physics course at this school at the beginning of the 2017-2018 school year. All 105 students were asked voluntarily to participate in the study. Students were provided permission slips detailing what will be required of them and their ability to opt out without consequences. Fifty-four students and parents signed permission slips, granting them permission to participate in the study. Fifty-two students participated in both the pretest and posttest.

In order to conduct the study at this urban high school, permission had to be granted by Mercer University and the superintendent of the high school where the study took place. Approval to conduct the study was granted by the Mercer Institutional Review Board for research Involving Human Subjects (H1706185) (Appendix B). Approval also had to be granted by the superintendent of the school where the research took place (Appendix D).

Research Design

This study employed a correlational research design to examine the relationship between high school students' physics epistemological beliefs and the covariates of gender, grade level/age, socioeconomic status, ethnicity, and GPA. This type of design allowed for the observation of multiple variables while describing the relationship that exists between them (Jhangiani, Chiang, & Price, 2015). In this study, the relationship that was examined was between high school students' physics epistemological beliefs and each covariate. The covariates of gender, grade level/age, socioeconomic status, ethnicity, and GPA were measured on the individual nominal scales. Physics epistemological beliefs were measured on an ordinal scale through the Colorado Learning Attitudes about Science Survey (Appendix A). Approval was given by a faculty member at the University of Colorado to use the Colorado Learning Attitudes about Science Survey (Appendix C).

Timeline

Students taking College Physics or AP Physics 1 at the urban high school were presented with permission slips the first day of school. The Colorado Learning Attitudes about Science Survey (CLASS) was administered to all students taking College Physics and AP Physics in the fall of 2017. The first administration occurred at the beginning of the school year in August 2017 after permission was obtained from the parents/guardians of the students as well as student consent. The second administration of the CLASS occurred after 11 weeks of high school physics instruction.

Research Questions

There were nine research questions in this study. Each research question examined the extent to which physics epistemological beliefs varied between the first and second administrations of the CLASS when controlling for gender, ethnicity, socioeconomic status, grade, and GPA.

1. To what extent do the pretest/posttest overall mean score of physics epistemological beliefs as measured by the CLASS between the beginning and the end of the semester of high school physics differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?

2. To what extent do the pretest/posttest scores in the Real World Connections category of the CLASS between the beginning and end of the semester of high school physics differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
3. To what extent do the pretest/posttest scores in the Sense Making/Effort category of the CLASS between the beginning and end of the semester of high school physics differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
4. To what extent do the pretest/posttest scores in the Personal Interest category of the CLASS between the beginning and end of the semester of high school physics differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
5. To what extent do the pretest/posttest scores in the Conceptual Understanding category of the CLASS between the beginning and end of the semester of high school physics differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
6. To what extent do the pretest/posttest scores in the Applied Conceptual Understanding category of the CLASS between the beginning and end of the semester of high school physics differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
7. To what extent do the pretest/posttest scores in the Problem Solving General category of the CLASS between the beginning and end of the semester of high

school physics differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?

8. To what extent do the pretest/posttest scores in the Problem Solving Confidence category of the CLASS between the beginning and end of the semester of high school physics differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?
9. To what extent do the pretest/posttest scores in the Problem Solving Sophistication category of the CLASS between the beginning and end of the semester of high school physics differ when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA?

Effect Size Predictions

Based on previous studies that utilized the CLASS and their effect sizes, the researched made effect size predictions for each of the research questions. The effect size predictions were:

1. A medium effect size in the overall mean score of physics epistemological beliefs as measured by the CLASS between the beginning and the end of the semester of high school physics when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA will be observed.
2. A medium effect size in physics epistemological beliefs in the Real World Connections category of the CLASS between the beginning and end of the semester of high school physics when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA will be observed.

3. A medium effect size in physics epistemological beliefs in the Sense Making/Effort category of the CLASS between the beginning and end of the semester of high school physics when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA will be observed.
4. A medium effect size in physics epistemological beliefs in the Personal Interest category of the CLASS between the beginning and end of the semester of high school physics when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA will be observed.
5. A medium effect size in physics epistemological beliefs in the Conceptual Understanding category of the CLASS between the beginning and end of the semester of high school physics when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA will be observed.
6. A medium effect size in physics epistemological beliefs in the Applied Conceptual Understanding category of the CLASS between the beginning and end of the semester of high school physics when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA will be observed.
7. A medium effect size in physics epistemological beliefs in the Problem Solving General category of the CLASS between the beginning and end of the semester of high school physics when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA will be observed.
8. A medium effect size in physics epistemological beliefs in the Problem Solving Confidence category of the CLASS between the beginning and end of the

semester of high school physics when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA will be observed.

9. A medium effect size in physics epistemological beliefs in the Problem Solving Sophistication category of the CLASS between the beginning and end of the semester of high school physics when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA will be observed.

Colorado Learning Attitudes about Science Survey (CLASS)

The CLASS is a 42-item, eight-category, Likert-scale survey "probing students' beliefs about physics and physics learning and distinguishing the beliefs of experts from those as novices" (Adams et al., 2006, p.1). The CLASS provided self-reported information about students' physics epistemological beliefs. Due to the wide applicability of the CLASS, the researcher used the survey with high school students in order to determine their physics epistemological beliefs. The 42 items on the CLASS are disaggregated into eight categories: Real World Connections, Personal Interest, Sense Making/Effort, Conceptual Understanding, Applied Conceptual Understanding, Problem Solving General, Problem Solving Confidence, and Problem Solving Sophistication.

Adams et al. (2006) checked the CLASS for validity and reliability. Specifically, the developers of the CLASS examined face validity, construct validity, concurrent validity, and predictive validity. Face validity was established through interviews with physics faculty as well as students for clarity of statements. Surveys were also administered to examine content of statements. Construct validity was established by administering the CLASS to thousands of students and using factor analysis to statistically determine the categories. Predictive validity was validated through the correlation of students' beliefs and prior physics performance. Concurrent validity was verified by analyzing students' responses to ensure it measures what it is supposed to. Reliability was tested on survey responses in fall 2004 and spring 2005. The Cronbach's α values were 0.98 for agree and disagree whereas neutral was 0.88 (Adams, et al., 2006). The neutral value is lower than the agree and disagree responses due to several possible reasons.

The CLASS provided information about high school students' physics epistemological beliefs as well as what factors influence them. According to Ding and Zheng (2016), "The CLASS is designed specifically for the use in physics to gauge participants' epistemological views about physics and learning physics" (p. 3).The outcome variable in this study were high school students' physics epistemological beliefs as measured overall and for each of the following sections of the CLASS: Real World Connections, Personal Interest, Sense Making/Effort, Conceptual Understanding, Applied Conceptual Understanding, Problem Solving General, Problem Solving Confidence, and Problem Solving Sophistication. The covariates in this study were gender, grade/age, socioeconomic status, ethnicity, and GPA. Participants' pretest and posttest scores for each section of the CLASS, as well as overall scores, were matched. Participants also provided information regarding gender, ethnicity, and grade. Information related to socioeconomic status and GPA at the beginning of the school year were obtained through the guidance department at the high school.

Sample

The quantitative sample was 52 students taking College Physics and AP Physics 1during the 2017-2018 school year. Only juniors or seniors were able to sign up for

College Physics or AP Physics 1. The sample consisted of males and females who signed up for either physics course. These urban high school students had differing racial and socioeconomic backgrounds. An assortment of grade points averages, from the previous school year, were represented by these students.

Data Collection

A quantitative methodological approach employed in this study. In this case, the researcher wanted to determine the extent to which epistemological beliefs of students varied from the beginning of high school physics and compare it to their physics epistemological beliefs after 11 weeks of physics instruction. The CLASS was administered at the beginning of the school year, as well as after 11 weeks of high school physics instruction to determine high school students' physics epistemological beliefs.

Students who took College Physics and AP Physics 1 covered similar topics within the mechanics domain of physics. During the timeframe of this study, students in College Physics and AP Physics 1 covered vectors, kinematics, and projectile motion. In order to better understand the topics covered in those physics classes, the curricula for College Physics and AP Physics 1 were included in this study. Regardless of the level of physics, the instruction students received was similar and included lecture, solving physics problems, and conducting physics experiments by the same Pennsylvania certified physics teacher.

Students in both first-year physics courses were administered the CLASS after permission was obtained from parents/guardians and students also signed informed consent documentation. Prior to taking the CLASS, students received directions from the physics teacher to thoroughly read each statement and to select the number to which their beliefs correspond at the current time. Students were told that a 1 on the CLASS corresponds to strongly disagree and a 5 to strongly disagree. Furthermore, students were encouraged to answer all questions based on their current beliefs regarding physics. Students were also aware that they have the entire class period, of 40 minutes, to answer the survey. Students took the CLASS electronically during physics class in one class period through SurveyMonkey®. Although Adams et al. (2005) claimed that the survey only takes ten minutes to complete, students were given an entire class period, if necessary, to ensure they read all statements thoroughly. Some students took as little as ten minutes whereas other students took more than 30 minutes. After students completed the CLASS, they exited out of the survey and continued with solving physics problems independently as to not both other students. The teacher remained at his desk until all students completed the CLASS in order to not influence the students during the administration.

Data Analysis

Scoring of the CLASS was done by calculating the percent favorable, where the student's response agrees with the expert, or percent unfavorable, where the student's response disagrees with the expert. These individual scores from each item were then averaged to determine overall average percent favorable score. Each category was also examined in terms of favorable scores. CLASS survey results were analyzed by comparing overall pretest and posttest results as well as pretest and posttest results in each category. Analysis of the data collected and interpreted from the CLASS was conducted using the most recent version of SPSS (Statistical Package for the Social Sciences).

Descriptive statistics were determined for each of the controlling variables and reported in terms of overall in category and as a percentage. The mean and standard error were determined overall, and for each separate category of the CLASS, at the beginning of the semester when controlling for gender, grade/age, ethnicity, socioeconomic status, and GPA. The mean and standard error were calculated for pretest and posttest data of the CLASS to determine the overall percent favorable as well as percent favorable in each category. The means were utilized in order to determine the extent overall which scores varies between the administrations.

The results from this study were statistically analyzed using repeated measures ANOVA because the same students took the CLASS prior to and after 11 weeks of high school physics instruction (Huck, 2012; Field, 2009). In this study, students were given the CLASS before any high school physics instruction. Students then had 11 weeks of high school physics instruction in a formal class by a Pennsylvania certified physics teacher. After 11 weeks of high school physics instruction, students were again given the CLASS.

With the repeated measured test, there are multiple criteria that must be met. The first criterion that must be met is the independence clause. In this study, because students answered the survey on their own during school hours, students' scores should not be influenced by others, so the independence clause was met. The other criteria, homogeneity, sphericity, and multivariate normality were tested using SPSS.

Statistical Assumptions

The researcher examined the statistical data from the repeated measures ANOVA for statistical significance using $\alpha = 0.05$. If the p value for the overall score, and scores for each category, on the CLASS was less than 0.05, then the result was deemed statistically significant. However, if the *p* value for the overall scores, and scores for each category of the CLASS was greater than 0.05, then the researcher determined the result to not be statistically significant.

The researcher acknowledged there is a difference between statistical significance and practical significance. Even if statistical significance is obtained, that does not guarantee usefulness or practical significance (Vacha-Haase, 2001). Effect size describes the size of the difference between the groups.

Partial eta squared values (η_p^2) were calculated to examine effect sizes. According to Olejnik and Algina (2003), studies that utilize one or more repeated measures ANOVA should report partial eta squared values. The Statistical Package for the Social Sciences (SPSS) version 23 was used to calculate partial eta squared values for the researcher. According to Cohen (1988), partial eta squared values of 0.01 or less were considered small, values of 0.06 or less were considered medium, and values of 0.14 or greater were considered large effect sizes.

Warner (2013) suggested using Cohen's *d* to calculate the effect size, since that calculation is independent of the sample size. Cohen (1988) has classified effect sizes as small (d = 0.20), medium (d = 0.50), and large (d = 0.80). According to Maxwell and Delaney (2004), effect sizes should be used to compare studies with different designs; previous studies utilized Cohen's *d* to determine effect sizes. The researcher calculated Cohen's *d* values through the formula provided by Cohen (1988):

$$d = 2[\sqrt{(\eta_p^2/(1- \eta_p^2)}] \text{ (p.276)}$$

However, Lakens (2013) suggested that Cohen's d_{rm} should be calculated for a within - subjects design, because Cohen's *d* does not provide information regarding the study's design.

With α = 0.05, and β = 0.20, in order to have a small effect size, 85 students would be necessary, whereas to have a medium effect size, 15 students would be necessary (Faul, Erdfelder, Buchner, & Lang, 2013). This was determined due to having nine outcome variables: overall scores of the CLASS as well as scores for each category. This study had 52 participants, so a medium effect size was possible.

Summary

This study employed a quantitative methodology to examine high school students' physics epistemological beliefs. More specifically, this study utilized the Colorado Learning Attitudes about Science Survey (CLASS) to determine what physics epistemological beliefs students have regarding physics when controlling for gender, grade/age, socioeconomic status, ethnicity, and GPA. Students in this study were high school juniors and seniors taking physics for the first time in an urban high school in southeastern Pennsylvania. These students were administered the CLASS prior to any physics instruction at the beginning of the 2017 school year. Students were then administered the CLASS after 11 weeks of high school physics instruction. The hypothesis was that after physics instruction students' physics epistemological beliefs will change, both overall and in each category of the CLASS. The researcher predicted a medium effect size, based on previous studies as well as the sample size. In addition, the factors of gender, grade/age, socioeconomic status, ethnicity, and GPA were examined to see if any were correlated to physics epistemological beliefs. In order to determine the extent to which physics epistemological beliefs varied, as well as the potential factors that influenced them, the data from the CLASS was analyzed using a repeated measures ANOVA.

CHAPTER 4

RESULTS

The present study was conducted in order to determine the extent to which high school students' school students' physics epistemological beliefs varied after 11 weeks of physics instruction. While students have general, domain-general, and domain-specific epistemological beliefs, this study focused on students' physics epistemological beliefs in high school. After students' first physics course, there is a sharp decline in physics enrollment (Orzel, 2015). According to Slaughter et al. (2011), a potential reason for this decline in interest and enrollment may be due to the negative beliefs formed in high school physics due to their physics experiences. Thus, high school physics becomes a critical time to determine students' physics epistemological beliefs. After this first experience with physics, students will make decisions based on that experience and the beliefs they formed during that experience. Additionally, the researcher believed that other factors, such as gender, ethnicity, socioeconomic status, grade and grade point average (GPA) also could be associated students' beliefs and need to be examined.

Therefore, the focus of the present study was to examine high school students' physics epistemological beliefs utilizing the Colorado Learning Attitudes about Science Survey (CLASS) while controlling for gender, ethnicity, socioeconomic status, grade, and GPA. The CLASS is a Likert scale survey comprised of 42 questions that measures physics epistemological beliefs to which students can answer from strongly agree to strongly disagree. The questions of the CLASS were divided into the following eight categories, according to Adams et al. (2006): Sense Making/Effort, Personal Interest, Real World Connection, Conceptual Understanding, Applied Conceptual Understanding, Problem Solving General, Problem Solving Confidence, and Problem Solving Sophistication.

This study was conducted specifically to determine the change in epistemological beliefs as measured by the extent to which overall pretest and posttest scores differed when utilizing the CLASS while controlling for gender, ethnicity, socioeconomic status, grade, and grade point average (GPA). This study also examined to what extent pretest and posttest scores varied in each category of the CLASS while controlling for gender, ethnicity, socioeconomic status, grade, and GPA.

Since students' physics epistemological beliefs can be measured using the CLASS, the CLASS becomes a useful tool in determining what students' physics epistemological beliefs are, regardless of the setting. It is important to know what students' physics epistemological beliefs are since they influence the future decisions students make regarding physics. If it can be established that pretest and posttest scores on the CLASS vary by a large degree, then further examination needs to be considered as to why. In addition, it also becomes significant as to whether the variations are positive or negative and if the controlling variables are potential causes for this variation. Furthermore, by determining students' physics epistemological beliefs upon entering high school physics and after physics instruction, the curriculum and instruction students experienced in high school physics might also merit future exploration.

Descriptive Statistics

This study on high school students' physics epistemological beliefs was conducted at an urban high school in southeastern Pennsylvania. Although the high school contained over one thousand students in grades 10-12, students are not required to take physics to graduate. Therefore, students that take physics elect to do so, which could influence this study's results by limiting student responses to those with an interest in physics. Prior to the beginning of the 2017-2018 school year, approximately 125 students selected to take either College Physics or AP Physics 1, both introductory physics courses, during either their junior or senior years in high school. Based on the course the students chose, they received a different curriculum. While the curricula for College Physics and AP Physics 1 differed, the main topics were similar: vectors, kinematics, and projectile motion. Students traversed through this curriculum with a certified physics teacher who has five years of experience teaching physics. Students received the physics curricula through lecture, problem solving, and experimentation; traditional methods for teaching physics taught by the same physics teacher.

The study began with 54 students in grades 11 or 12 taking either College Physics or AP Physics 1. Typical physics class size ranged from as low as eight students to as high as 28 students. Class size was determined by administration prior to the school year based on teacher and student schedules. Two students were eliminated from the study because one student did not complete both the pretest and posttest and the other student transferred out of the physics course during this timeframe. Therefore, this study had 52 students completing the pretest at the beginning of the school year and the posttest after 11 weeks of physics instruction either from the College Physics or AP Physics 1 curricula. Students and their parent/guardian elected to participate in the pretest and posttest by signing permission slips. Students were not obligated nor coerced into participation; this study was also not factored into any grades. Therefore, the results obtained should reflect students' true physics epistemological beliefs.

Certain factors, such as gender, socioeconomic status, ethnicity, grade level, and GPA, have been questioned as to their correlation to students' physics epistemological beliefs. Therefore, this study controlled for the aforementioned factors. Table 5, below, shows the descriptive statistics relating to the controlled factors for the participants in this study.

Table 5

Descriptive Statistics of the Controlling Factors

Controlling Factors	Number of Students	Percentage of Sample
Gender		
Male	30	57.7
Female	22	42.3
Socioeconomic Status		
Economically Disadvantaged	18	34.6
Not Economically Disadvantaged	34	65.4
Ethnicity		
White	31	59.6
African American	4	7.7
Latino/Hispanic	11	21.2
Other	6	11.5
Grade		
11th	38	73.1
12th	14	26.9
GPA binned		
Above 4.40	3	5.77
3.20-4.40	43	82.7
2.00-3.20	6	11.5
Below 2.00	0	0

Socioeconomic status was defined as being economically disadvantaged or not. The same criteria to determine economically disadvantaged as Conley et al. (2004) utilized, was implemented in this study; if students received free or reduced lunch, they were considered economically disadvantaged, if not, then they were not considered economically disadvantaged. The students' GPA upon entering the 2017-2018 school year was used. GPA, a continuous variable, was categorized into four categories, using visual binning in SPSS.

Analysis of the Data

In this study, the same subjects were given the CLASS prior to and after 11 weeks of high school physics instruction during their physics class in school. Because this was a within-subjects study, a repeated measures ANOVA was utilized in order to answer the research questions and to determine effect size. Means from the pretest and posttest scores were calculated using the repeated measures ANOVA. The means were utilized to answer the research questions relating to the overall extent of which scores varied as well as the extent to which scores varied in each category of the CLASS. Effect sizes were also obtained from the repeated measures ANOVA.

Statistical Assumptions for Repeated Measures

Since this study utilized a repeated measures ANOVA, certain assumption must be met. According to Field (2009), the assumptions for a repeated measures design are independence, multivariate normality, and sphericity. Homogeneity was also tested in order to determine if the variances among the variables were similar. Outliers, which would influence results, were also examined using Cook's distance and standardized residual values.

The independence assumption was met without any statistical tests. This assumption requires that students answer the questions without assistance and is not influenced by others. Students in this study completed the pretest and posttest during their physics class while the teacher remained silent and at his desk. All students had the same physics teacher and were not clustered. Therefore, students' answers should not have been influenced by others and the assumption of independence was met.

The second assumption of equal variances was tested using Levene's test. Results of the Levene's test, in Table 6, below, were not significant for any of the variables so the assumption of homogeneity is met. In all cases, as per the Levene's test, homogeneity was met so the variables have equal variance.

Table 6

Levene's Test Results for CLASS Categories

Category of the CLASS	$F(24,27)$	p
Real World Connections		
Pretest	.83	.667
Posttest	.69	.821
Sense Making/Effort		
Pretest	.85	.659
Posttest	1.62	.112
Personal Interest		
Pretest	.88	.622
Posttest	.80	.704
Conceptual Understanding		
Pretest	1.83	.065
Posttest	1.68	.096
Applied Conceptual Understanding		
Pretest	1.63	.110
Posttest	1.21	.313

Table 6-continued

Problem Solving General		
Pretest	.85	.660
Posttest	.53	.940
Problem Solving Confidence		
Pretest	.95	.548
Posttest	.51	.951
Problem Solving Sophistication		
Pretest	1.17	.345
Posttest	1.34	.230

The third assumption, when utilizing the repeated measures ANOVA, was sphericity. This study examined the extent to which the pretest and posttest scores varied on each of the nine constructs. Therefore, there were only two conditions. According to Field (2009), "if you have a repeated-measures variable that only has two levels, then sphericity is met" (p. 561). Thus, sphericity was met because there were only two conditions: pretest and posttest.

The fourth assumption of multivariate normality was tested using the Kolmogorov-Smirnov test, as well as analyzing histograms. Table 7, below, shows the results of the Kolmogorov-Smirnov test results. The third condition of normality, a sample size greater than 30, was met in all categories of the CLASS since the sample size was 52. In all cases, the histograms also showed normality.

Table 7

Kolmogorov-Smirnov Test Results for Categories of the CLASS

Category of the CLASS	*D*(52)	*p*
Real World Connections		
Pretest	.14	.013
Posttest	.19	<.001
Sense Making/Effort		
Pretest	.12	.050
Posttest	.13	.041
Personal Interest		
Pretest	.09	.200
Posttest	.12	.051
Conceptual Understanding		
Pretest	.07	.200
Posttest	.11	.197
Applied Conceptual Understanding		
Pretest	.08	.200
Posttest	.11	.100
Problem Solving General		
Pretest	.12	.074
Posttest	.11	.180
Problem Solving Confidence		
Pretest	.18	<.001
Posttest	.18	<.001

Table 7-continued

Problem Solving Sophistication		
Pretest	.12	.065
Posttest	.11	.200

Because of the deviation from normality in several of the mean scores, the influence of outliers needed to be tested. In order to test for outliers, standardized residuals and Cook's distance were calculated. Standardized residuals were utilized because "the residuals that were converted to z-scores can be used for comparison against universal guidelines as to what is acceptable or unacceptable" (Field, 2009, p. 306). Below, in Table 8, are the standardized residual scores, as well as the Cook's distances. According to Stevens (1984), "to determine whether an outlier is influential, Cook's distance needs to be used" (p. 337). Cook's distance examines how one case can influence a model and values greater than one are concerning, according to Cook and Weisberg (1982). Below, in Table 8, are the standardized residual scores, as well as the Cook's distances.

Table 8

Tests for Outliers

Category of the CLASS	Minimum Standardized Residual	Maximum Standardized Residual	Minimum Cook's Distance	Maximum Cook's Distance
Real World Connections				
Pretest	-1.91	1.63	.00	.25
Posttest	-2.74	1.86	.00	.31

Table 8-continued

Sense Making/Effort				
Pretest	-2.02	2.00	.00	.29
Posttest	-2.27	1.76	.00	.27
Personal Interest				
Pretest	.00	.15	.00	.32
Posttest	-1.98	2.66	.00	.15
Conceptual Understanding				
Pretest	-2.07	1.77	.00	.26
Posttest	-2.15	1.99	.00	.20
Applied Conceptual Understanding				
Pretest	-2.13	1.98	.00	.38
Posttest	-1.99	2.18	.00	.21
Problem Solving General				
Pretest	-2.20	1.76	.00	.18
Posttest	-1.84	2.41	.00	.22
Problem Solving Confidence				
Pretest	-1.84	2.41	.00	.18
Posttest	-2.23	2.30	.00	.18
Problem Solving Sophistication				
Pretest	-2.17	2.28	.00	.43
Posttest	-1.85	2.07	.00	.20

Furthermore, because the standardized residuals and Cook's distance for all of the categories of the CLASS did not indicate specific outliers, it is assumed that the data is normal and no data was removed.

Results

A repeated measures ANOVA was performed in order to determine the extent to which pretest and posttest scores varied on the CLASS overall. The overall results between the pretest and posttest scores overall were significant, $F(1, 43) = 5.85$, $p = .020$, $\eta_p^2 = 0.12$, $d = .74$, $d_{rm} = .51$. Comparing the estimated marginal means between the first administration (the pretest) and second administration, the estimated marginal mean increased by 0.15, $M_1 = 3.11$, $SE_1 = .07$ and $M_2 = 3.26$, $SE_2 = .07$. Thus, the extent to which the overall pretest and posttest scores differed was by +0.15. Between the first administration and the second administration, overall scores in physics epistemological beliefs for 29 out of the 52 students increased.

The between-subject factors of gender, ethnicity, socioeconomic status, grade level, and GPA were also examined with respect to pretest and posttest scores. Gender was determined to not be associated the two administrations, $p = .276$, $\eta_p^2 = .03$, $d = .33$. Ethnicity was also found to be not significant, $p = .538$, $\eta_p^2 = .05$, $d = .45$. The third factor, socioeconomic status, was determined to be not significant, $p = 0.193$, $\eta_p^2 = 0.04$, $d = .40$. Grade level was also not significant when examining overall pretest and posttest scores, $p = .328$, $\eta_p^2 = .02$, $d = .30$. Grade point average when entering physics was also found to be not significant, $p = .128$, $\eta_p^2 = .09$, $d = .63$. Therefore, the factors of gender, ethnicity, socioeconomic status, grade level, and GPA were determined to not be associated with pretest or posttest overall scores of the CLASS.

Univariate Analysis for Each Section of the CLASS

In order to answer the other research questions a univariate analysis was conducted for each of the eight categories of the CLASS. Sphericity was assumed since there were only two administrations.

To answer the research questions regarding the extent to which pretest and posttest scores in each category of the CLASS differed, the estimated marginal means were examined. The means for each category, as well as the standard error and standard deviations are in Table 9, below.

Table 9

Mean, Standard Error, and Standard Deviation CLASS Categories

Categories of the CLASS	*M*	*SE*	*SD*
Real World Connections			
Pretest	3.04	.12	.45
Posttest	3.10	.08	.36
Sense Making/Effort			
Pretest	3.14	.09	.33
Posttest	3.15	.08	.32
Personal Interest			
Pretest	3.41	.14	.54
Posttest	3.56	.13	.53
Conceptual Understanding			
Pretest	2.62	.01	.52
Posttest	2.78	.17	.75
Applied Conceptual Understanding			
Pretest	2.91	.12	.44
Posttest	3.21	.14	.63
Problem Solving General			
Pretest	3.40	.08	.29
Posttest	3.52	.09	.33
Problem Solving Confidence			
Pretest	3.32	.11	.38
Posttest	3.61	.09	.32
Problem Solving Sophistication			
Pretest	3.04	.10	.36
Posttest	3.18	.11	.46

Figure 2, below, depicts this information graphically, with series 1 being the pretest and series 2 being the posttest.

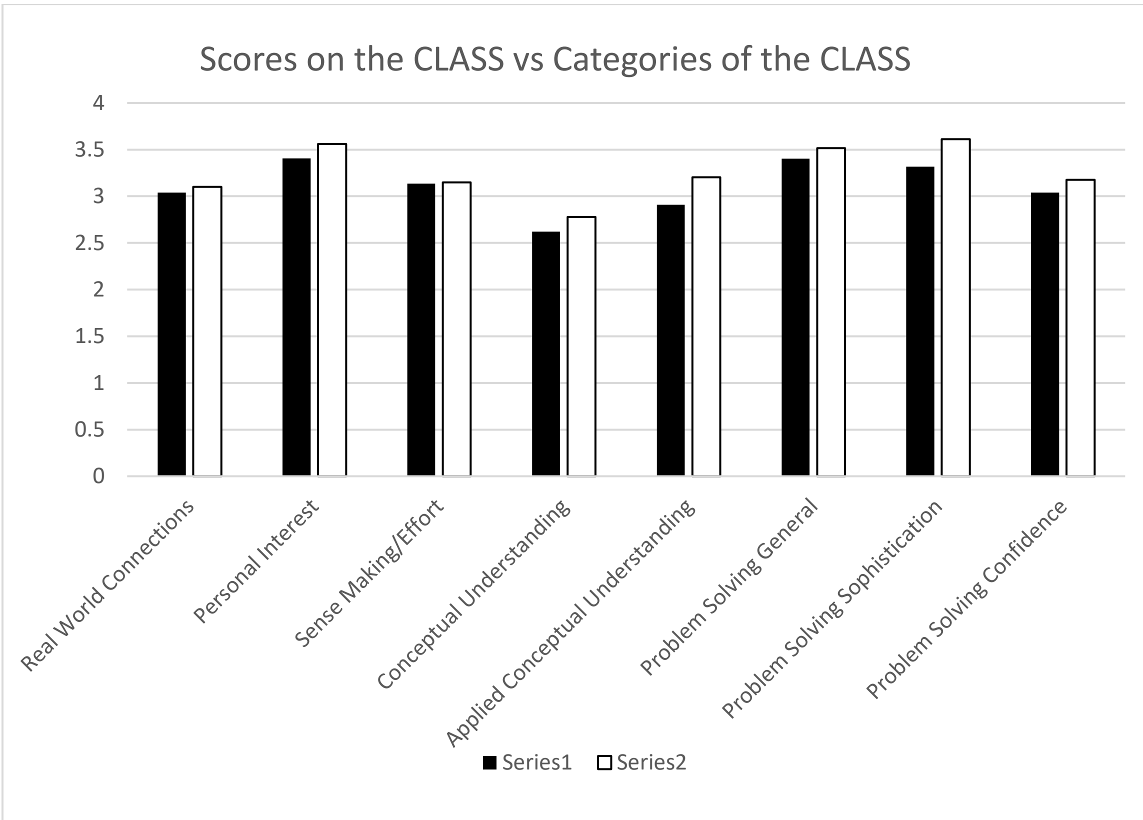

Figure 2. Scores on the CLASS vs. Categories of the CLASS

Table 10, below, displays the extent to which pretest and posttest mean scores varied in each category of the CLASS as well as the corresponding effect sizes. Additionally, Table 10 also provides information regarding how many students' physics epistemological beliefs became more expert-like in each category.

Table 10

CLASS Category Effect Sizes and Score Variations

CLASS Category	p	η_p^2	d	d_{rm}	Change in Pretest and Posttest Cores	Students with More Expert-like Beliefs*
Real World Connections	.588	.01	.17	.14	.06	18
Sense Making/Effort	.902	.00	.00	.03	.01	23
Personal Interest	.199	.04	.38	.33	.15	20
Conceptual Understanding	.220	.04	.38	.31	.16	18
Applied Conceptual Understanding	.019	.12	.74	.63	.30	30
Problem Solving General	.276	.03	.34	.32	.12	30
Problem Solving Confidence	.010	.15	.83	.70	.29	27
Problem Solving Sophistication	.226	.03	.38	.34	.14	23

*Out of 52 students

Summary

Results from the repeated measures ANOVA showed posttest scores overall, and in each category of the CLASS, were higher than pretest scores. Results regarding statistical significance and effect size were also calculated overall. Posttest scores in each category of the CLASS were higher than pretest scores. Results regarding statistical significance and effect size for each category of the CLASS were also calculated.

The between-subject factors of gender, ethnicity, socioeconomic status, grade level, and GPA were fixed factors in the repeated measures ANOVA. None of these factors were deemed significant when examining the extent to which pretest and posttest scores differed overall between the administrations. All of these results, including practical significance, are discussed in the next section. Also discussed in Chapter 5 are implications for practice and suggestions for further research.

CHAPTER 5

FINDINGS, CONCLUSIONS, AND IMPLICATIONS

This study focused on high school students' physics epistemological beliefs prior to and after 11 weeks of traditional high school physics instruction at an urban high school in southeastern Pennsylvania. Fifty-two students, taking their first introductory physics course in either AP Physics 1 or College Physics, participated in the study. The research questions in this study examined the extent to which pretest and posttest scores varied by utilizing the Colorado Learning Attitudes about Science Survey (CLASS). The CLASS is a 42-item survey developed by researchers at the University of Colorado to measure physics epistemological beliefs. The 42 items were grouped into the following eight categories: Real World Connection, Sense Making/Effort, Personal Interest, Conceptual Understanding, Applied Conceptual Understanding, Problem Solving General, Problem Solving Sophistication, and Problem Solving Confidence. Based on the scores of the CLASS, students can be labeled on a continuum as more novice-like or more expert-like in terms of their physics epistemological beliefs.

Revelations in Physics Epistemological Beliefs

High school students' physics epistemological beliefs were measured twice; one at the beginning of the school year and once after 11 weeks of traditional physics instruction by one physics teacher. The students' physics epistemological beliefs were analyzed on a novice-like to expert-like continuum to determine if they were more novice-like or more expert-like after 11 weeks. Novices view knowledge as fragmented and incoherent whereas experts perceive knowledge as related and coherent (Gray, Adams, Wieman, & Perkins, 2008; Larkin, McDermott, Simon, & Simon, 1980; Larkin, 1983).

Pretest and Posttest Score Variance Overall

The first research question asked to what extent to pretest and posttest scores vary overall on the CLASS. The results demonstrated a difference in pretest and posttest scores of .15. Practically, these results showed 29 out of 52 students becoming more expert-like in their physics epistemological beliefs after receiving traditional physics instruction in high school. This result differs from the previous literature when traditional instruction was the preferred instructional method. Below, in *Figure 3*, is a comparison of study's overall pretest/posttest results and previous studies results, when traditional instruction was utilized.

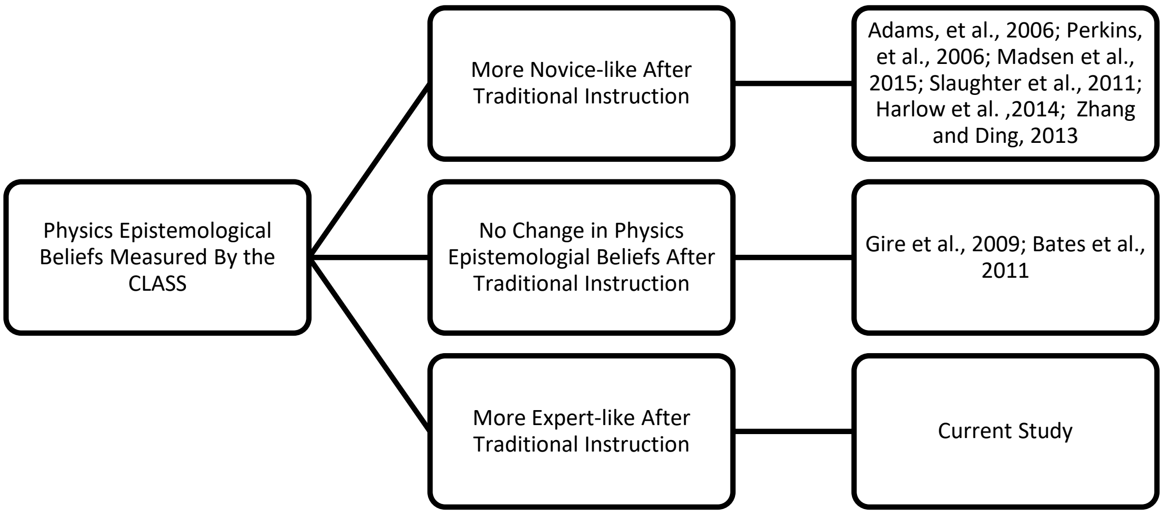

Figure 3. Comparison of Studies that Utilized the CLASS

This study illustrated that high school students can have positive shifts in their physics epistemological beliefs. Additionally, this study also revealed that it is possible to assist students in forming positive physics epistemological beliefs while in high school, which Madsen et al. (2015) found to be important to future physics study. Students' epistemological sophistication did not increase in previous studies that utilized traditional instruction. Rather, students either had no shifts in physics epistemological beliefs or they became more novice-like after traditional instruction.

In terms of effect size, as measured in previous studies with Cohen's *d*, the studies ranged from little effect to large effect when examining overall mean scores between pretests and posttests. Previous studies that had medium-to-large effect sizes utilized nontraditional instruction in college settings, like modeling and peer instruction (Brewe et al., 2009; Otero & Gray, 2010; Lindsey et al., 2012; Brewe et al., 2013). However, this study utilized traditional instruction in a high school setting. This study demonstrated that there was both statistical significance and medium effect size between pretest and posttest scores overall. The statistical significance was p = .020, and the effect size was d = .74. According to Cohen (1992), d = .74 corresponds to a medium effect. Similarly, Cohen's d_{rm} and partial eta squared values also depicted a medium effect size for this study. From that, it can be determined that the administrations of the pretest and the posttest have both statistical significance and a statistical effect. No published high school studies have determined effect size, but the medium effect size suggested that posttest scores have a greater probability of being higher than pretest scores. This study also demonstrated that students' physics epistemological sophistication can increase even during their first formal physics class and posttest scores have a probability of being higher than pretest scores, after 11 weeks of high school physics instruction, regardless of the curricula.

Pretest and Posttest Score Variance Each Category of the CLASS

Each of the following research questions asked to what extent each category of the CLASS varied between pretest and posttest administrations. The Real World Connection's category scores increased by .07, which indicated a 1.4% change. The posttest was greater than the pretest in the Personal Interest category by .15, which indicated a 3.0% growth. In the Sense Making/Effort category, the posttest was slightly greater than the pretest mean by .01, which demonstrated a growth in physics epistemological sophistication of 0.2%. The Conceptual Understanding category increased by .16, which indicated an increase in expert-like beliefs of 3.2%. In the Applied Conceptual Understanding category, the mean increased by .30, which equated to a growth in epistemological sophistication of 6.0. The scores from the pretest and posttest increased in the Problem Solving General category by .11, which equated to an increase in expert-like beliefs of 2.2%. In the Problem Solving Sophistication category of the CLASS, the posttest scores were .14 higher than the pretest scores, which meant that 2.8% of the students grew in their epistemological sophistication. The Problem Solving Confidence category also had increases in scores from pretest to posttest by .30; 6.0% of the students became more expert-like. All categories of the CLASS saw increased mean scores from the pretest, which was administered at the beginning of the school year, to posttest scores, which was administered after 11 weeks of physics instruction in a high school setting.

The results of this high school study on physics epistemological beliefs were comparable in some areas of similar college studies but differed in others. Milner-Bolotin, Antimirova, and Petro (2011) found that scores increased in the Real World Connections category, but scores decreased in the Problem Solving General and Sense Making/Effort categories. The results of this study are similar to that of Milner-Bolotin, Antirmirova, and Petro in the Real World Connections category, indicating a positive shift. However, the decreases in Problem Solving General and Sense Making/Effort were not observed in this study. Otero and Gray (2008) found with non-science majors, the highest positive shifts occurred in the Personal Interest, Problem Solving Sophistication, Conceptual Understanding, and Applied Conceptual Understanding categories. The participants in this study were not all potential science majors, since not all students in either College Physics or AP Physics 1 would study physics in college. Like Otero and Gray (2008), this study had the largest positive increases occurring in the Personal

Interest, Conceptual Understanding, and Applied Conceptual Understanding categories. In contrast, though, this study did not have the largest positive shift in the Problem Solving Sophistication category; it was in the Problem Solving Confidence category.

In terms of effect size for each category of the CLASS, Cohen's *d* values range from predicting a small to large effect size. The largest effect size was in the Problem Solving Confidence category and the smallest effect size was in the Sense Making/Effort Category. However, when Cohen's d_{rm} was calculated, the effect sizes in all categories were small-to-medium indicating that the administration has little effect on physics epistemological beliefs. Partial eta squared effect sizes displayed similar results; small-to-medium effect sizes in all categories.

Controlling Factors

This study also controlled for the factors of gender, ethnicity, socioeconomic status, grade, and GPA, and those results can be found in the Ancillary Results (Appendix E). None of these factors were statistically significant to the overall mean scores of the CLASS. Although Milner-Bolotin, Antimirova, and Petro (2011) did state that demographics could influence epistemological beliefs, it was not found to not be associated with overall physics epistemological beliefs in this study. The possibility exists that practically, some of the demographic features could influence the overall mean scores, due to the medium effect size.

Multiple researchers determined that demographic factors, like those investigated in this study, influenced physics epistemological beliefs. For example, Perkins et. al (2006) found that gender was influential on physics epistemological beliefs; men had more expert-like beliefs after a semester of instruction. Slaughter et al. (2011) found similar results regarding gender and physics epistemological beliefs. This study, in contrast, did not find gender to be statistically significant in neither the overall mean scores nor the mean scores in any category of the CLASS. This meant that being male or female did not correlate to more epistemological sophistication in any category of the CLASS. Therefore, both genders have the potential to achieve greater epistemological sophistication after physics instruction. Effect size values for gender and scores overall and for each category of the CLASS were deemed as small-to-medium indicating that gender could be associated physics epistemological beliefs.

Ding and Zhang (2016) found that grade and age made a difference in physics epistemological beliefs. However, in this study, grade level was found to not be statistically significant. It terms of effect size, *d* values ranged from 0.11-0.53, indicated a small-to-medium effect. With the small-to-medium effect size, the potential exists that grade could be correlated with students' physics epistemological beliefs.

The fixed factors of gender and grade/age and their influence on physics epistemological beliefs when utilizing the CLASS had already been examined in previous studies whereas the fixed factors of GPA, ethnicity, and socioeconomic status had not. Some researchers found that these factors influenced general epistemological beliefs. For example, Paulsen and Wells (1988) found that GPA influences general epistemological beliefs, as did Schommer (2000). In this study, GPA was determined to not significantly impact the overall mean scores on the CLASS nor the scores in any category. Effect sizes were determined to be small-to-medium both overall and for each category of the CLASS meaning that the potential could exist with different GPAs to have different physics epistemological beliefs. Conley et al. (2004) found that there was a direct correlation between socioeconomic status and general epistemological beliefs. In this study, socioeconomic status was not significant to the overall mean scores. However, socioeconomic status was found to be significant in the Problem Solving Sophistication category of the CLASS. That result indicated that students determined to be economically disadvantaged, as compared to those that are not, have significantly different scores in the Problem Solving Sophistication category of the CLASS. In terms of effect size, it was deemed that socioeconomic status had a small-to-medium effect on all categories of the CLASS as well as overall. This indicated that practically, socioeconomic status could have some association to students' physics epistemological beliefs. Conley et al. (2004) included ethnicity in their study because they cited the lack of information relating ethnicity and epistemological beliefs; they found no significant relationship between ethnicity and epistemological beliefs. The results of this study match Conley et al. (2004); no categories of the CLASS were associated with ethnicity. However, there was a large effect size of ethnicity on the Personal Interest category, meaning the probability of being white correlates to a greater Personal Interest in physics.

Practical Significance

The practical significance of this study was also examined. This study showed little correlation between any of the controlling variables and the categories of the CLASS. Therefore, the potential exists for all students, regardless of demographics, to become more expert-like in their physics epistemological beliefs during high school. This means that all students could become more expert-like in all areas of physics. In addition, the physics teacher in this study utilized traditional high school physics instruction. Because more expert-like beliefs were attained after traditional physics instruction, the potential exists for all students to become more expert-like in their physics epistemological beliefs. Physics education should examine this study and use if for reference to highlight how high school students' physics epistemological beliefs can become more expert-like in students' formal physics course in high school. Furthermore, although physics educators cannot agree on one superior form of instruction, the findings from this study demonstrated that high school students' physics epistemological beliefs can become more expert-like after receiving traditional instruction in the form of lecture, problem solving, and experimentation. Implications for practice were made based on the findings from this study.

Implications for Practice

Students develop beliefs from their perceptions and experiences (Furinghetti & Pehkonen, 2002). Students have perceptions about physics before a formal course, but their first formal experiences with physics tends to occur in high school. Madsen et al. (2015) stated that positive epistemological beliefs are formed in students' K-12 education. Because high school is the first-time students have a physics course, it becomes a critical time for the formation of physics epistemological beliefs. The results from this study demonstrated that students' physics epistemological beliefs can become more expert-like with traditional physics instruction in a high school in the United States. This is critical to physics epistemological belief formation of students. However, this is contradictory to many studies at the collegiate level that utilized traditional instruction. This study depicted that it is possible to assist students in forming more expert-like physics epistemological beliefs with traditional instruction as soon as they take their first physics course in high school.

The examination of the formation of physics epistemological beliefs in high school becomes important because, according to Slaughter et al. (2011), one potential reason for the decline in physics interest is due to negative beliefs formed in high school. This study also showed that students can become more expert-like in their overall physics epistemological beliefs, as well as specific areas, after 11 weeks of physics instruction. In this study, students' physics epistemological beliefs became more expert-like in all categories of the CLASS. The various categories of the CLASS describe students' conceptual understanding, problem solving skills, and personal interest in physics. By knowing that students' physics epistemological beliefs in all categories became more expert-like, it is hopeful that the trend of decreasing enrollment in higher level physics courses, as described by Orzel (2015), can be changed. This is particularly important due to the significant impact that a physics education has on society (American Institute of Physics, 2007).

Conley et al. (2004) suggested that personal factors could facilitate or constrain development of epistemological beliefs. This study examined the factors of gender, ethnicity, socioeconomic status, grade level, and GPA and found that gender, grade level, ethnicity and GPA were not statistically significant. However, socioeconomic status was correlated to Problem Solving Sophistication, with those students not being economically disadvantaged having more expert-like beliefs about problem solving. Because of the significance of socioeconomic status on physics epistemological beliefs, teachers need to determine if students receive free or reduced lunch and provide more opportunities and experiences within physics class to assist them in achieving epistemological sophistication.

Although statistical significance was determined between the pretest and the posttest on overall CLASS scores, effect size was also calculated between pretest and posttest scores. Because a medium effect was found, there is a noticeable significance between the posttest and pretest scores. Because high school students' physics epistemological beliefs became more expert-like after traversing a portion of the AP Physics 1 or College Physics curricula with a certified physics teaching utilizing traditional physics instruction, the potential exists that that either the curriculum or instruction, or both, influenced posttest scores, making them more expert-like. This is significant because in many previous studies, traditional instruction led to more novice-like beliefs; this study contradicted those studies done at the undergraduate level. This study also leads the researcher to believe that although traditional instruction did not positively influence physics epistemological beliefs in collegiate studies, it could be beneficial in high school setting, where students are first experiencing physics and form those initial epistemological beliefs (Muis et al., 2016).

This study, albeit with 52 students, set the benchmark for other studies that examine high school students' physics epistemological beliefs and multiple fixed factors that have not been related to physics epistemological beliefs, such as ethnicity and socioeconomic status. By knowing more information regarding high school students' physics epistemological beliefs and fixed factors such as gender, ethnicity, socioeconomic status, grade, and GPA, curriculum and instruction can be differentiated by the personal needs of students. Furthermore, the information about physics epistemological beliefs and these controlling variables can be utilized as comparisons in future studies.

Suggestions for Future Research

Because students develop their expert-like views in K-12 education, it is important to know what those views are, particularly when there is such a disparity between students taking physics for the first or second time (Madsen et al., 2015; Gire et al., 2007). Due to the lack of information regarding high school students' physics epistemological beliefs, more research needs to be conducted at the high school level. Although this study demonstrated that traditional instruction can assist students in achieving more expert-like physics epistemological beliefs, due to only having 52 students, it cannot be generalized that this will happen in all cases. Additionally, studies that can control for some of the threats to validity in this study would be beneficial. For example, history has the potential to influence this study; future studies could include qualitative portions to control for this. Additionally, maturation, could have been an impact in this study, since students should acquire more physics knowledge and experience after instruction. Another potential threat was utilizing the same test twice in order to measure physics epistemological beliefs; future research could examine this threat. A further threat to validity could have been experimenter expectation; this could be tested in the future by interviewing students regarding the CLASS.

More research needs on physics epistemological beliefs to be conducted in the United States. The only two published studies utilizing the CLASS at the high school level were in Croatia and China, neither of which were comparable to collegiate studies. Neither of which were comparable to this study.

In addition to more studies being conducted in high schools in United States, more studies need to be performed similarly to those done previously at the collegiate level. This study's research design was modeled after those collegiate studies in order to be comparable. The two previously published high school studies were not similar, and thus not comparable. The designs were different and did not provide effect sizes so neither statistical significance nor effect size could be examined. This implied that future studies in high school settings that utilize the CLASS should be given at the beginning of the semester and again at the end of the semester after physics instruction has occurred.

Future studies at the high school level also need to have effect size calculated. By calculating effect size, multiple studies with different designs and different sample sizes can be compared (Lakens, 2013). Effect sizes also provide information regarding practical significance, meaning whether the result is important or not in the practical world (Huck, 2012). Since effect size values were previously given in terms of Cohen's *d*, it is important that future studies utilize the same notation. However, because a repeated measures ANOVA was conducted in this study, partial eta squared values and Cohen's d_{rm} were also provided regarding effect size. According to Preacher and Kelly (2011), providing multiple effect sizes values allows for greater understanding; thus, future studies should follow this procedure if a repeated measures ANOVA is used for calculations.

Because this study demonstrated that students' physics epistemological beliefs increased after 11 weeks of traditional high school physics instruction, how that type of instruction was presented should be investigated. In addition, the effect that the instruction had on students should be investigated. Furthermore, as noted in previous collegiate studies, different types of instruction produced different results in terms of physics epistemological beliefs; this requires investigation at the high school level to ascertain if similar results would occur.

The curriculum that students received at the high school level merits investigation. Although the topics in College Physics and AP Physics 1 were similar, the rigor was not. This would require qualitative studies investigating how the rigor influenced students' physics epistemological beliefs. In addition, the curricula that high school students received during 11 weeks as compared to collegiate studies also warrants consideration, since the curriculum influences instruction.

Other qualitative studies should also be conducted on high school students' physics epistemological beliefs. Specifically, students should be questioned as to why they answered the survey a particular way or why they changed their answers from one administration to another. Additionally, students should be questioned as to how the instruction and curriculum influenced their answers on the CLASS. Studies could also be conducted in a high school setting to determine their future interest in physics and how that relates to physics epistemological beliefs, similar to that of Perkins et al. (2006).

Due to the paucity of studies related to physics epistemological beliefs and the fixed factors, such as gender, ethnicity, socioeconomic status, grade, and GPA, more studies need to incorporate those factors. Whether those are conducted qualitatively or quantitatively, more information research needs to be acquired on how those factors could potentially influence physics epistemological beliefs. Furthermore, if future studies show similar results to this study, with ethnicity and socioeconomic status influencing particular categories and not others, qualitative investigations should ensue.

An additional area for research would be to do multiple administrations of the CLASS throughout the year. This would provide more data regarding curriculum and instruction. Furthermore, it would also show how physics epistemological beliefs can change over time. It would also provide students multiple opportunities to express how they feel about physics. This information could be useful when students are trying to determine whether physics is going to be part of their future plans or not.

Summary

The present study was designed to determine the extent to which high school students' physics epistemological beliefs change after high school physics instruction. Because students' epistemological beliefs influence students' motivation and behaviors, it is important to know what those epistemological beliefs are (Buehl & Alexander, 2001; Garner & Alexander, 1994). By knowing how students' physics epistemological beliefs change over time, one is better able to predict whether students will continue taking physics in the future or not. This is important, not only for science, but also for society as a whole.

In order to measure high school students' physics epistemological beliefs, the Colorado Learning Attitudes about Science Survey (CLASS) was administered to students, both at the beginning of the school year and after 11 weeks of high school physics instruction. Fifty-two students, with differing demographic information, at an urban high school in southeastern Pennsylvania, participated in the study. The CLASS consists of 42 Likert scale questions where students could answer from strongly agree to strongly disagree. The 42 items were grouped the following eight categories: Real World Connection, Sense Making/Effort, Personal Interest, Conceptual Understanding, Applied

Conceptual Understanding, Problem Solving General, Problem Solving Sophistication, and Problem Solving Confidence (Adams et al., 2006).

Because students' epistemological beliefs are developed in K-12 education, but the factors that influence them are uncertain, this study included the controlling variables of gender, ethnicity, socioeconomic status, grade, and GPA (Madsen et al., 2015; Gire, Jones, & Price, 2007). Each one of these factors was examined in relation to the overall difference in pretest and posttest scores on the CLASS as well as how each factor influenced each category of the CLASS.

In order to answer the research questions, a repeated measures ANOVA was conducted. The extent of the difference between the overall mean scores between the pretest and the posttest was calculated using the repeated measures ANOVA. Additionally, what controlling factors were significant were also determined using the calculations from the repeated measures ANOVA. By examining the univariate results, each separate category of the CLASS was examined as to the extent pretest and posttest scores varied. In addition, each of the controlling variables was examined in order to see if it was correlated with any categories of the CLASS.

The posttest scores were greater than the pretest scores on the overall scores of the CLASS. In addition, there was statistical significant difference in these values, indicating that posttest values with significantly higher than pretest vales. In all categories of the CLASS, posttest scores were greater than pretest scores. However, for each of the categories of the CLASS, there was not a statistically significant difference between the posttest and pretest values. Medium effect sizes were determined overall, as well as in the categories of the CLASS.

Overall results of the pretest and posttest scores on the CLASS were not statistically significant in terms of any of the controlling variables. In fact, gender, grade, and GPA were not found to be statistically significant in any of the categories of the CLASS. Socioeconomic status was found to be statistically significant in the Problem Solving Sophistication category.

The researcher predicted a medium effect size, in terms of Cohen's *d*, based on effect size values from previous collegiate studies that utilized the CLASS. In most cases, the effect size was small-to-medium, confirming the researcher's prediction. While a large effect size was found in the Problem Solving Confidence category between pretest and posttest results using Cohen's *d*, Cohen's d_{rm} and the partial eta squared values depicted medium effect sizes. This indicated that students' physics problem solving confidence increased after 11 weeks of high school physics instruction. Additionally, a large effect size was found between ethnicity and the Personal Interest category, again with Cohen's *d*, indicating that different ethnic groups would have different interest in physics. Cohen's d_{rm} and partial eta squared values depicted medium effect sizes in this category also.

Although this study does provide some insight into high school students' physics epistemological beliefs, more research needs to be conducted (Zhang & Ding, 2013). The results did demonstrate that with traditional physics instruction in high school, students can attain more expert-like beliefs. In terms of the controlling variables of gender, ethnicity, socioeconomic status, grade, and GPA, only socioeconomic status was found to significant. Additionally, socioeconomic status was only significant in terms of Problems Solving Sophistication category of the CLASS. Therefore, "the factors that influence these beliefs have not been established and further research needs to be conducted with high school students and their physics epistemological beliefs with the controlling variables of gender, ethnicity, socioeconomic status, grade, and GPA (Gire et al., 2007). This study will add to the literature by providing information about high school students' physics epistemological beliefs when traditional physics instruction is utilized as well as the influence demographic factors such as gender, ethnicity, socioeconomic status, grade, and GPA have on those beliefs.

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APPENDICES

APPENDIX A

COLORADO LEARNING ATTITUDES ABOUT SCIENCE SURVEY

Colorado Learning Attitudes about Science Survey
http://www.colorado.edu/sei/surveys/Faculty/CLASS-PHYS-faculty.html
Adams et al. (2006)

Please put an X in the space that best describes you in each of the following categories.

1. Gender
    a. Male _______
    b. Female _____
2. Ethnicity
    a. White _
    b. African American _________
    c. Latino/Hispanic _____
    d. Asian or Pacific Islander __________
    e. Native American or American Indian ____________
    f. Other _______
3. Grade
    a. 11^{th} _________
    b. 12^{th} _________
4. Student ID number ________

Introduction

Here are a number of statements that may or may not describe your beliefs about learning physics. You are asked to rate each statement by selecting a number between 1 and 5 where the numbers mean the following:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Choose one of the above five choices that best expresses your feeling about the statement. If you don't understand a statement, leave it blank. If you have no strong opinion, choose 3.

Survey

1. A significant problem in learning physics is being able to memorize all the information I need to know.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

2. When I am solving a physics problem, I try to decide what would be a reasonable value for the answer.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

3. I think about the physics I experience in everyday life.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

4. It is useful for me to do lots and lots of problems when learning physics.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

5. After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

6. Knowledge in physics consists of many disconnected topics.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

7. As physicists learn more, most physics ideas we use today are likely to be proven wrong.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

8. When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

9. I find that reading the text in detail is a good way for me to learn physics.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

10. There is usually only one correct approach to solving a physics problem.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

11. I am not satisfied until I understand why something works the way it does.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

12. I cannot learn physics if the teacher does not explain things well in class.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

13. I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

14. I study physics to learn knowledge that will be useful in my life outside of school.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

15. If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

16. Nearly everyone is capable of understanding physics if they work at it.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

17. Understanding physics basically means being able to recall something you've read or been shown.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

18. There could be two different correct values for the answer to a physics problem if I use two different approaches.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

19. To understand physics I discuss it with friends and other students.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

20. I do not spend more than five minutes stuck on a physics problem before giving up or seeking help from someone else.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

21. If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

22. If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

23. In doing a physics problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

24. In physics, it is important for me to make sense out of formulas before I can use them correctly.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

25. I enjoy solving physics problems.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

26. In physics, mathematical formulas express meaningful relationships among measurable quantities.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

27. It is important for the government to approve new scientific ideas before they can be widely accepted.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

28. Learning physics changes my ideas about how the world works.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

29. To learn physics, I only need to memorize solutions to sample problems.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

30. Reasoning skills used to understand physics can be helpful to me in my everyday life.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

31. We use this statement to discard the survey of people who are not reading the questions. Please select agree-option 4 (not strongly agree) for this question to preserve your answers.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

32. Spending a lot of time understanding where formulas come from is a waste of time.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

33. I find carefully analyzing only a few problems in detail is a good way for me to learn physics.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

34. I can usually figure out a way to solve physics problems.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

35. The subject of physics has little relation to what I experience in the real world.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

36. There are times I solve a physics problem more than one way to help my understanding.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

37. To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

38. It is possible to explain physics ideas without mathematical formulas.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

39. When I solve a physics problem, I explicitly think about which physics ideas apply to the problem.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

40. If I get stuck on a physics problem, there is no chance I'll figure it out on my own.

Strongly Disagree 1 2 3 4 5 Strongly Agree

○ ○ ○ ○ ○ ◉ not answered

41. It is possible for physicists to carefully perform the same experiment and get two very different results that are both correct.

Strongly Disagree	1	2	3	4	5	Strongly Agree		
	○	○	○	○	○		◉	not answered

42. When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.

Strongly Disagree	1	2	3	4	5	Strongly Agree		
	○	○	○	○	○		◉	not answered

APPENDIX B

MERCER UNIVERSITY IRB APPROVAL

MERCER UNIVERSITY

Institutional Review Board
For Research Involving Human Subjects

Friday, July 14, 2017

Ms. Audrey D. Smeltzer-Schwab

1501 Mercer University Drive

Tift College of Education Macon, GA 31207-0001

RE: Physics Epistemological Beliefs of High School Students (H1706185)

Dear Ms. Smeltzer-Schwab:

On behalf of Mercer University's Institutional Review Board for Human Subjects Research, your application submitted on 30-Jun-2017 for the above referenced protocol was reviewed in accordance with Federal Regulations 21 CFR 56.110(b) and 45 CFR 46.110(b) (for expedited review) and was approved under category(ies) 7 per 63 FR 60364.

Your application was approved for one year of study on 14-Jul-2017. The protocol expires on 13-Jul-2018. If the study continues beyond one year, it must be re-evaluated by the IRB Committee. **Item(s) Approved:**

Initial Application- To determine high school students' physics epistemological beliefs at the beginning of the school year and a over a semester of instruction. Use of pre/post questionnaires via an online survey.

NOTE: Please report to the committee when the protocol is initiated. Report to the Committee immediately any changes in the protocol or consent form and **ALL** accidents, injuries, and serious or unexpected adverse events that occur to your subjects as a result of this study.

We at the IRB and the Office of Research Compliance are dedicated to providing the best service to our research community. As one of our investigators, we value your feedback and ask that you please take a moment to complete our Satisfaction Survey and help us to improve the quality of our service.

It has been a pleasure working with you and we wish you much success with your project! If you need any further assistance, please feel free to contact our office.

Respectfully,

Ava Chambliss-Richardson, Ph.D., CIP, CIM.

Associate Director of Human Research Protec on Programs (HRPP)

Member

Institutional Review Board

"Mercer University has adopted and agrees to conduct its clinical research studies in accordance with the International Conference on Harmonization's (ICH) Guidelines for Good Clinical Practice."

Mercer University IRB & Office of Research Compliance
Phone: 478-301-4101 | Email: ORC_Mercer@Mercer.Edu | Fax: 478-301-2329 1501 Mercer University Drive, Macon, Georgia 31207-0001

APPENDIX C

APPROVAL FROM THE UNIVERSITY OF COLORADO TO USE AND REPRINT THE CLASS

Email permission:

- **Kathy Perkins** <perkinsk@colorado.edu>
- Today at 3:35 PM

To

- kristab@jila.colorado.edu
- Kathy Perkins
- bluetiger313@yahoo.com

CC

- Wendy Adams
- Noah D Finkelstein

Message body

Hi Audrey,

Yes, you may re-print the questions in your dissertation as long as you give proper attribution, citing the original paper with Wendy Adams etc. as authors, and the University of Colorado Boulder.

All the best,

Kathy Perkins

On 2/21/2018 1:03 PM, Krista Beck wrote:

hi Kathy: I don't know who this goes to... you maybe?

thanks!

-------- Forwarded Message --------

Subject: Colorado Learning Attitudes about Science Survey-one more question

Date: Wed, 21 Feb 2018 19:20:14 +0000 (UTC)

From: Audrey Smeltzer <bluetiger313@yahoo.com>

To: Audrey Smeltzer <bluetiger313@yahoo.com>

To: kristab@jila.colorado.edu <kristab@jila.colorado.edu>, Wendy Adams <wendy.adams@colorado.edu>, finkelsn@colorado.edu <finkelsn@colorado.edu>

Good afternoon,

Thank you for getting permission to use the CLASS. I did use the CLASS to measure high school students' epistemological beliefs and I defended my dissertation today. I am writing to request permission to reprint the CLASS as an appendix in my dissertation, High School Students' Physics Epistemological Beliefs. Upon being granted this permission, I would be happy to share my results with you.

Also, I hate to be forward, but there are multiple dissertation deadlines at the beginning of March so I can graduate this May. That being said, if you could let me know as soon as possible regarding the permission to reprint the CLASS, I would greatly appreciate it.

Thank you

Audrey Smeltzer-Schwab

Mercer University

PhD Curriculum and Instruction

Class of 2018

Krista Beck <kristab@jila.colorado.edu>

02/02/17 at 10:22 AM To bluetiger313@yahoo.com

Message body

Dear Audrey: You have permission - you're all set!

best,

~Krista

-------- Forwarded Message --------

Subject: Re: Colorado Learning Attitudes about Science Survey

Date: Wed, 1 Feb 2017 23:13:54 +0000

From: Noah D Finkelstein <finkelsn@colorado.edu>

To: Krista K. Beck <kristab@jila.colorado.edu>

Sure .. all are welcome to use this instrument...

more questions could go to Wendy Adams <wendy.adams@colorado.edu>

hope this helps

hope you're well

n

On Feb 1, 2017, at 12:48 PM, Krista Beck <kristab@jila.colorado.edu> wrote:

Dear Noah: This woman would like to use your CLASS research for her thesis. Can you please send her permission, or should I send this along to someone else?

thank you!

~krista

-------- Forwarded Message --------

Subject: Colorado Learning Attitudes about Science Survey

Date: Wed, 1 Feb 2017 19:34:32 +0000 (UTC)

From: Audrey Smeltzer <bluetiger313@yahoo.com>

Reply-To: Audrey Smeltzer <bluetiger313@yahoo.com>

To: krista.beck@colorado.edu <krista.beck@colorado.edu>

Good afternoon,

I had called on the phone asking about the Colorado Learning Attitudes about Science Survey. I am a PhD student at Mercer University and I am working on my dissertation that will examine attitudes and beliefs of high school females regarding physics.
I would like to use the survey because I think it is applicable to what I am trying to measure. My university says that I need written permission from you to use the survey so that is why I am emailing you. I appreciate your help with this.

Audrey Smeltzer-Schwab

Mercer University

PhD Curriculum and Instruction 2018

APPENDIX D

APPROVAL FROM HIGH SCHOOL WHERE STUDY TOOK PLACE

August 23, 2017

Mercer University

IRB & Office of Research Compliance

1501 Mercer University Drive

Macon, GA 31207-0001

RE: **Doctoral Candidate**

Audrey D. Smeltzer-Schwab

Topic: **Physics Epistemological Beliefs of High School Students**

To Whom It May Concern:

This letter is in reference to Ms. Audrey D. Smeltzer-Schwab's request to conduct a survey at M High School (a pseudonym) as she begins the data acquisition stage of her dissertation entitled, Physics Epistemological Beliefs of High School Students. Ms. Schwab has provided all of the appropriate documentation and is permitted to conduct this survey.

If you have any questions, please feel free to contact me.

Sincerely,

Joseph E. Macharola, Ed.D.

Superintendent of Schools

APPENDIX E

ANCILLARY RESULTS

Ancillary Results

Because of the importance of physics in society, and the significance of physics epistemological beliefs on students' future study, the researcher chose to extend the study. The researcher hoped that the ancillary results would promote future studies relating to physics epistemological beliefs of high school students. The ancillary results from this study included the interaction between the administrations and the sections of the CLASS, the controlling factors and each category of the CLASS, and the controlling factors with the interaction of the administrations and each section of the CLASS.

Because there were nine separate research questions, and nine separate categories examined regarding the CLASS, sphericity was reexamined using Mauchly's test of sphericity. Mauchly's test indicated that the assumption for sphericity had been violated, $\chi^2(27) = 258.83$, $p = <.001$, therefore, the Greenhouse-Geisser corrected tests are reported ($\varepsilon = .30$). The results show that the different parts of the CLASS did significantly impact the scores for each section of the CLASS, $F(7, 301) = 9.58$, $p = <.001$, $\eta_p^2 = .18$, $d = .94$.

The interaction between the administrations and the sections of the CLASS was also examined. In order to determine if there was significance, sphericity needed to be examined. Because sphericity was violated, $\chi^2(27) = 139.35$, $p = <.001$, the Greenhouse-Geisser corrected tests are reported ($\varepsilon = .52$). The results show that the interaction between the administrations and the categories of the CLASS were not significant, $F(7, 301) = 1.04$, $p = .387$, $\eta_p^2 = .02$, $d = .31$.

With regards to the between-subject factors of gender, ethnicity, socioeconomic status, grade level, and GPA, none were determined to be significant to the overall extent of the difference in scores between pretest and posttest. The results are shown in Table E1, below.

Table E1

Controlling Variables and CLASS Overall Scores

Controlling Variable	*M*	*F*(1,43)	*p*	η_p^2	*d*
Gender	.95	1.22	.276	.03	.33
Socioeconomic Status	1.14	1.75	.193	.04	.40
Ethnicity	.73	.73	.538	.05	.45
Grade level	.85	.98	.328	.02	.30
GPA	1.26	2.15	.128	.09	.63

Each category of the CLASS was also examined in terms of each between-subjects factor. With regards to each category of the CLASS and gender, no category of the CLASS was significantly influenced by gender. The results for gender and each category of the CLASS are displayed in Table E2, below.

Table E2

Gender and Categories of the CLASS

Category of the CLASS	*M*	*F*(1,43)	*p*	η_p^2	*d*
Real World Connection	.68	2.16	.149	.05	.45
Sense Making/Effort	.11	.09	.761	.00	.00
Personal Interest	.09	.02	.890	.00	.00
Conceptual Understanding	.32	.19	.669	.00	.13
Applied Conceptual Understanding	.25	.16	.688	.00	.13
Problem Solving General	.39	1.09	.302	.03	.32
Problem Solving Confidence	.32	.57	.454	.01	.23
Problem Solving Sophistication	.74	2.76	.104	.06	.51

With regards to each category of the CLASS and ethnicity, no category of the CLASS was found significant in terms of ethnicity. The results for ethnicity and each category of the CLASS are shown in Table E3, below.

Table E3

Ethnicity and Categories of the CLASS

Category of the CLASS	*M*	*F*(3,43)	*p*	η_p^2	*d*
Real World Connection	.23	.25	.864	.02	.26
Sense Making/Effort	.37	.99	.410	.06	.52
Personal Interest	.96	2.31	.090	.14	.80
Conceptual Understanding	.59	.62	.609	.04	.41
Applied Conceptual Understanding	.55	.81	.495	.05	.47
Problem Solving General	.09	.07	.976	.01	.14
Problem Solving Confidence	.16	.14	.936	.01	.20
Problem Solving Sophistication	.50	1.26	.301	.06	.51

With regards to each category of the CLASS and socioeconomic status, all but one category was determined to be significant. The only category of the CLASS significantly related to socioeconomic status was Problem Solving Sophistication. These results are shown in Table E4, below.

Table E4

Socioeconomic Status and Categories of the CLASS

Category of the CLASS	*M*	*F*(1,43)	*p*	η_p^2	*d*
Real World Connection	.08	.03	.867	.00	.06
Sense Making/Effort	.22	.33	.567	.01	.18
Personal Interest	.59	.87	.357	.02	.29
Conceptual Understanding	1.51	4.04	.051	.09	.61
Applied Conceptual Understanding	1.14	3.44	.071	.07	.57
Problem Solving General	.04	.02	.903	.00	.00
Problem Solving Confidence	.11	.06	.802	.00	.01
Problem Solving Sophistication	.92	4.27	.045	.09	.63

With regards to the CLASS and grade level, it was determined that grade level was not significantly correlated to any category of the CLASS. The results regarding grade level and category of the CLASS are displayed in Table E5, below.

Table E5

Grade Level and Categories of the CLASS

Category of the CLASS	*M*	*F*(1,43)	*p*	η_p^2	*d*
Real World Connection	.81	3.05	.088	.07	.53
Sense Making/Effort	.30	.64	.428	.02	.25
Personal Interest	.40	.39	.533	.01	.19
Conceptual Understanding	.26	.12	.736	.00	.11
Applied Conceptual Understanding	.45	.54	.466	.01	.22
Problem Solving General	.28	.35	.560	.01	.18
Problem Solving Confidence	.19	.19	.665	.00	.13
Problem Solving Sophistication	.39	.75	.393	.02	.26

With regards to GPA and each category of the CLASS, it was determined that GPA was not significantly correlated to any category of the CLASS. The results for GPA and each category of the CLASS are shown in Table E6, below.

Table E6

GPA and Categories of the CLASS

Category of the CLASS	*M*	*F*(2,43)	*p*	η_p^2	*d*
Real World Connection	.47	1.03	.366	.05	.44
Sense Making/Effort	.53	1.99	.149	.09	.61
Personal Interest	.37	.35	.708	.02	.26
Conceptual Understanding	1.07	2.05	.141	.09	.62
Applied Conceptual Understanding	.09	2.03	.144	.09	.61
Problem Solving General	.28	.56	.574	.03	.33
Problem Solving Confidence	.00	.00	.998	.00	.00
Problem Solving Sophistication	.60	1.83	.173	.08	.58

The association of each between-subject factor with the interaction of the categories of the CLASS and its administrations was examined. Because a repeated measures ANOVA was conducted, and since it was more than two categories, sphericity had to be checked. It was found using Mauchly's test of sphericity that the CLASS*Administration interaction violated sphericity, $\chi^2(27) = 139.35$, p = <.001, therefore, the Greenhouse-Geisser corrected tests are reported ($\varepsilon = .52$). Gender was found to be not significant to the CLASS*Administrations interaction, $F(3.667, 157.74)$ =

.16, p = .303, η_p^2 = .03, d = .34. Ethnicity was determined as significant to the CLASS*Administrations interaction, $F(11.01, 157.74) = 2.17$, p = .019, η_p^2 = .13, d = .78. Socioeconomic status did not significant impact the CLASS*Administrations interaction, $F(3.67, 157.74) = 1.14$, p = .339, η_p^2 = .03, d = .33. Grade level was significant to the CLASS*Administrations interaction, $F(3.67, 157.74) = 5.07$, p = .001, η_p^2 = .11, d = .69. GPA was not significantly associated with the CLASS*Administrations interaction, $F(7.34, 157.74) = 1.95$, p = .062, η_p^2 = .08, d = .60.