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Inquiry-based laboratory investigations and student performance on standardized tests in biological science

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2013

Abstract

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MS, Osmania University, India, 1978

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Doctoral Study Submitted in Partial Fulfillment

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Administrative Leadership for Teaching and Learning

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Abstract

Achievement data from the 3rd International Mathematics and Sciences Study and Program for International Student Assessment in science have indicated that Black students from economically disadvantaged families underachieve at alarming rates in comparison to White and economically advantaged peer groups. The study site was a predominately Black, urban school district experiencing underachievement. The purpose of this correlational study was to examine the relationship between students' use of inquiry-based laboratory investigations and their performance on the Biology End of Course Test, as well as to examine the relationship while partialling out the effects of student gender. Constructivist theory formed the theoretical foundation of the study. Students' perceived levels of experience with inquiry-based laboratory investigations were measured using the Laboratory Program Variable Inventory (LPVI) survey. LPVI scores of 256 students were correlated with test scores and were examined by student gender. The Pearson correlation coefficient revealed a small direct correlation between students' experience in inquiry-based laboratory investigation classes and standardized test scores on the Biology EOCT. A partial correlational analysis indicated that the correlation remained after controlling for gender. This study may prompt a change from teacher-centered to student-centered pedagogy at the local site in order to increase academic achievement for all students. The results of this study may also influence administrators and policy makers to initiate local, state, or nationwide curricular development. A change in curriculum may promote social change as students become more competent, and more able, to succeed in life beyond secondary school.

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Dedication

This work is lovingly dedicated in memory to my wonderful mother, who instilled in me a belief in education and who always encouraged me to follow my dreams.

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I would like to thank Dr. Franklin Campbelljones, the chair of my committee, for his unlimited assistance, unwavering support, and dedication in helping me succeed. I am grateful for your dedication to my learning, which has provided the necessary scaffolds to support my growth. To the members of my doctoral committee Dr. Patricia Hanrahan and Dr. Michelle Brown, I express my sincere thanks for providing invaluable advice, support, direction, and insightful suggestions throughout the development of this research. Most of all, I would like to thank my husband for standing by my side, giving me all my strength, and never letting me quit. Without his continued encouragement, I would not have been able to make this dream come true. I would like to thank my amazing daughter for listening to my frustrations and providing technological support. To my family and friends, I would like to express my deepest appreciation for providing support and encouragement throughout my doctoral journey.

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Section 1: Introduction to the Study

The Nation's Report Card, a study published by the National Assessment of Educational Progress (NAEP), revealed that the performance gap between Black and White students widened between 2000 and 2005 (U.S. Department of Education [DOE], 2006). As indicated by the Trends in International Mathematics and Science Study (TIMSS; DOE, 2007b), this gap persisted in 2007. Black students in fourth and eighth grades had lower scores than other students. From 1996 to 2005, science scores of 12th-grade Black students were also lower than scores of White, Asian, and multiracial students. National data from the Program for International Student Assessment in science (PISA, 2009) showed that science literacy scores of U.S. students were lower than scores for 16 of 29 nations from the Organization for Economic Cooperation and Development. Nearly one quarter (24.4%) of U.S. 15-year-olds do not reach the baseline level of science achievement (PISA, 2009).

The report card issued by the Georgia Department of Education (GDOE) for 2005-2010 showed substantial improvement in the scores of racial minority students on standardized tests in biology, but there was a conspicuous difference between the scores of Black and White students (GDOE, 2010). Improvement was evident because the achievement gap of 37 percentage points in 2005 narrowed to 29 percentage points in 2010 (GDOE, 2010). The trend could be treated as positive, as the reduction was due to an increase in the achievement of Black students. However, the gap is still large and needs attention. The GDOE Report Cards revealed marked differences in performance among ethnic groups, not taking into account factors that may influence underperformance of any one group.

In the Early Childhood Longitudinal Study, researchers examined relationships among gender, poverty, and ethnicity in the science performance of 8,741 fifth graders. An analysis of variance (ANOVA) revealed that the performance of male students was significantly better than that of female students on science assessments (Kay, Hui, & Lee, 2010). There are gender disparities in science, and students attending urban schools seem to be at increased risk because of higher levels of negative social pressures (Lewis, James, Hancock, & Hill, 2008).

Background of the Problem

Researchers have sought reasons for the underachievement of students in core subjects including science and have found that some of the causes were low socioeconomic status, family influence, failing schools, cultural gaps, lack of experienced teachers, and lack of parental involvement (Lynch, 2006). The No Child Left Behind (NCLB) Act (No Child Left Behind, 2002) holds teachers accountable for the performance of students in kindergarten through 12th grade (K-12), regardless of their race/ethnicity and socioeconomic backgrounds. Standardized test scores are the basis of measuring student performance for all public schools in the United States. This situation is an important reason why it is imperative for schools to provide meaningful science instruction through inquiry.

This correlational, quantitative research study examined whether inquiry-based laboratory (i.e., lab) investigations can be correlated with improved standardized-test scores for students. The outcome of the study may provide insight on whether professionals should initiate inquiry-based techniques to improve student achievement in science and address the fundamentals that may lead to underachievement relative to accessibility and academic service.

Achievement data collected in the TIMMS and PISA (2009) suggested that Black students from low-socioeconomic-status households underperformed at alarming rates compared to their White peers from economically advantaged families. Closing the academic achievement gap is a high priority of U.S. schools (Berends, Lucas, & Penaloza, 2008). Various elements have contributed to the low achievement of students in science, and these have included lack of motivation, personal responsibility, and discrimination (Smith, 2008). However, researchers have also suggested that the strategies used by educators to increase the performance of Black students may be inadequate, as the gap between Black and White students persists.

Problem Statement

Although considerable research and scholarship exist on students' performance in science, few researchers have recommended a curriculum that incorporates inquiry for high school students (Duschl, 2008). Given the research regarding underachievement of students in science, more research is required to determine alternate techniques for decreasing the achievement gap (Gregory, Skiba, & Noguera, 2010). Thus, further study is required to determine factors that influence students' underachievement in science in high schools to add to efforts in educational reform and curriculum development.

Inquiry-based science instruction emphasizes student-centered activities oriented toward concrete observable concepts and uses questions that students can answer via investigations (Colburn, 2008). Inquiry-based science involves three levels of inquiry: (a) the structured inquiry lab, which involves predetermined answers; (b) guided inquiry, in which the teacher proposes the question; and (c) open inquiry, in which students generate questions, hypotheses, procedures, conclusions, and reports (Leonard, 2010). Sweeney, Hansen, Verma, and Dunkhase (2009) conducted lab investigations on diffusion and osmosis using guided inquiry. They indicated that students developed the skills of creating and evaluating questions and procedures for investigations while also learning about osmosis and diffusion. In inquiry-based laboratory investigations, probing questions are asked by the teacher, and students design their own procedures and formulate their own results. In student-initiated inquiry, students create their own questions, plan a procedure for answering questions, and then carry out the procedure and formulate the results (Llewellyn, 2005).

The low performance of students on standardized tests in biology has been a cause of concern for public-school administrators. This situation was of particular concern for a metropolitan public school system with an enrollment of over 49,000 students. These students attended classes in 57 elementary, 22 middle, and 14 high schools. Data from annual results of the End-Of-Course test (EOCT) in biology, retrieved from the GDOE (2010), indicated that student proficiency rates on standardized tests ranged between 57% and 64% from 2008 to 2010 for all students at the state level. Over the same time period, proficiency on standardized tests at the district level was 36% to

49% and at individual schools was 39% to 69%. The demographic breakdown of these statistics showed a marked difference between Black and White students: 71% to 79% proficiency of White students at the state level versus 41% to 50% of Black students, 86% to 90% proficiency of White students at the district level versus 34% to 44% of Black students, and 88% to 91% proficiency of White students at the school level versus 34% to 66% of Black students. Therefore, while proficiency rates have improved over time, these data indicated there was still a large discrepancy between the scores of White and Black, high school students. This problem warrants further investigation to understand why gaps in science achievement persist between Black and White students (Williams, 2009).

The heart of inquiry science is investigation. Teaching this subject in a rote fashion rather than challenging students to observe and make their own deductions does them a major disservice. As noted, schools with a majority Black student population often lack the laboratory equipment that more affluent White school districts have, as well as qualified or dedicated teachers to present the somewhat rigorous inquiry-based-science curriculum found in the more affluent districts. Turner and Rios (2008) investigated whether teaching science through inquiry-based activities (a) improved experimental-design laboratory skills of students and (b) increased scores on standardized tests. They indicated that laboratory activities increased students' understanding of science and process skills.

According to Long (2010), inquiry-oriented teaching promotes creativity by increasing curiosity and motivates students to learn. However, high-stakes testing and the new focus on accountability have impacted the way science educators deliver instruction (Berry, Daughtrey, & Wieder, 2010). This correlational, quantitative research study examined whether inquiry-based laboratory (i.e., lab) investigations can be correlated with improved standardized-test scores for students, and it examined whether there is a significant difference in the performance of students from different learning settings on EOCT biology examinations. I also examined differences in learning setting and gender as they relate to the performance of students on EOCT biology examinations. The findings of this study may provide insights to teachers, who may decide to use inquiry-based techniques to improve student achievement in science.

Nature of the Study

The purpose of this correlational, quantitative study was to test the relationship between students' use of inquiry-based laboratory investigations in class (as indicated by the LPVI survey) and students' biology performance as measured by standardized test scores in biology on the End Of Course Test (EOCT), as well as to investigate this relationship while partialling out the effects of student gender. In the first phase of the study, the Laboratory Program Variable Inventory (LPVI) survey (Abraham, 1982) was used to collect students' self-reports on their use of inquiry-based and non-inquiry-based laboratory investigations in their classes. In the second phase of the study, I examined differences by gender in EOCT scores from both learning settings. The independent variables were learning setting (i.e., inquiry-based and non-inquiry-based laboratory investigations) and gender (i.e., male and female). In inquiry-based laboratory investigations, students use integrated process skills such as the following:

- identifying variables,
- writing hypotheses,
- designing experiments and investigations,
- constructing data tables and graphs, and
- analyzing the relationship between variables.

The LPVI was used to survey students on their use of these integrated process skills in their classes. Non-inquiry-based laboratory investigations may be described as teacher-centered, and students may follow systematic procedures directed by the teacher.

The dependent variable for this study was biology standardized test (EOCT) scores. The EOCT is a state-mandated test that aligns with state professional standards and helps identify students' strengths and weaknesses in various domains. The EOCT is administered during the spring, summer, and fall. The EOCT program in Georgia evaluates student achievement in eight core high-school courses: (a) biology, (b) ninth-grade literature and composition, (c) economics, (d) U.S. history, (e) Algebra I, (f) American literature, (g) geometry, and (h) physical science. In Section 3, EOCT tests are discussed in further detail.

The sample for this research study was approximately 300 students enrolled in regular biology courses who had completed the EOCT in biology in the previous year at six selected high schools in an urban public school district. Schools in the district are located in four regions: south, north, east, and west. The schools were selected from the south and west regions based on approval given by the principals to conduct the study on their sites. This district is located in a metropolitan area in the southeastern U.S. The student population of the school district is 81% Black, 11% White, and 8% other racial/ethnic groups. The LPVI survey was administered to students of all racial/ethnic groups who enrolled in a biology course and completed the Biology EOCT in the previous academic year, 2011- 2012.

The second component of the research was to determine whether male students perform better than female students on the EOCT. The first step of the research design involved gathering Biology EOCT scores from the April 2012 administration. The quantitative data were analyzed using descriptive analysis, and the Pearson correlation *r* was used to analyze the results of both LPVI survey scores and EOCT scores in biology in order to determine whether a relationship exists between the two variables. Student scores on the EOCT, disaggregated by gender, were also analyzed to determine if there was a significant difference in EOCT biology test scores by gender, using partial correlational analysis. Archived student test data were obtained from the department of research planning and development of an urban school district.

Purpose of the Study

The purpose of this correlational, quantitative study was to test the relationship between students' use of inquiry-based laboratory investigations in class (as indicated by the LPVI survey) and students' biology performance as measured by standardized test scores in biology on the EOCT. Another purpose was to examine the relationship while partialling out the effects of student gender. Inquiry-based science usually involves observing; questioning; designing experiments; planning investigations; and using tools to gather, analyze, and interpret data (National Science Educational Standards, 1996). In this study, inquiry-based laboratory investigation was used to conceptually represent inquiry-based science; this learning setting includes all of the criteria required for inquiry-based teaching (Yager, 2009). As noted, the independent variables were learning setting and gender. The dependent variable was the biology EOCT scores of students.

Research Questions and Hypotheses

The research questions to be investigated were:

Research Question 1 (RQ1): What is the relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes?

Research Question 2 (RQ2): What is the relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when controlling for student gender?

Null Hypothesis 1 (H_{01}): There is no relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes.

Null Hypothesis 2 (H_{02}): There is no relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when controlling for student gender.

Alternative Hypothesis 1(H_1): There is a relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes.

Alternative Hypothesis 2 (H_2): There is a relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when controlling for student gender.

Theoretical Framework

The theoretical framework of the study reflects the principles of the constructivist theory of John Dewey (1916). Constructivist education emphasizes developing critical-thinking skills through the learner's active construction of knowledge based on experience. In a constructivist approach, students learn through inquiry, unlike the traditional approach in which learning is a process of gaining fixed knowledge (Vianna & Stetsenko, 2006). Students actively engage in creating, interpreting, and reorganizing knowledge in constructivist learning. Teachers not only take an active role in the learning process, but also maintain a balance between teacher- and student-directed teaching (Gordon, 2008).

Theories of constructivism from cognitive psychology also suggest that learning improves when information is embedded within meaningful contexts (Brooks & Brooks, 1999). Children construct knowledge and understand concepts through their own activity. The principles of constructivism have significant implications for science education, as these principles emphasize the importance of students engrossing themselves in the investigative process, rather than memorizing facts.

In scientific inquiry, learners are intensely involved in developing an understanding of their surroundings (National Research Council, 1996). Inquiry-based science aims to enhance learning by increasing student involvement, kindling curiosity, and, offering multiple ways of learning. This study was designed to test the idea that inquiry-based laboratory investigations can affect students' learning and consequently improve their performance on standardized tests.

According to Campbell (2006), using inquiry as a central strategy for teaching science, promotes the conditions that Piaget deemed necessary for learning. The inquiry-based approach allows students to create their own knowledge. The proposed reform by National Research Council (1996) in science education reflects constructivist-learning theory. When exposed to an inquiry pattern of teaching, students are expected to make observations on the topic under consideration; formulate research queries; and collect, arrange, and analyze data in a scientific pattern (Leonard & Penick, 2009). Constructivist methods of teaching have been used to increase standardized-test scores and improve critical thinking skills of students (Beamer, Sickle, Harrison, & Temple, 2008).

Definitions of Terms

End-of-course test (EOCT): EOCT is a standardized test created to measure student achievement through effective instruction and assessment of standards specific to the eight EOCT core high school courses. The EOCT helps to ensure that all Georgia students have access to rigorous curriculum that meets high performance standards. The purpose of the EOCT is to provide diagnostic data that can be used to enhance the effectiveness of schools' instructional programs (Georgia Department of Education, 2010).

Inquiry-based laboratory investigation: A multifaceted activity that involves: observing; posing questions; designing experiments; planning investigations; using tools to gather, analyze, and interpret data; and communicating results (National Educational Standards, 2000, p. 23).

Non-inquiry-based laboratory investigations: In this learning setting, the students are provided with: the question to be investigated, materials to be used, a step-by-step procedure, safety precautions, a guide on how to organize the data in a table or a chart, and leading questions to assist in analyzing the data (Llewellyn, 2005).

Assumptions

The study was based on the following assumptions:

1. EOCT scores are a reliable measure of student performance in biology.
2. Teachers consistently use specified teaching strategies, namely inquiry-based versus non-inquiry-based laboratory investigations.
3. Students can identify the differences between inquiry-based and non-inquiry-based laboratory investigations.
4. Students honestly completed survey items to help determine whether they were in classes with inquiry-based or non-inquiry-based laboratory investigations.

Limitations of the Study

The study was limited to inquiry-based science, defined as inquiry-based laboratory investigations. The participants in the research were not a representative cross-section of all students in metropolitan public schools. Other factors that influence the performance of students on the EOCT, such as socioeconomic conditions, were not considered.

Scope and Delimitations

The study is confined to the following scope and delimitations.

1. The scope of the research was limited to the test scores of students on the Biology EOCT.
2. The study was limited to laboratory investigations. Other classes were not included. Factors such as student age and household socioeconomic conditions were not considered.
3. This study examined the relationship between students' use of inquiry-based laboratory investigations in class (as indicated by the LPVI survey) and students' biology performance as measured by standardized test scores on the Biology End Of Course Test (EOCT).

Through this study, a conjectured relationship between inquiry-based laboratory investigations and standardized biology test scores was examined. The emphasis was on the student's self-reported learning setting (inquiry-based laboratory investigations vs. non-inquiry-based laboratory investigations) and the relationship between the student's self-reported learning setting and EOCT score. Other teaching strategies that may affect student performance were not considered.

Significance of the Study

A study on the use of inquiry-based laboratory investigations and the performance of students on the EOCT was important for a number of reasons. National science educational standards require that high school teachers plan inquiry-based investigations that engage students in combining process and critical thinking skills toward the understanding of science (National Research Council, 1996). This research study may suggest a link between inquiry-based laboratory investigations and the standardized-test performance of students.

This study has implications for societal change at the classroom, school, district, state, and national levels. During the last two decades, many policy changes regarding high-stakes testing have occurred. The passing threshold on these standardized tests has risen from minimum competency to proficiency (Lee, 2008). Consequently, the challenge for administrators and teachers lies in increasing student scores on standardized tests as an indicator of successful academic achievement under NCLB. A long-term outcome of this study may be a change from teacher-centered to student-centered pedagogy in order to increase standardized test scores for all students. The results of this study may also influence administrators and policy makers to initiate local, state, or nationwide curricular change. A change in curricula may also promote social change as students become more competent, and more able, to succeed in life beyond secondary school.

Summary

Low academic achievement of students in science is a concern in the U.S. Several factors affect the underachievement of students, such as: socioeconomic conditions, parental involvement, time spent on homework, lack of personal responsibility, motivation, and confidence (Smith, 2008). Over the years, various recommendations have been made to encourage the development of an effective strategy to help students improve their skills. According to Turner and Rias (2008), inquiry-based laboratory investigations helped students develop critical-thinking skills. This study examined the relationship between students' use of inquiry-based laboratory investigations in class (as indicated by the LPVI survey) and students' biology performance as measured by standardized test scores on the Biology End of Course Test (EOCT).

The literature review in Section 2 of this study explains: (a) factors that contribute to the academic performance of Black students, (b) the basis of inquiry-based teaching, (c) the advantages of inquiry-based teaching over the traditional method of teaching, and (d) the effect of inquiry-based teaching on standardized test scores of Black students. Section three contains a description of the methodology I used to conduct the study. Section 4 presents findings resulting from analysis of the data collected in the study and Section 5 presents the discussion, conclusions, and Recommendations.

Section 2: Literature Review

The literature review is divided into six parts for clarity of presentation and presents a review of relevant scholarly articles about the low test scores of students on standardized tests in science. The first part of the review addresses how constructivist learning enhances the critical-thinking skills of students. The second part of the review covers the benefits of inquiry-based teaching over traditional practice. Best teaching practices to improve the performance of students in science are also described. Finally, I present an analysis of studies that have used similar methodology.

Method of Review

Databases that included information from Sage journals, the Educational Research Information Center (ERIC), the National Science Teachers Association (NSTA), and ProQuest were used to gather information for the literature review. The range of dates for the reviewed research studies was 2006–2010. Keywords such as *inquiry, science, Blacks, teaching strategies, standardized tests,* and *achievement gaps* were used in searching the websites and databases. This search returned 76 articles. Additional keywords were then added: *low achievement*, *best teaching practices*, *urban schools*, and *performance*. These keywords yielded research studies along with descriptive articles. The purpose of this review is to analyze studies of inquiry-based and non-inquiry-based science teaching and examine how inquiry-based teaching influences the performance of Black students on standardized tests in biology. The review also includes factors that affect the performance of Black students on standardized tests.

Theoretical Basis of Inquiry-Based Science Teaching

According to John Dewey (as cited in Llewellyn, 2005), learning and experience go hand-in-hand, and knowledge emerges from a personal interaction between the learner and the external environment. According to Llewellyn (2005), Dewey perceived teaching as a dynamic process that enables students to find solutions to problems of their interest. Like Dewey, Piaget (as cited in Llewellyn, 2005) believed knowledge was a result of the interaction between individuals and the environment, something that is constantly constructed and reconstructed from previous and new experiences. Furthermore, Vygotsky (1979) asserted that the construction of knowledge is socially mediated. The common theme among these theorists is the idea that students construct knowledge; they do not simply receive it.

Incorporating inquiry into science teaching is a method based on the theory of constructivism. The strategy of inquiry is predicated on the belief that students will develop thinking skills and scientific knowledge by reflecting on their lessons in relation to their previous experiences (Walker & Zeidler, 2007). Clearly defined instructional objectives and the dynamic exchange between teacher and student are essential for the productive implementation of constructivism (Correiro, Griffin, & Hart, 2008). Constructivist education is a process of concept construction and emphasizes developing critical-thinking skills. In a constructivist approach, students learn through inquiry as opposed to memorization, which is the traditional way of learning (Vianna & Stetsenko, 2006).

A researcher who studied whether constructivist learning increased understanding of simulation gaming indicated that it was positively related to the learning in simulation gaming (Lainema, 2008). Inquiry in the science classroom not only emulates the principles of constructivism, but also assists students in constructing knowledge based upon their previous experiences (Walker & Zeidler, 2007). In another study of constructivist teaching methods in a science classroom, teachers trained in constructivist methods collected data through surveys and interviews. They reported a remarkable change in grades on standardized tests and improved critical-thinking skills in students (Beamer et al., 2008).

Benefits of Inquiry-Based Science Teaching

Research findings on teaching science through experiments related to day-to-day life showed that positive attitudes can be generated toward science through exploration and discovery. This teaching method can also improve test scores and academic skills by aligning an experience-based science curriculum with the types of questions found on state exams (Connors & Perkins, 2009). For instance, Stephen (2007) investigated inquiry-based labs in botany and found that students developed: (a) conceptual understanding in science, (b) the ability to perform scientific inquiries, (c) a better understanding about inquiry, and (d) the ability to make connections to the real world.

Likewise, Concannon and Brown (2008) suggested transforming verification labs into inquiry-based labs. This transformation reportedly resulted in higher student engagement, clarification of students' misconceptions, and the realization that everyday questions can be investigated in science class.

An inquiry-based curriculum in earth science was adopted in five urban schools to teach fifth-grade students. Data were collected from pretests, posttests, the NAEP, and the TIMSS. The students showed significant improvement on science standardized-test scores (Lambert & Ariza, 2008). A similar study of inquiry-based activities in a biology classroom emphasized understanding of scientific concepts, competence in conducting scientific inquiry and understanding inquiry, and the relationship between nature and the history of science (Stephen, 2007).

By contrast, researchers in education have debated which teaching methodologies are best suited to improving student learning: traditional lecture or student-oriented activities. Wolf and Fraser (2007) compared inquiry-based and non-inquiry-based laboratory teaching, observed the attitudes of middle-school students, and measured their performance in physical science. The 1,434 participants were from four private and 14 public schools. Two groups with similar academic strengths were selected for inquiry-based and non-inquiry-based teaching. Students in the inquiry group were challenged to design their own experiments while the non-inquiry group was given detailed instructions to follow. Data were analyzed using a t test. The comparative study examined the cohesiveness of students in an inquiry classroom compared to a non-inquiry one. There was a slight difference in students' scores on standardized tests in an inquiry-based classroom compared to scores for students in the non-inquiry-based classroom.

In addition, Eysink et al. (2009) conducted a comparative study of four different instructional approaches: (a) multimedia learning, (b) learning through observation, (c) learning through self-based teaching, and (d) inquiry learning. They determined that the procedural method was inferior to the inquiry-based method in terms of content retention and conceptualization. Continuous exposure to inquiry-based learning helps students acquire and develop: (a) logical approaches to answering questions, (b) cognitive skills, and (c) positive attitudes toward learning science (Southerland, Smith, Sowell, & Kittleson, 2007).

Vanosdall, Klentschy, Hedges, and Weisbaum (2007) conducted a sequence of experiments designed to assess the influence of scaffold-guided inquiry (SGI) instructional practice on student achievement. The study included 20 fifth-grade teachers and 563 students from four elementary schools. Data were collected using pretests and posttests. Students whose teachers used SGI showed greater improvement on posttest results than the control group.

Contrary to the previously noted findings, Giles et al. (2006) examined the effects of teaching methods on learning and established ground rules for such studies using a statistically controlled design. A mixed linear model was used to analyze data collected through a quiz and quantitative responses to attitude questions. Researchers concluded that traditional teacher-centered lecture methods were slightly more effective than student-centered methods in improving student learning. Lack of strong instructional guidance not only impeded learning, but also might have caused misconceptions.

Moreover, Mehalik, Doppelt, and Schunn (2008a) studied middle-school students exposed to science instruction either through traditionally scripted inquiry or a design-based method. They indicated that the performance of low-achieving Black students improved with a systems-design approach. Specifically, achievements in science concepts, engagement, and retention were improved (Mehalik et al., 2008).

In addition, Metz (2008) incorporated statistics into teaching biology and used inquiry-based learning to strengthen student understanding of statistical analysis in biology laboratory investigations. Learning gains in statistics were measured using a survey instrument. Metz suggested that the use of statistics in biology might aid long-term retention of statistics knowledge.

Gengarelly and Abrams (2009) investigated the challenges and benefits of incorporating inquiry into science. Their research focused on teachers, graduate students, and the role of school culture in the implementation of inquiry. The graduate students in collaboration with schoolteachers introduced inquiry-based instruction in a school classroom. Teacher-directed inquiry was followed by structured inquiry, guided inquiry, and open inquiry. Interviews and other data indicated that the fundamental challenges to using inquiry were that students lacked the required skills and background knowledge and needed structured and guided inquiry to improve their knowledge and skills.

Although, several factors contributed to the low achievement of Black students on standardized tests, an instructional model of inquiry-based teaching that incorporated multimedia tools in the classroom improved the performance of Black students on standardized tests (Monica, 2005). Contrary to previously noted findings, Geier (2007) argued that a standards-based inquiry curriculum had improved the performance of urban Black middle-school students on standardized tests (Geier, 2007).

Additionally, Kirchner, Sweller, and Clark (2006) found that less guidance from teachers did not affect student-learning abilities. Simsek and Kabapinar (2010) investigated the outcome of inquiry-based research on logical interpretation of students in a fifth-grade science classroom in a private school in Istanbul, Turkey. During the project, students shared ideas, worked in small groups, discussed observations, collected data, and interpreted findings. Researchers indicated that problem based learning (PBL) improved students' conceptual understanding and misconceptions were diminished (Kirchner et al., 2006). However, it seems logical that PBL is specific enough to enhance and guide student learning in ways that traditional teacher-centered lecture approaches cannot.

Furthermore, Mastropieri et al. (2009) studied the effects of incorporating inquiry in teaching an easy topic (e.g., harmonic motion) to students with learning disabilities and mental retardation compared to regular education students. Researchers revealed that students with mental retardation and learning disabilities had difficulty applying knowledge to different issues and answering questions relating to them.

Shaw and Nagashima (2009) examined science learning through inquiry-based units of instruction measured by performance-based assessments. Their participants were 834 fifth-grade students from 14 elementary schools. An ANOVA determined there were significant differences between the performances of subgroups (i.e., American Indian/Alaskan Native, Asian, Black, Hispanic, and White). The researchers reported that no significant differences in performance were found between Whites and Blacks.

Moreover, Fradd and Lee (2009) addressed the roles of teachers in promoting science inquiry in a class with different ethnic groups by examining the effect of incorporating inquiry in teaching science, particularly with bilingual students. The participants were fourth-grade inner-city Hispanic and Haitian students from low socioeconomic households. The researchers indicated that neither explicit nor experimental instruction met the needs of students.

Research in education in the last few decades has focused on teaching strategies to determine whether teacher- or student-centered instruction is better for student achievement (Giles et al., 2006). Equally important are learning tools that support student-centered strategies, help students develop a greater understanding of science, and help science teachers to move from the traditional method of teaching to a more inquiry-based teaching style. Two hundred and fifty students from seventh- and eighth-grade science classes and two teachers participated in a project using the PSI (Personal Study Instrument). The researchers indicated that with such learning tools teachers engaged in critical reflection about their teaching and easily transformed their teaching to an inquiry-based style (Foti & Ring, 2008).

Other researchers examined the effectiveness of software that was developed to design inquiry-based projects in genetics. The interactions among students, teachers, software, and curriculum showed a significant difference in inquiry skills of middle-school students who designed the inquiry projects (Eslinger et al., 2008).

In addition, Le, Lockwood, Stecher, Hamilton, and Martinez (2009) explored the relationship between reform-oriented teaching and science achievement. Reform-oriented teaching, in which students engage actively and develop complex cognitive skills, has its roots in constructivism. Multiple measures of performance and diverse classroom practices were used. Researchers indicated that greater exposure to reform-oriented teaching was not significantly associated with higher student achievement; reform-oriented teaching had a significant relationship with open-ended measures compared to multiple-choice tests in science and mathematics.

Zacharias (2008) investigated the possibility of combining virtual experimentation with actual experimentation and observed changes in students' conceptual understanding of electrical circuits. The participants were 88 undergraduate students. Data were collected from pretests and posttests and an analysis of covariance (ANCOVA) was used to examine the data. Results confirmed that using actual and virtual experimentation significantly improved the ability of the undergraduate students to grasp scientific concepts.

Drake and Long (2009) investigated PBL in science in a fourth-grade science classroom. Using a quasi-experimental design, the researchers investigated: (a) content knowledge of students, (b) stereotypical images of scientists, (c) time-on-task, and (d) the transfer of problem-solving skills. The participants were Hispanic, Black, and Other minorities. Student outcomes were compared to those of a control group who received instruction in a thematic format. The pretests and posttests on content knowledge indicated that PBL had a positive effect because the students showed evidence of collateral learning.

Thus far, this review of the literature has indicated that previous results reported by researchers have shown that inquiry-based laboratory investigations tended to generate positive attitudes towards learning science and helped students develop better conceptual understanding of the subject than non-inquiry labs did. However, limited research has addressed the effect of inquiry-based teaching on Black students and their performance on standardized tests.

Performance of Black Students in Science

Data from the GDOE (2009) indicated that although a significant increase in science test scores has occurred, an achievement gap remains between Black and White students. In the district of the proposed study, the percentage of Black students who met expectations on the EOCT in biology was 43% for academic year (AY) 2008-2009 and 42% for AY 2007-2008 (GDOE, 2009).

According to Allen (2006), most U.S. urban middle-school students live in high-poverty communities and perform poorly in science. This historically poor performance not only presents challenges in learning high-school science but also hinders efforts to improve science education. A teacher-support model was developed to address the variation in science curricula, lack of materials, and underprepared teachers. These factors, along with initial low levels of proficiency, hinder improvement in science performance. The model includes a common science curriculum, and ongoing professional development and in-class support for teachers. A cohort of students at three middle schools was selected and the model was followed for four years. Allen indicated that achievement levels in science were substantially higher compared to students in three control groups.

Turner and Rios (2008) observed the effect of inquiry-based teaching on the performance of diverse student groups including: Blacks, Whites, Hispanics, Asians, and Native Americans. The researchers suggested that when exposed to inquiry-based teaching, students could: comprehend the nature of science, assimilate knowledge, and foster thinking skills. A similar study by Hug, Krajcik, and Marx (2005) on inquiry-based curricula included Black students from an urban middle school. Researchers showed that the project-based curriculum helped students design experiments and pose meaningful questions. In addition, throughout their investigations, students made strong connections to the real world.

Teaching historically underserved urban students by incorporating inquiry into a standards-based science curriculum can lead to improved standardized-test scores (Geier, 2007). A study of inquiry-based teaching illustrated that a standards-based inquiry curriculum positively influenced the performance of urban Black middle-school students on standardized tests. Drake and Long (2009) indicated that the exposure of Black and other minority students to PBL resulted in an improvement in their academic achievement.

Styron and Peasant (2010) indicated that Black students enrolled in ninth-grade academies with block scheduling, team teaching, and professional learning communities (PLCs) achieved higher scores on standardized tests than students from traditional high schools. Ford, Grantham, and Whiting (2008) explored how psychological and social factors affected the test scores of Black students. Researchers indicated that schools with large Black student populations usually lack technology-based instruction and rigorous curricula. In addition, less qualified and less experienced teachers as well as an unsafe school atmosphere affected the performance of Black students. Low-income and Black students usually experience didactic instruction and are taught interactively less often than other students (Smith et al., 2007). Gifted Black students contribute to the achievement gap when they do not put much effort into academics, and instead spend time engaged in nonacademic activities and succumb to peer-pressure (Ford, Grantham, & Whiting, 2008).

Gender and Performance of Black Students in Science

Achievement test data collected through various sources indicated that mixed-race students and students from economically disadvantaged families underachieved at alarming rates compared to White and economically advantaged peer groups (Education Trust, 2005). In one study, researchers examined gender differences in Black youth for school racial discrimination and academic engagement outcomes. Data were collected through surveys. Participants included 204 boys and 206 girls in 11th grade at an urban high school. Researchers indicated that although no significant difference was found between standardized-test scores of boys and girls, the mean grade point average (GPA) of the girls was significantly higher than the boys (Tabbye, Deborah, Ciara, & Courtney, 2008).

Furthermore, Monique, Henry, and Frances (2011) examined low academic performance of Black boys compared to Black girls. Longitudinal studies of 113 children from low-income families were conducted using student's self-report and achievement data. Multiple regression analyses (MRAs) revealed there were no significant gender differences in mathematics and reading achievement.

Additionally, Ketty and June (2010) examined gender and ethnic differences using DISCOVER, a performance-based assessment. Participants included 941 fifth-graders who represented six ethnicities. Multivariate analysis of variance (MANOVA) results yielded a significant interaction, but no effect was found for ethnicity or activity. All ethnic groups were well represented, but no gender differences were found.

Similarly, Mickelson and Greene (2006) explored gender differences for Black middle-school students on standardized test scores. The academic outcomes, as measured by standardized test scores, indicated that Black girls attained higher test scores and grades compared to Black boys. According to Linn, Else-Quest, Hyde, (2008), standardized-test scores in the U.S. have revealed that girls score as high as boys in math. Miller, Blessing, and Schwartz (2006) examined gender differences, attitudes towards science classes, and understanding of science. The researchers indicated girls were more interested in majoring in science than boys but showed low interest in biology.

Cokey and Moore (2007) examined the extent of interdependency between ethnicity and scholastic achievements for 274 college participants. Academic achievement seemed to be negatively affected by ethnic identity for men and had a positive effect on the academic achievement of women.

Importance of Inquiry-Based Science Teaching for Performance of Black Students in Science

Test scores of Black students and the gap in achievement between Black and White students continue to cause problems in the U.S. (Berends et al., 2008). The National Research Council (1996) called for a different kind of instruction in science. According to National Science Educational Standards (NSES), inquiry is a central part of teaching standards and students actively develop critical and logical skills. As Gunel (2007) found, creating a learning environment in which students were actively engaged in the inquiry process based on the constructivist view of learning was challenging and difficult.

A pilot study by Drake and Long (2009) compared PBL and direct instruction using a quasi-experimental design. Participants were Black and other minority fourth-grade students. Data were collected through pretests, posttests, and Draw-a-Scientist tests. Results indicated that students exposed to PBL showed evidence of collateral learning while those in the direct-instruction group did not.

Salinas et al. (2010) examined the effect of learner-centered classrooms and schools on the academic outcomes of minority and nonminority students. The sample included students from 236 elementary schools from six learner-centered schools and six traditional schools. Data were test scores and nontraditional measures. A two-way ANOVA was performed to compare the scores. Results indicated that the minority students not only had scores that equaled those of their White peers but also had higher scores in nontraditional measures such as: (a) the ability to complete a task, (b) inherent motivation, (c) creativity, (d) initiative, (e) cooperative learning, and (f) openness to diversity (Salinas et al., 2010). These results seem to indicate that inquiry-based approaches are especially beneficial for ethnic minority students; thus, they may be a promising approach to close the achievement gap. Another study of inquiry-based teaching indicated that a standards-based inquiry curriculum positively influenced the performance of Black urban middle-school students on standardized tests (Geier, 2007).

Unlike traditional methods, inquiry-based learning requires students to play an active role in their learning as they try to develop a solution to problems and tasks (Oliver, 2007). The NSES reform model requires student-centered teaching practices in science. The inquiry-based process is collaborative; students take responsibility for learning and decision-making and share questions and ideas on problem solving (Bransfield, Holt, & Natasi, 2007). The challenge for teachers is to teach the content-based curriculum to help students improve their test scores and incorporate inquiry into their classes.

Research has shown that students between the ages of 11 and 16 lose their enthusiasm for science. To address this problem, many countries have incorporated a strong emphasis on inquiry and critical thinking into their curriculum (Macpherson, 2009). In a study by Macpherson, regular teachers had the task of imparting knowledge to students, and in turn, students assessed their ability to recall this knowledge on the state-governed tests (Macpherson, 2009). Inquiry-based teaching makes this task feasible, adds to the creative abilities of teachers by stimulating a sense of curiosity through experimentation, encourages students to seek knowledge through questions, and seek answers through experimentation (Long, 2010). The philosophy behind this approach is to embed principles in students' minds, not as a set of lines from chapters to be recalled, but as a source of enrichment in the thinking process. This knowledge is logically aligned and used to understand science as natural phenomena (Long, 2010).

Leonard and Penick (2009) defined the concept of inquiry in a school atmosphere. Teachers used an inquiry pattern of teaching and expected students to: (a) observes topics under consideration; (b) formulate research queries; and (c) collect, arrange, and analyze data in a scientific pattern. Leonard and Penick included group efforts in testing hypotheses, exchanging ideas, and developing an understanding of the concepts while pursuing answers to research queries. Their results revealed that when students engaged in the process of scientific inquiry they found answers to intriguing questions. As an added benefit, this level of active engagement reduced student restlessness and classroom management issues. Leonard and Penick recommended that inquiry be incorporated into the science classroom for the improved conceptual understanding of science.

Inquiry-based teaching practices are aligned with the NSES. Previous researchers revealed that inquiry-based teaching practices enhanced the performance of Black and other minority students. However, lack of knowledge and lack of proper inquiry-based instructional resources make teachers unable to clarify misconceptions of students learning science. An inquiry-based model is student-centered, stimulates curiosity, encourages students to ask probing questions and seek answers through experimentation, and encourages students to take responsibility for learning and decision-making. It is challenging for teachers to teach the content-based curriculum to help students improve their test scores and incorporate inquiry into their classes. Previous research findings indicated that incorporating inquiry was beneficial for ethnic minority students; thus, it is a promising approach to closing the achievement gap.

Teacher Use of Inquiry-Based Science Teaching

Learning tools that support student-centered strategies in the classroom are as important as the constructivist approach. These tools can help science teacher's move away from traditional teaching methods and towards an inquiry-based style. Foti and Ring (2008) conducted a study of learning tools with two teachers and 250 students in seventh- and eighth-grade science. Results indicated that when they used learning tools, teachers engaged in critical reflection about their teaching and easily transformed their approach to inquiry-based teaching.

In another study, researchers examined the effectiveness of software developed to design inquiry-based projects in genetics (Eslinger et al., 2008). Technology incorporated curriculum showed a significant difference in inquiry skills of the middle-school students in designing projects (Eslinger, White, Frederiksen, & Brobst, 2008). Furthermore, Kazempour (2009) conducted a case study to examine the potential factors that aid or inhibit the use of student-centered instruction in a science classroom. Kazempour reported that although a substantial change was found in the instructional practices that enhanced student-learning, certain factors inhibited teachers from incorporating inquiry into their classes such as a lack of: (a) time, (b) flexibility, (c) resources, and (d) support from peer group and decision-makers.

A study by Campbell (2006) provided insight into challenges to reforming science education. Twenty-two science teachers who were open to investigating inquiry-based instruction participated in a professional-development project. Phenomenological analysis findings showed that the main obstacles identified were the ability to assess inquiry and the lack of resources needed to implement inquiry.

Quantitative Studies of Inquiry-Based Science Teaching

Sulaiman, Suan, and Abdullah (2009) conducted a quantitative study using survey methodology and observed the correlation between inquiry, constructivist, and demonstration approaches. Data were collected through a questionnaire from a sample of 239 primary-school science teachers in four states. A positive correlation was found between the inquiry, constructivist, and demonstration approaches. A further study by Panasan and Nuangchalerm (2010) used quantitative approaches that compared the outcomes of two teaching methods, inquiry-based and project-based activities. Participants were 88 fifth-grade students divided into two groups using cluster random sampling; eight lesson plans were used for each method. Data were collected through pretests and posttests. Researchers indicated that both methods were efficient and effective and there was no difference in achievement, science-process skills, or analytical thinking of students. Therefore, the researchers suggested that science teachers could implement both of these methods to give students a better understanding of science concepts.

A similar study by Turner and Rios (2008) used a quantitative approach to determine whether inquiry-based activities enhanced the ability of students to design laboratory investigations. The participants were sophomore students from a suburban high school. Data were collected from pretests and posttests and analyzed using a paired-samples *t* test. Their analysis indicated statistically significant gains and an enhanced ability of students to design laboratory investigations.

Furthermore, in a quasi-experimental design, Reilly and McNamara (2007) measured the relationship between cognitive abilities of high school students and their science scores on content-based tests. They also examined the predictability of results on traditional tests based upon the measurement of cognitive abilities. Participants were students from suburban, rural, and urban schools and from different socioeconomic and racial/ethnic backgrounds. The sample consisted of students in 9th-12th grades from four schools in Norfolk, Virginia; Americus, Georgia; and Prestonsburg, Kentucky. Data were collected from three tests: (a) reading skills, (b) science knowledge, and (c) strategy. Results indicated reading skills played a prominent role in content-based science achievement.

Qualitative and Mixed-Methods Studies of Teaching Methods

McGlamery (2004) conducted a qualitative study to investigate how to retain Black girls in higher-level science classes. The program involved 206 Black females in upper-level science courses in an urban high school. The study design was based on constructivist theory and included a student-centered curriculum, tutoring services, cohort group recruitment, and a summer research program. The researcher used qualitative methods to collect data through interviews and field notes taken by the participants.

McGlamery indicated that the student-centered science curriculum and small-group projects helped Black girls succeed in upper-level science.

Moreover, in a multiple-case mixed-methods study, Jeremy (2009) investigated the relationship between reading and achievement on a science test. The study included three high school students assessed on the Connecticut academic performance test in physical and earth science. Jeremy's findings across the schools indicated a positive relationship between students' reading performance and standardized tests in science.

Studies Using Survey Methods to Assess Learning Models

Gedja (2006) developed the Inquiry-based Instruction in a Secondary Science Classroom (IISSC) teacher survey, adapted from the BSCS (1992) 5E model. The first part of the IISSC contains 35 items designed to measure the extent to which teachers practice the indicators of the 5E model: engagement, exploration, explanation, extension, and evaluation. IISSC includes three items measuring engagement, four items measuring exploration, eight items measuring explanation, nine items measuring elaboration, and 11 items measuring evaluation. Construct and content validity were tested during the development of the instrument, and it was pilot tested.

Surveys have been shown to be useful methods for studying pedagogical strategies. Researchers who studied survey measures of classroom instruction, which compared student and teacher reports to improve the use and understanding of survey data in educational policy, found low correlations and small but significant mean differences between student and teacher reports (Desimone, Smith, & Frisvold, 2010). Another survey, the Comparing Student Achievement in the PBL Classroom and

Traditional Teaching Methods Classroom (CSAPLCTTM) developed by Dobbs (2008), includes 20 multiple-choice questions on teaching philosophy and methods in chemistry. Dobbs reported that the reliability of the instrument was found to be .72, using Cronbach's alpha.

Stewart (2008) used a survey to study important outcomes of classroom instruction from the perspective of students. The survey contains four components with 24 statements that assess student learning competencies, personal motivation, and student and teacher roles. Stewart indicated that students whose teachers used inquiry-based instruction benefited more than students from non-inquiry classrooms (Stewart, 2008).

Similarly, in a survey administered by Supovitz, Mayer, and Khale (2000) over a 3-year period teachers were asked about the effect of science professional-development sessions on their attitudes and beliefs about teaching and their classroom practices. The researchers obtained information on the instructional methods used in participating classrooms through teacher interviews, observation, and student responses to questionnaires. The rubric that describes an inquiry-based teacher adapted from Llewellyn (2004) was used to aid in the categorization of classes based on instruction. Rubric items represent 11 elements of instruction, and each one provides an example of "the traditional approach" and "Inquiry approaches" (Stewart, 2008). The findings were remarkably consistent across the subjects of science and mathematics.

Summary

The purpose of this correlational, quantitative study, was to test the relationship between students' use of inquiry-based laboratory investigations in class (as indicated by the LPVI survey) and students' biology performance as measured by standardized test scores on the biology End Of Course Test (EOCT), and also to examine the relationship while partialling out the effects of student gender.

The literature review revealed that several factors contribute to the achievement gap between Black and White students. Though there has been an overall increase in science scores over the past few years the achievement gap remains. Researchers have identified multiple factors that have contributed to low performance in Black students.

For the last few decades, research in education has focused on teaching strategies, to determine whether student-centered teaching is better than teacher-centered (Giles et al., 2006). Although a few researchers favored teacher-centered strategies, the majority opinion has favored the use of student-centered pedagogy. Researchers indicated that inquiry-based teaching and laboratory investigations tended to promote positive attitudes towards learning science and helped students develop conceptual understanding of the subject better than non-inquiry teaching and laboratory investigations. Previous research findings suggested that incorporating inquiry was useful for ethnic minority students and was a promising approach to close the achievement gap. However, few researchers have addressed the effect of inquiry-based laboratory investigations on performance on standardized tests of high school students. This study was designed to investigate the relationship between inquiry-based laboratory investigations in the science classroom and standardized-test scores of students. Section three presented the methodology, data collection methods, and data analysis. The results are presented in section four.

Section 3: Research Method

The purpose of this correlational, quantitative study was to test the relationship between students' use of inquiry-based laboratory investigations in class (as indicated by the LPVI survey) and students' performance in biology as measured by standardized test scores on the Biology End of Course Test (EOCT). Another purpose was to examine the the relationship while partialling out the effects of student gender. The demographic indicators studied were race/ethnicity (through the setting and sample) and student gender.

This methodology section includes a detailed description of the research design that was used in this study. Other components of this section include: (a) setting, (b) research questions, (c) an explanation of the steps in the survey process, (d) data collection and analysis procedures, (e) measures taken for participants' protection, and (f) the researcher's role. The survey instrument and the reliability of the survey instrument are discussed. Finally, the statistical steps that were used to examine the research questions are explored.

Research Design and Approach

The purpose of this study was to test the relationship between students' use of inquiry-based laboratory investigations in class (as indicated by the LPVI survey) and students' biology performance as measured by standardized test scores on the Biology EOCT. Another purpose was to examine the relationship while partialling out the effects of student gender. This study was non-experimental because the intended research used secondary data from a treatment that had already taken place within the inquiry-based laboratory investigation classes (Knuchel, 2010).

A quantitative analysis was appropriate because this study involved statistical analysis, comparison of groups, measuring relationships between variables, and collection and analysis of numerical data (Creswell, 2003), which were obtained from questionnaires and the EOCT. A quantitative study explores the magnitude of relationships amongst study variables (Firestone, 1987). A qualitative study, by contrast, is suitable for text analysis, description, analysis, and thematic development (Creswell, 2003). Therefore, it was not suited for the purpose of this study.

A survey instrument was used to collect students' self-reports. Survey data can be used to describe the current conditions of, show change in, and allow comparisons between or among students' self-reports of inquiry-based investigations (Fink, 2006). According to Fink (2006), a valid survey will result in consistent information and produce accurate information. A questionnaire is inexpensive, requires a limited amount of time to administer, and is a relatively easy method of collecting data from a large sample. When personally administered, a questionnaire spurs dialogue with the researcher and respondents; affording an opportunity for the researcher to explain unclear items to the study group (Airasian & Gay, 2003). The purpose of the demographic survey was to collect gender and race/ethnicity student data. Gender was the second independent variable. The gender and race/ethnicity variables were summarized to provide a demographic profile of the students in the study (Appendix A).

Two different sources of data were used in this study. The first set of data included results from the Laboratory Program Variable Inventory (LPVI; Abraham, 1982). The LPVI was used to measure the independent variable (i.e., type of learning setting) to determine if students were in classes with inquiry-based laboratory investigations or classes that used non-inquiry-based laboratory investigations. The LPVI is a survey instrument designed to identify students whose teachers use open-inquiry-based, guided inquiry, or non-inquiry-based laboratory investigations. The survey questions were asked in a way that clearly indicated which students received inquiry-based instruction and which received non-inquiry-based instruction.

The second part of the data collection involved collecting EOCT scores in biology for the test that was administered in April 2012. Archival test data for EOCT scores in biology were requested from the department of research planning and development for all biology students who completed the Biology EOCT in the previous year. Permission from the parents was obtained via consent forms to access the EOCT scores. Only I had access to individual school EOCT data. The data were imported into PASW (formerly SPSS), version 20.0 software for analysis.

Descriptive and inferential statistics were used to analyze the quantitative data. Pearson correlation *r* was used to analyze the degree of relationship between scores on the LPVI survey and the EOCT scores of individual students, as the Pearson *r* results in the most precise estimate of correlation. The Pearson correlation test was selected because the Pearson correlation measures the direction and degree of a linear relationship between two variables (Gravetter & Wallnau, 2008). The most commonly used technique was the product moment correlation coefficient, usually referred to as the Pearson *r* (Gay & Airasian, 2003).

Setting and Sample

This urban school district has 59 elementary schools, 16 middle schools, 23 high schools, seven charter schools, one adult learning center, and two nontraditional programs (GDOE, 2010). According to a report published by the Georgia Department of Education (2010), 48,805 students were enrolled in this district for AY 2010-2011. High schools in the district are located in four regions: south, north, east, and west. The schools selected for the study are located in the south and west regions. Approval was received from the principals to conduct the study at their site. I did not get the permission from schools located in the west. Hence, they were excluded from the study. The most diverse high school is located on the north side. As this school is my work site, it was excluded from the study. The student population of the school district was 81% Black, 11% White, and 8% of other racial/ethnic groups.

The percentage of enrolled students per race/ethnicity at the district level for the 2009-2010 academic year is shown in Table 1.

Table 1

Percentage of Enrolled Students According to Race/Ethnicity Group at District Level, 2009-2010

Racial/ethnic group	District level
Asian	1%
Black	81%
Hispanic	5%
White	11%
Multiracial	2%
Total	100%

Of the 23 high schools, 21 high schools had a predominantly Black population, ranging between 93% and 99%. All races/ethnicities were included in the study. However, the largest percentage of students participating in the survey was Black, as the student population of these high schools is predominantly African American.

Study participants were drawn from the population of students enrolled in biology courses at six high schools who had completed the 2012 EOCT in biology. The six high schools selected for this study reside in a single urban school district. Each school had four small learning communities (SLCs). There were approximately 150 students enrolled in biology, with an average of 25 students per class.

Participant Eligibility and Sample Characteristics

The initial eligibility criteria for the participants were enrollment in a regular biology course and completion of the 2012 Biology EOCT. Data collection included the

EOCT test score, student grade level, gender, race/ethnicity, and survey scores.

Study participants met the following requirements:

- Students enrolled in regular biology course at the six high schools in the urban district located in a metropolitan area in Southeastern Georgia, and completed biology EOCT during the 2012 academic year,
- Student assent, and
- Parental consent.

Parental consent was necessary, as all the study participants were minors.

Sampling Method and Sample Size

Convenience sampling was used. Convenience sampling is a form of nonrandom sampling which involves the use of existing groups. Data were collected for all race/ethnic groups and analyzed. A total sample size of at least 304 students was required, as recommended by the sample size calculator (American Research Group, Inc. 2000) at a confidence level of 95% for a population size of 1,450.

Instrumentation

Laboratory Program Variable Inventory (LPVI)

Inquiry-based laboratory instruction was assessed using the LPVI (Abraham, 1982). As designed, the LPVI used a Q-sort methodology. Students' self-reported use of inquiry-based laboratory investigations was measured using scores from the LPVI survey (Appendix B). The LPVI survey was used to collect the scores of students who self-reported membership in inquiry-based laboratory investigation classes and the scores of students who self-reported membership in non-inquiry-based laboratory investigation classes. The LPVI was previously used in a series of chemistry experiments to investigate laboratory formats such as verification laboratories, guided-inquiry laboratories, and open/guided-inquiry laboratories (Abraham, 1982).

A study by Rogers (2010) used the LPVI in a study on pre-nursing students' self-report use of traditional and inquiry-based chemistry laboratories. According to Rogers (2010), the LPVI contains 25 descriptive statements aligned with the five essential features of inquiry, as per the national science educational standards. Construct and content validity were tested during the development of the instrument. Content items were directly related to the conceptual framework and the statements were generated in several brainstorming sessions with science educators. The statements were then pilot-tested with individual subjects and ambiguous statements were modified (Abraham, 1982).

Several educators have used the instrument successfully with science students from high school sophomores through the undergraduate level. Aubrecht, Lin, Demaree, Brooks, and Zou (2006) reported the results from different versions of physics by inquiry courses (i.e. properties of matter, electric circuits, as well as astronomy by sight and optics) using the LPVI. According to Aubrecht (1999), the LVPI is a valuable tool because it provides researchers with information about how students perceive what actually happened in a course without the need for lengthy classroom observations.

The LPVI was designed for the Q-sort methodology (Abraham, 1982). However, in this study, I utilized the LPVI with a Likert scale for ease of data collection and analysis. Klooster, Visser, and Jong (2008) applied both the Q-sort methodology and the

Likert scale in their study. Both methods produced consistent results. Eysink, Jong, Berthold, Kolloffel, Opfermann, & Wouters, (2009), compared the Likert scale and the Q-sort. Internal consistencies for the distribution of participants' responses were compared. Researchers indicated that Likert-scale internal consistencies were higher than the Q-sort. However, internal consistencies departed significantly in regards to the distribution of responses. A clear factor structure was obtained from both Likert and Q-sort formats. In addition, Ross and Michael (2005) studied motivating factors. They surveyed university students, first by ranking (i.e. Q-sort) the students' motivators and then by having the students rate those motivators on a Likert scale. This information clarified results and provided a deeper understanding of student motivators.

It is important to note that permission was obtained from Abraham (1982) to modify LPVI statements for a Likert format (Appendix C). Request for Permission to modify the instrument is located in Appendix D. In this study, LPVI statements were adapted so that responses could be provided in a Likert-scale format. The LPVI was a two-page questionnaire with 25 statements concerning inquiry-based and non-inquiry-based laboratory investigations. The original scale consisted of 13 items addressing non-inquiry-based learning. For the purpose of data analysis, these 13 items were reverse coded. Thus, the scale was used to determine if students were in classes with inquiry-based or non-inquiry-based laboratory investigations. Composite means for all items were calculated. An example of a positive statement is "Students asked to design their own experiments." A score of five or four on this statement would indicate a positive response towards inquiry-based laboratory investigations. The survey was carefully adapted with two objectives in mind: to reduce non-responses and to reduce measurement error (Dillman, 2000). The higher the total score, the more inquiry-based the classroom experience. The point values are reversed for negatively-worded statements (Airasian & Gay, 2003). The purpose of the demographic survey was to collect gender and race/ethnicity student data. Gender was the second independent variable. The gender and race/ethnicity variables were summarized to provide a demographic profile of the students in the study.

Biology EOCT

A standardized test (i.e. EOCT) constructed by the Georgia Department of Education (GDOE) was used to measure biology achievement of students. The Biology EOCT is a paper-and-pencil test that evaluates the content knowledge of the participants. The test contains both knowledge and conceptually-oriented items. The EOCT was reported as highly reliable with a Cronbach's alpha coefficient above .90 (GDOE, 2010). Test questions contained biology concepts from the professional standards of the state (i.e. cell structure and functions, genetics and heredity, biological systems, ecology, and evolution). There were three main administrations of the EOCT during the school year: winter, spring, and summer. In addition to the three main administrations, online mid-month administrations were available to accommodate school schedules. The EOCT in biology included two sections. Each section contained 40 multiple-choice questions and takes 45-60 minutes to complete. Each question on the EOCT purportedly measures a standard within a content domain that represents the ability to understand and communicate biological concepts. Tests are scored and the results determine the scale score, grade conversion score, performance level, and domain level information for each student. The EOCT scores range from 200-450. Students who score 400 meet the GDOE standard and those who score 450 exceed the standard. Written permission was obtained from the school district to access the EOCT data.

Reliability and Validity of Instruments

Content validity of the LPVI survey was established at the time of its development. Statements included in Abraham's (1982) original survey were generated in several brainstorming sessions with science educators familiar with many laboratory techniques. The statements were then pilot tested with individual subjects. Ambiguous statements were modified once the pilot was complete.

Lewicki (1993) modified the Laboratory Program Variable Inventory (LPVI) developed by Abraham (1982) on a four point scale ranging from *rarely occurs* to *very often occurs*. The majority of items were scored 1 to 4 so that a higher score reflected a characteristic of the constructivist method. For some items, the scoring was reversed so that the higher score reflected a decreased occurrence of the activity. The survey was administered to college students enrolled in general chemistry laboratory class. The alpha reliability coefficient for the Laboratory Survey was 0.80. Content validity was established by two college education professors who were familiar with the two treatments used in the study. A modified version of the Laboratory Program Variables Inventory (LPVI), a Q-type instrument, has been used to study students' perceptions of introductory physics labs (Lin, Demaree, Zou, & Aubrecht 1982).

Internal consistency is a common reliability measure that deals with one test at a time. To test for internal consistency, the coefficient alpha (i.e. Cronbach's alpha) was calculated to determine how well the different items complement each other on the same dimensions (Fink, 2006). Cronbach's alpha provides information about the consistency among the items in a single test. The alpha coefficient value ranges between 0 and 1. An alpha coefficient value of .70 indicates an acceptable level of reliability and a value of .80 or higher indicates good reliability. As noted, a Cronbach's alpha of .70 or higher is considered acceptable in most social science research situations and indicates that the reliability of the survey instrument is adequate.

EOCT is a well-established standardized test that has demonstrated reliability evaluated by statistical methods. Cronbach's coefficient alpha ranged from .79 to .86 for reading, .85 to .89 for English, .87 to .91 for mathematics, .89 to .90 for science, and .88 to .91 for social studies (GDOE, 2010).

Data Collection

Data were collected at six high school sites in an urban school district. Permission from Walden University Institutional Review Board was obtained prior to data collection. The IRB approval # was 02-11-13-0131343. Permission was obtained from the school district and the principals of six high schools to conduct the research (Appendix E). Each school was given a three digit code to protect the identity of the students. After obtaining the permission from IRB, the homerooms were selected. The criterion for selecting the homerooms was based on students who completed the 2012 biology EOCT biology. Students enrolled in 9th grade biology and completed their EOCT were moved to their

10th grade homerooms as a cohort group. The students enrolled in 10th grade biology were moved to 11th grade homerooms. These students and their respective homerooms were targeted for the study.

There were 25 students in each homeroom. Four homerooms from each school were selected. The last twenty minutes of the homeroom was utilized to give instructions and distribute the assent (Appendix F), and consent forms. Consent forms were given to the students who completed the 2012 biology EOCT in the previous year. Parent consent forms along with assent forms were sent home, as well. A stamped envelope with my mailing address was attached to the consent form. Students whose parents signed the consent form as well as those parents who refused consent returned one copy of student assent form. The forms were returned either by U.S. mail in a self-addressed stamped envelope to me or returned to the school drop box provided in the counselor's office located on each floor of the school. All parent forms were approved by IRB.

There were four small learning communities in each of the schools. Thus, there was a counselor's office located on each floor. The drop box was locked. Only I had the key to access it. Also, the offices were located in the area of the building with the least traffic. Students and parents were asked to keep one set of the signed forms at home for their records. The parent consent form included a brief explanation of purpose of the survey, risks and benefits of participating in the study, and also sought permission to use their student's EOCT scores in biology for research purposes. Assent forms were given to the students who completed the 2012 biology EOCT.

Subsequent to obtaining permission from the school district and principals, I discussed the purpose of the research during the homeroom period with teachers and all students who had completed 2012biology EOCT. Students were informed that participation is voluntary. I read aloud the assent form and answered students' questions. Assent forms included the purpose of the study, risk and benefits, protection of students' privacy, and an assurance that the student's participation was voluntary. Students were asked to provide their signature and their email ID on the assent form. Only I had the access to the student's email ID.

The survey link using Survey Monkey was sent to students' email ID, so that the students could take the survey. Through the email data collector in Survey Monkey, it was possible to track the respondents, and their email ID could be matched with their names. No individual student's name was provided to the department of planning and accountability. The electronic version of class roster reports was obtained from Research Planning & Development department for all six high schools. These reports contained student name, gender, ethnic group, and their 2012 biology EOCT scale score. Accordingly, the survey responses were linked to the 2012 biology EOCT scores.

After collecting both assent and consent forms, an online confidential survey link using Survey Monkey was sent to the students' email ID to protect their privacy. All students who provided the consent had the opportunity to complete the survey online through Survey Monkey. This ensured a higher return rate. All race/ethnic groups were included in the study. Data were collected from all ethnic groups and analyzed. Accordingly, student demographic stratification was considered in the data analysis. The study did not target any particular ethnic group. In light of this, stigmatization was not a threat for any potential participant. Figures 1 and 2 highlight student demographic stratification as maintained by the Georgia Department of Education. (http://archives.gadoe.org/Reporting).

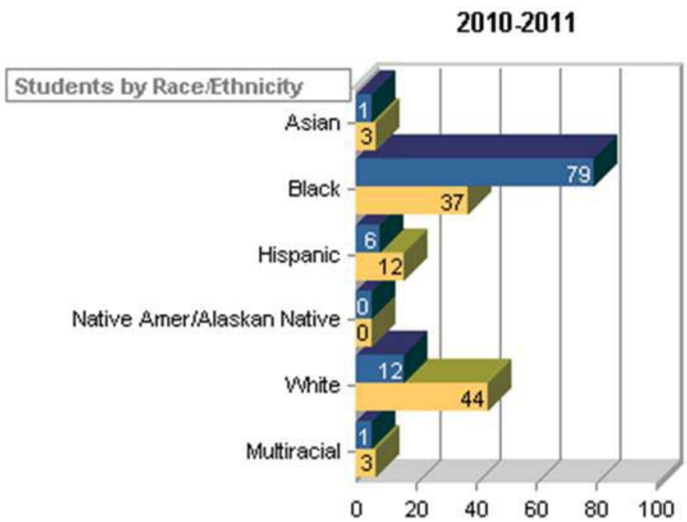

Figure 1. Percentage of enrolled students according to race/ethnicity group at district level. From http://archives.gadoe.org/Reporting

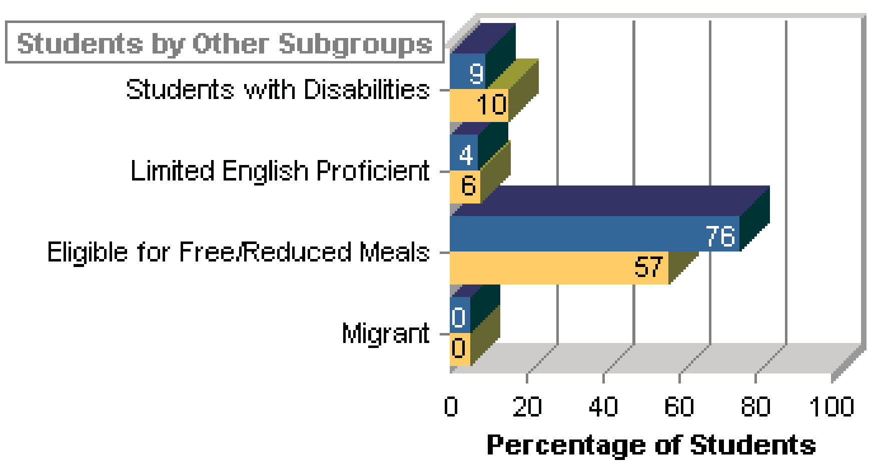

Figure 2. Percentage of enrolled students according to race/ethnicity group at district level. Retrieved from http://archives.gadoe.org/Reporting

As evidenced in the student population stratification, the largest ethnic group is Black. Hence, the students participating in the survey were predominantly African American. Participants were given an opportunity to exclude their data from the study. Electronic data were password protected with a secure password accessible only by me.

Student performance on the biology EOCT was reported on a scale that ranged from 200 to above 450 or more for state standards-based performance tests. According to the GDOE (2010), to meet expectations on the Biology EOCT, students must answer 70% of the test items correctly. Only I had the access to the test scores. All students' records were stored in a file cabinet with a single lock. In this study, I collected the data related to demographic descriptors included ethnicity and gender through the survey. Names of the students, student ID, school site or organization were not revealed. Identifiers included the email ID provided by the students through the assent form. This identifier was used only to send the survey link, so that the participants could take the survey.

Data Analysis

In the first phase of the study, the Laboratory Program Variable Inventory (LPVI) survey (Abraham, 1982) was used to collect students' self-reports on their use of inquiry-based and non-inquiry-based laboratory investigations in their classes. Individual student scores on LPVI were collected through an email data collector, Survey Monkey. Aggregate scores of the individual students were calculated. Data collected for all ethnic groups were analyzed and reported. Individual survey scores of students who self-reported using Inquiry-based laboratory investigations and also students who self-reported using non inquiry-based laboratory investigations were matched with the individual biology EOCT scores.

Descriptive statistics were used to determine the mean, median, and standard deviation. The data imported into PASW (formerly SPSS) 20.0 software were used to analyze student data. Pearson correlation *r* was utilized in the analysis of the results of both the LPVI survey and 2012 biology EOCT scores to determine whether a relationship existed between the two variables, with a Type I alpha error rate of 0.05. The learning setting was an independent variable and the EOCT scores in biology was the dependent variable. Therefore, the Pearson correlation *r* was used to measure the degree and the direction of the linear relationship between LPVI scores and EOCT scores (Gravetter & Wallnau, 2005). In the second phase of the study, I assessed the differences by gender from both learning settings on the Biology EOCT using partial correlation analysis. In this analysis, I collected the data related to demographic descriptors.

A brief report of the study results was sent within a six month period to students and parents involved in the study. In addition, the publication of the study results in the school newsletter ensured sufficient communication of study outcomes to students. Further, a handout providing details of the results was made accessible to others that were interested in the study. A presentation of the study results was also delivered at a PTSA meeting.

Research Questions and Hypotheses

The research questions investigated were:

Research Question 1 (RQ1): What is the relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes?

Null Hypothesis 1 (H01): There is no relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes.

Alternative Hypothesis 1(H1): There is a relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes.

The Pearson correlation measure was used to analyze the results of both LPVI survey scores and End of Course Test scores in biology to determine whether a relationship existed between the two variables, with a Type I alpha error rate of 0.05. The degree of relationship was expressed as a correlation coefficient. A correlation coefficient is a decimal number ranging from +1.00 to -1. A coefficient near +1 has a high size and a positive direction. If the coefficients are near .00, the variables are not related. A coefficient near -1.00 has a high size and negative or inverse direction. The end results of data analysis are a number of correlation coefficients, ranging between -1.00 and +1.00. (Gay &Airasian, 2003). The first independent variable was the learning setting (i.e. inquiry-based laboratory investigations versus non-inquiry-based laboratory investigations) and the dependent variable was EOCT biology scores. Pearson correlation was used to measure the degree and the direction of the linear relationship between individual student's LPVI scores and individual student's EOCT scores (Gravetter & Wallnau, 2005).

Research Question 2 (RQ2): What is the relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when controlling for student gender?

Null Hypothesis 2 (H02): There is no relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when controlling for student gender.

Alternative Hypothesis 2 (H2): There is a relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when controlling for student gender.

The second independent variable was the gender (i.e. male versus female). The dependent variable was the 2012 EOCT biology scores. A partial correlation analysis was used to examine, the relationship while partialling out the effects of student gender.

Protection of Participants' Rights

Participants encountered minimal risk by being involved in the study. Minimum risk was ensured because consent was received by the school officials and the parents of the student participants, prior to conducting the study. In addition, the IRB application was approved by the Walden University Review Board. Participants experienced minimal stress or anxiety from answering survey questions. Furthermore, I took all possible steps to protect the confidentiality of the students' data by limiting access to the data.

Specifically, protections of electronic data were made possible by using unique user storage IDs and passwords and by the proper destruction of data.

The largest percentage of students participating in the survey was Black, due to student demographic. Since the study included all the ethnic groups and the data were analyzed for all the groups, there was no risk of fostering negative stereotypes about one particular ethnic group. All groups were included in the study, so that all students had equal opportunity to contribute to the data collection. There were no penalties for refusing to participate or withdrawing. Sufficient time was given to the participants to make decision whether to participate or withdraw from the study.

To protect the students from safety and privacy risks, the information they provided was not disclosed to others at any time of the research. Names of the students, student identification, school site or organization were not revealed in the study. The study included all students having completed a Biology course during the prescribed timeline. Data regarding race/ethnicity was collected by the Georgia State Department of Education (GDOE). In turn, GDOE produced a student demographic stratification analysis.

In terms of this study, all data will be destroyed after five years using appropriate measures for data disposal. In particular, electronic data will be destroyed using specific software product (i.e. Erase or CyberScrub). The study may not directly benefit the study participants, but the students who continue to take biology courses that offer the laboratory method of investigations will likely reap the benefits of this study, as it is proven that this method of instruction increases content retention and clarity of scientific concepts. By extension, society benefits due to the increased academic preparedness of American citizens in the science. In addition, the international science community may benefit from this study, since it focuses on improving instructional strategies and practices for teaching science.

Role of the Researcher

At the time of data collection I was employed by the school district in which the study was conducted. I continue to teach Biology to various grade levels using inquiry-based teaching in the school district in which the study took place. She has been in her current position for ten years. The study was not administered in the school where I am currently working. Study participants were students that attended other schools in the district.

Summary

The purpose of the study was to determine whether inquiry-based laboratory investigations can improve the standardized test scores (EOCT) of students and also to examine, the relationship while partialling out the effects of student gender. Section three presented the research methodology that was used in the study with a description of the variables identified for generating relevant results. The setting, sampling method, sample size, data collection, and method of analyzing the data were discussed. The following two sections include descriptions of the findings, data interpretation, and conclusions that were drawn from the study. Specifically, section four includes the results of the uantitative data analysis, and section five the discussion of the results along with study conclusions.

Section 4: Results

The primary purpose of this quantitative study was to determine the relationship between students' use of inquiry-based laboratory investigations in class (as indicated by the LPVI survey) and students' biology performance as measured by standardized test scores in biology on the EOCT. A secondary purpose was to examine the relationship while partialling out the effects of student gender. Section 4 presents findings resulting from analysis of the data collected in the study. This section features the research questions that were addressed in the study, the research tools, the data collection instruments used, the data analysis, a summary, and interpretation of the outcomes.

There were two main research questions guiding this study relative to the primary and secondary purposes:

Research Question 1 (RQ1): What is the relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes?

Research Question 2 (RQ2): What is the relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when controlling for student gender?

The following corresponding hypotheses were investigated.

Null Hypothesis 1 (H_{01}): There is no relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes.

Null Hypothesis 2 (*H_{02})*: There is no relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when controlling for student gender.

Alternative Hypotheses 1(H_1): There is a relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes.

Alternative Hypothesis 2 (H_2): There is a relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when controlling for student gender.

The independent variables were learning setting and gender. The dependent variable was students' Biology EOCT scores. The purpose of the EOCT was to assess student achievement in Georgia Performance Standards in the eight EOCT core courses. The Georgia Department of Education (2012) reported the following:

> Data from the End of Course Test will also be used to differentiate instruction in the classroom and procure data to measure the efficacy of classroom instruction. A student's final grade includes 80% of course work and 20% of EOCT scores. In biology, the cut score that indicates a student is meeting the EOCT standard is 400 on a scale of 400-650. The cut score that indicates a student is exceeding the standard is 450. In addition to a scale score, a grade conversion scale, ranging from 0-100, describes student performance on an EOCT. (p.68)

Based on these findings, the final course grade must be a 70 or higher to pass the course.

Inquiry-based laboratory investigations, which the school uses to instruct students, were assessed using a self-report survey called the Laboratory Program Variables Inventory (LPVI). Developed by Abraham (1982), the LPVI survey was used to determine the scores of students who self-reported membership in inquiry-based versus non-inquiry-based laboratory investigation classes. The survey consisted of 25 statements describing interactions between students and teachers as well as students and material. Additionally, students' experiences in the laboratory were assessed. They were coded on a 5-point Likert scale with the following categories: 1 = *strongly disagree*, 2 = *disagree*, 3 = *neutral*, 4 = *agree*, and 5 = *strongly agree*. Scores ranging from 3.0 to 5.0 indicate a higher level of inquiry-based laboratory investigations. Lower scores indicate more traditional or non-inquiry-based labs. Survey items were analyzed for internal consistency using Cronbach's alpha. The Cronbach's alpha was calculated to be .85, indicating good reliability of the survey instrument (Fink, 2006).

Data from the biology EOCT were compared and analyzed with the LPVI survey data to determine the relationship between students' use of inquiry-based laboratory investigations in class and students' biology standardized test performance.

Research Procedures

The setting for this study was six high schools from an urban school district. The schools were within a 10-mile radius from my employer. The location of the schools was convenient and allowed me to promptly address any questions or concerns. After obtaining permission from the research planning and development department of the school district, a letter of cooperation from the school principals was obtained to conduct the survey. Prior to conducting the study, approval from Walden University IRB was received. The IRB approval number was 02-11-13-0131343.

Informed consent and assent forms were distributed to 588 students who had completed their EOCT in 2012 at the six high schools. Parental consent forms were sent to the parents with a self-addressed stamped envelope. After signing, parents were asked to either return the form by mail or have their student place it in the designated drop box, located in the school counselor's office at each campus. Parents were also instructed to keep a copy of the consent form for their own records. Students wrote their email address on their assent forms. They were given a week to decide to participate in the study. After 1 week, I visited the six schools to collect the assent and consent forms. During the first week, there was poor response from the students. In light of this, the following week, I revisited the homerooms and discussed the purpose of the research and benefits with the educators teaching science. As a result, participation increased.

The parent consent form included a brief explanation of the purpose of the survey, a description of the risks and benefits of participating in the study, and a request for permission to use students' EOCT scores in biology for research purposes. All members of the sample received an email invitation. A survey link was also sent to their email address through Survey Monkey. Students completed the online survey in real time. Weekly reminders were sent to students who needed to complete the online survey. Of the 588 forms distributed, 256 valid completed surveys were received. Overall, 43% of the students invited to participate did complete the survey.

Research Tools

There were two sets of tools used in the study. They were the Laboratory Program Variables Inventory (LPVI) and 2012 Biology EOCT scores. The LPVI (Abraham, 1982) was used to assess inquiry-based laboratory investigations conducted by students enrolled in the biology course of study. I obtained information on students' self-reported use of inquiry-based laboratory investigations using scores from the LPVI survey. The LPVI survey was used to collect student data through Survey Monkey. Students self-reported membership in inquiry-based laboratory investigation classes and non-inquiry-based laboratory investigation classes. The LPVI was designed using the Q-sort methodology (Abraham, 1982). However, in this study, the LPVI was developed as a Likert scale for ease of data collection and analysis. It is important to note that permission was granted by Abraham to modify LPVI statements using a Likert scale format. The LPVI is a two-page questionnaire with 25 statements concerning inquiry-based and non-inquiry-based laboratory investigations. The original scale consists of 25 items, including 13 items addressing non-inquiry-based learning. Composite means for all items were calculated. A higher score indicated a perceived level of experience in inquiry-based laboratory investigation classes. A score of 5 or 4 on each statement indicated a positive response toward inquiry-based laboratory investigations.

The End of Course Test (EOCT), a standardized test constructed by the Georgia Department of Education (GDOE), is used to measure student achievement in biology. A paper-and-pencil test, the Biology EOCT evaluates content knowledge. The test contains both knowledge and conceptually oriented items. Biology concepts that reflect the professional standards of the state—cell structure and functions, genetics and heredity, biological systems, ecology, and evolution—are included in the test. The EOCT in biology includes two sections. Each section contains 40 multiple-choice questions. It takes 45-60 minutes to complete each section. Each question on the EOCT measures a standard within a content domain that represents the ability to understand and communicate biological concepts. The test was administered during the winter, spring, and summer school calendar terms. In addition to the three main administrations, online mid-month administrations were available to accommodate varying student and school schedules. The EOCT scores range from 200-450. Students who score 400 meet the GDOE standard of proficiency. Those who score 450 exceed the standard.

Data Organization

The data collected through Survey Monkey were organized in Microsoft Excel, version 2007, for analysis. Individual student data were input in a spreadsheet. The spreadsheet included the sum of the survey scores for each student, corresponding EOCT scores, along with the gender and ethnicity of each student who responded to the survey. Student ethnicity was coded as per the EOCT reports that I received from the district. They were: W = Caucasians, B = African Americans, AI = American Indian or Alaska Native, H = Hispanic or Latino, and M = Multiracial. Student names and email addresses were also excluded from the spreadsheet, in order to insure confidentiality. For the purpose of data analysis the gender was coded as male = 1, and female = 2.

The electronic data were stored on my computer with a unique password to which she had sole access. Hard copies of the assent and consent forms collected from each school were organized in six binders. These binders were stored in locked cabinets to which only I had the keys. All data will be stored for the next five years.

Data Analysis and Results

Two different sources of data were collected for this study. The first set of data included results from the Laboratory Program Variables Inventory (LPVI) (Abraham, 1982). The LPVI was used to measure the independent variable (i.e. type of learning setting) to determine if students were in classes with inquiry-based laboratory investigations or classes that utilized non-inquiry based laboratory investigations.

Table 2 indicates the percentage of respondents for each statement on the LPVI. Students agreed or strongly agreed to all statements except items 4, 7, 9, and 24. Students mostly agreed with Statement 2 (i.e. Questions in the laboratory manual require the interpretation of the data), whereas they least agreed with Statement 4 (Students are allowed to go beyond laboratory exercises and do experiments on their own).

Table 2

Percentage of Respondents for Each Statement on the Survey Laboratory Program Variable Inventory

	Survey Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
1.	Students follow step by step instructions in the laboratory manual.	1.7%	4.1%	22.4%	44.9%	26.9%
2.	Questions in the laboratory manual require the interpretation of the data.	1.0%	3.4%	22.0%	54.6%	19.0%
3.	The instructor is concerned with correction of data.	2.4%	6.1%	15.6%	42.9%	33.0%
4.	Students are allowed to go beyond laboratory exercises and do experiments on their own.	28.4%	30.1%	21.6%	12.5%	7.4%
5	Laboratory activities are used to develop categories.	1.7%	1.3%	17.8%	54.5%	24.6%
6.	The instructor lectures to the whole class.	1.3%	8.1%	21.1%	36.2%	33.2%
7.	Students are asked to design their own experiment.	18.4%	36.7%	24.8%	13.9%	6.1%
8.	During laboratory students record information requested by the instructor or the laboratory manual.	14.0%	2.0%	16.2%	50.0%	30.4%
9.	Laboratory session raise new problems or result in data that cannot be explained immediately.	5.1%	22.6%	40.2%	25.0%	7.1%

(Table continues)

	Survey Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
10.	The instructor or laboratory manual identifies the problem to be investigated.	1.3%	4.4%	21.8%	54.4%	18.1%
11.	Laboratory activities require students to solve problems.	1.0%	2.7%	17.3%	52.9%	26.1%
12.	The laboratory manual requires that specific questions be answered.	1.0%	2.0%	20.1%	51.7%	25.2%
13.	The instructor or laboratory manual requires that students explain why certain things happen	0.3%	3.0%	17.4%	53.7%	25.5%
14.	Laboratory is used to investigate a problem that comes in class.	3.4%	21.2%	31.2%	34.6%	9.6%
15.	Laboratory experiments develop critical thinking skills in biology.	2.1%	1.7%	22.3%	46.9%	27.1%
16.	Questions in the laboratory manual require that students use evidence to back up their conclusions.	1.4%	1.7%	16.2%	47.0%	33.8%
17.	Students discuss their data and conclusions with each other.	2.4%	4.5%	22.3%	47.3%	23.6%
19	During laboratory students, record information they feel is important.	3.0%	5.1%	20.6%	46.3%	25.0%

	Survey Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
20.	Students propose their own explanations for observed phenomenon.	1.7%	7.2%	33.0%	43.3%	14.8%
21.	Students identify the problems to be investigated.	2.4%	4.7%	25.1%	49.2%	18.6%
22. .	During laboratory students check the correction of their work with the instructor.	1.7%	4.7%	19.3%	45.4%	28.8%
23.	In discussion with the instructor, assumptions are challenged and conclusions must be justified.	0.7%	5.1%	19.9%	47.6%	26.7%
24.	Students usually know the general outcome of the experiment before doing the experiment.	7.8%	22.6%	36.8%	25.3%	7.4%
25.	The instructor gives information to students in small groups.	3.0%	13.5%	30.3%	37.0%	16.2%

Frequencies and percentage of the survey LPVI scores are presented in Table 3. As presented in Table 3, LPVI scores ranged from 44 to 125. The frequency distribution ranged between 1 to 17, and the cumulative percentage ranged from 4 to100. The mean LPVI score was 91.48 (*SD* = 10.96).

Table 3

Frequencies and Percentage of the Survey LPVI Scores (N = 256)

Scores		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	44.00	1	.4	.4	.4
	45.00	1	.4	.4	.8
	69.00	1	.4	.4	1.2
	73.00	3	1.2	1.2	2.3
	75.00	5	2.0	2.0	4.3
	76.00	8	3.1	3.1	7.4
	77.00	8	3.1	3.1	10.5
	78.00	2	.8	.8	11.3
	79.00	3	1.2	1.2	12.5
	80.00	6	2.3	2.3	14.8
	81.00	3	1.2	1.2	16.0
	82.00	6	2.3	2.3	18.4
	83.00	9	3.5	3.5	21.9
	84.00	4	1.6	1.6	23.4
	85.00	9	3.5	3.5	27.0
	86.00	5	2.0	2.0	28.9
	87.00	12	4.7	4.7	33.6
	88.00	17	6.6	6.6	40.2
	89.00	8	3.1	3.1	43.4
	90.00	15	5.9	5.9	49.2
	91.00	12	4.7	4.7	53.9
	92.00	8	3.1	3.1	57.0
	93.00	8	3.1	3.1	60.2
	94.00	10	3.9	3.9	64.1
	95.00	6	2.3	2.3	66.4
	96.00	8	3.1	3.1	69.5
	97.00	7	2.7	2.7	72.3
	98.00	7	2.7	2.7	75.0
	99.00	7	2.7	2.7	77.7
	100.00	7	2.7	2.7	80.5

(Table continues)

Scores	Frequency	Percent	Valid Percent	Cumulative Percent
103.00	9	3.5	3.5	89.1
104.00	2	.8	.8	89.8
105.00	1	.4	.4	90.2
106.00	4	1.6	1.6	91.8
107.00	3	1.2	1.2	93.0
108.00	3	1.2	1.2	94.1
109.00	2	.8	.8	94.9
110.00	1	.4	.4	95.3
112.00	1	.4	.4	95.7
113.00	4	1.6	1.6	97.3
114.00	2	.8	.8	98.0
115.00	2	.8	.8	98.8
119.00	1	.4	.4	99.2
123.00	1	.4	.4	99.6
125.00	1	.4	.4	100.0
Total	256	100.0	100.0	

The second part of the data collection involved gathering EOCT scores in biology for the test that was administered in 2012. Archival EOCT test score data were retrieved from the Department of Research Planning and Development for all students who completed the biology EOCT in 2012. After six weeks, LPVI data collected through Survey Monkey were downloaded into MS Excel. Shortly after, student EOCT scores were added to this file. The data were imported into PASW (formerly SPSS), version 20.0, for analysis. Categorical data were recoded, as needed, into numerical data (e.g., male = 1, female = 2). The data were examined for outliers using scatterplots as shown in Figure Example 3. No outliers were found.

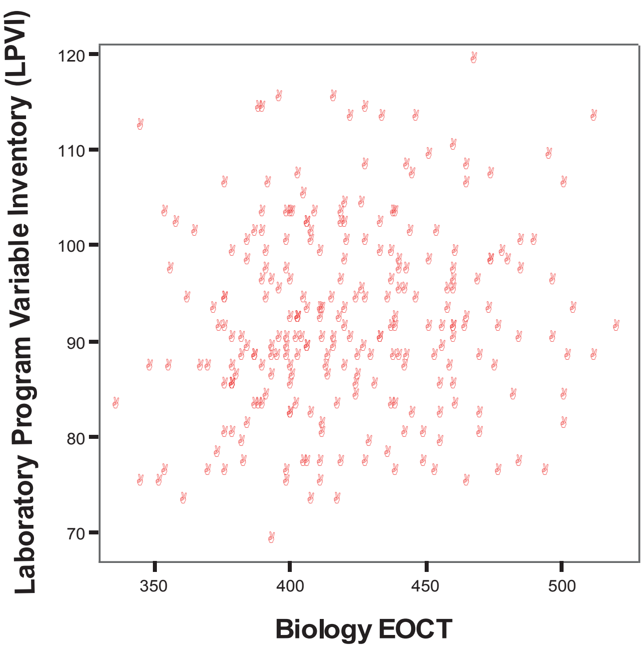

Figure 3. Sample scatter plot.

I further defined the analyses with an examination of descriptive statistics, Pearson correlation, and partial correlation.

Description of the Sample

A total of 256 cases were included in the study. There were more females (60.2%, n = 154) than males (39.8%, n = 102). Table 4 represents the frequencies and percentages for the demographic variables. The majority of the respondents were Black (97.3%, n = 249). There was one American Indian student (0.4%), one White student (0.4%), two Asian or Hispanic students (0.8%), and three multi-racial students (1.2%). The information related to student ethnicity was obtained through a demographic question used in the survey, "Are you White, Black or African-American, American Indian or Alaskan Native, Asian, Native Hawaiian or other Pacific islander, or other?" The information related to gender was obtained through the second question on the survey, "Are you a male or female?"

Table 4

Frequencies and Percentages for the Demographic Variables (N = 256)

Variables	Frequency	Percentage
Gender		
Females	155	60.2
Males	102	39.8
Race		
American Indian	1	0.4
Asian or Hispanic	2	0.8
Black	249	97.3
White	1	0.4
Multi-racial	3	1.2

Description of the Study Variables

As presented in Table 5, LPVI scores ranged from 44 to 125. The mean LPVI score was 91.48 (*SD* = 10.96). Biology EOCT scores ranged from 337 to 550. The mean EOCT score was 422.96 (*SD* = 38.22). Neither of the variables was significantly skewed. The skew statistic was .20 and .39 for LPVI and biology EOCT, respectively.

Table 5

Descriptive Statistics for the Study Variables (N = 256)

Variables	Range	*M*	*SD*	Skew	Kurtosis
LPVI	44 to 125	91.48	10.96	-.20	2.03
Biology EOCT	337 to 550	422.96	38.22	.39	-.15

Note. SE for skew statistic = .15. SE for kurtosis statistic = .30.

Hypotheses Tests

First Hypothesis

It was hypothesized that there would be a relationship between perceived level of experience in inquiry-based laboratory investigation classes and standardized test scores. The null hypothesis stated there was no relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes. To test these hypotheses, a Pearson correlation procedure was conducted. The outcome of the Pearson correlation is shown in Table 6. The findings in Table 6 revealed that perceived level of experience in inquiry-based laboratory investigation classes, as measured by the LPVI, was associated with standardized test scores, as measured by the Biology EOCT, $r = .12$, $p = .04$.

Table 6

Pearson Correlation

		Laboratory Program Variable Inventory (LPVI)	Biology EOCT
Laboratory Program Variable Inventory (LPVI)	Pearson Correlation	1	.126*
	Sig. (2-tailed)		.044
	N	256	256
Biology EOCT	Pearson Correlation	.126*	1
	Sig. (2-tailed)	.044	
	N	256	256

* Correlation is significant at the 0.05 level (2-tailed).

The Pearson correlation test was conducted to analyze the results of both LPVI survey scores and End of Course Test scores in biology to determine whether a relationship existed between the two variables, with a Type I alpha error rate of 0.05. The independent variables were learning setting and gender, and the dependent variable was students' biology EOCT scores. The mean LPVI score was 91.48 (*SD* = 10.96) and the mean EOCT score was 422.96 (*SD* = 38.22). The results presented in Table 7 reveal that perceived level of experience in inquiry-based laboratory investigation classes, as measured by the LPVI, was associated with standardized test scores, as measured by the Biology EOCT, $r = .12$, $p = .04$. A correlation of .12 indicated a small direct correlation such that an increase in LPVI scores was associated with an increase in biology EOCT scores. Given these results, the null hypothesis was rejected.

Table 7

Results of Pearson Correlations (N = 256)

		Laboratory Program Variable Inventory (LPVI)
Biology EOCT	Pearson Correlation	.12*
	Sig. (2-tailed)	.04

Note. * indicates p is less than .05.

The results presented in Table 7 show a correlation of .12, indicating a direct correlation. Hence, an increase in LPVI scores was associated with an increase in biology EOCT scores.

Second Hypothesis

The second hypothesis postulated that there would be a relationship between perceived level of experience in inquiry-based laboratory investigation classes and standardized test scores, when controlling for student gender. The null hypothesis stated that there was no relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when controlling for student gender. To test these hypotheses, a partial correlation procedure was conducted. The findings of the partial correlation for the LPVI and biology EOCT scores for gender are shown in Table 8. These findings revealed that after controlling for gender, perceived level of experience in inquiry-based laboratory investigation classes, as measured by the LPVI, remained correlated with standardized test scores, as measured by the biology EOCT, $r = .12$, $p = .04$. A correlation of .12 indicated a small direct correlation such that an increase in LPVI scores was associated with an increase in biology EOCT scores. Given these results, the null hypothesis was rejected.

Table 8

Partial Correlations

Control Variables			Laboratory Program Variable Inventory (LPVI)	Biology EOCT	GEN_NUM
-none-[a]	Laboratory Program Variable Inventory (LPVI)	Correlation	1.00	.12	.01
		Significance (2-tailed)	.	.04	.80
		Df	0	254	25
	Biology EOCT	Correlation	.12	1.00	.01
		Significance (2-tailed)	.04	.	.86
		Df	254	0	254
	GEN_NUM	Correlation	.01	.01	1.00
		Significance (2-tailed)	.80	.86	.
		Df	25	254	0
GEN_NUM	Laboratory Program Variable Inventory (LPVI)	Correlation	1.00	.12	
		Significance (2-tailed)	.	.04	

[a] Cells contain zero-order (Pearson) correlations.

The findings of Zero-order correlation for the LPVI, biology EOCT scores, and gender are found in Table 9. These findings revealed that the perceived level of experience in inquiry-based laboratory investigation classes, as measured by the LPVI, was associated with standardized test scores, as measured by the biology EOCT, $r = .12$. A correlation of .12 indicated a direct correlation.

Table 9

Zero-Order Correlation Results for the LPVI, Biology EOCT, and Gender (N = 256)

Variables	1	2
1. LPVI		
2. Biology EOCT	.12	
3. Gender	.01	.01

Summary

The statistical analysis used to test the hypotheses was the Pearson correlation. Data from 256 participants were included in the analyses. The results revealed a direct statistically significant correlation (r = .12, p = .04) between perceived level of experience in inquiry-based laboratory investigation classes (as measured by the LPVI) and standardized test scores (as measured by the biology EOCT). The correlation remained after controlling for gender. Based on the findings from the data analysis, both the null hypotheses were rejected and the alternative hypotheses were accepted, thus supporting the reviewed literature. The study adds to the body of literature on inquiry-based laboratory investigations by offering further evidence which verified that a relationship exists between inquiry-based laboratory investigations and students' performance on standardized tests.

Section 5: Discussion, Conclusions, and Recommendations

Overview

The foundation of this research study was conceptualized after reviewing a study conducted by Turner and Rios (2008) that focused on science instruction through the use of inquiry-based activities. Turner and Rios concluded that students who learned through inquiry demonstrated increased performance on standardized tests and improved laboratory skills in experiment designing. The hypotheses presented in this study were intended to strengthen the views of researchers who claim that inquiry-based laboratory investigations in science instruction lead to an increase in standardized test scores in the sciences.

The low performance of students on standardized tests in biology is a cause of concern for public school administrators. Consequently, it is imperative for schools to provide meaningful science instruction through inquiry. This quantitative research study examined the correlation between inquiry-based laboratory investigations and standardized test scores for students. Descriptive and inferential statistics were used to analyze the quantitative data. Pearson correlation r was used to analyze the degree of relationship between LPVI survey scores and the Biology EOCT scores of individual students. The study also examined whether there was a significant difference in standardized test scores by gender within the student population studied, using partial correlational analysis.

Study participants included 256 high school students in biology courses completing the 2012 Biology EOCT in six high schools. All students who provided consent had an opportunity to complete the online survey through Survey Monkey. All racial/ethnic groups were included in the study.

Two different sources of data were collected for this study. The first set of data consisted of the results from the Laboratory Program Variable Inventory (LPVI) (Abraham, 1982). The LPVI survey was used to collect students' self-reports on their use of inquiry-based and non-inquiry-based laboratory investigations in their classes. The second part of the data collection effort involved school district archival test data for EOCT scores in biology for the 2012 academic year. Pearson correlation *r* was used to analyze the degree of relationship between scores on the LPVI survey and the EOCT scores of individual students.

As described in Section 4, these hypotheses were tested using the Pearson correlation procedure:

Null Hypothesis 1: There is no relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes.

Null Hypothesis 2: There is no relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when controlling for student gender.

Alternative Hypothesis 1: There is a relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes.

Alternative Hypothesis 2: There is a relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when controlling for student gender.

Findings

The primary statistical limitation to this study was the amount of variance unaccounted for in the analysis. The correlation between perceived level of experience in inquiry-based laboratory investigation classes and standardized test scores was only .12, indicating a weak linear relationship. The coefficient of determination (*r* squared) was .01. Thus, only 1% of perceived level of experience in inquiry-based laboratory investigation classes was directly accounted for by standardized test scores, and vice versa. Other factors not included in this study, or controlled for, may contribute to this correlation. A second limitation is reverse causation.

The findings revealed that student perceived level of experience in inquiry-based laboratory investigation classes, as measured by the LPVI, was associated with standardized test scores, as measured by the Biology EOCT, $r = .12$, $p = .04$. A correlation of .12 indicated a direct correlation such that an increase in LPVI scores was associated with an increase in Biology EOCT scores. Given these results, the null hypothesis was rejected.

Question 2 was a continuation of the first and focused on student subpopulations by asking if there was a relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when student gender was controlled. The null hypothesis stated that there was no relationship between perceived level of experience in inquiry-based laboratory investigation classes and standardized test scores when controlling for student gender. The alternate hypothesis stated that there was a relationship between perceived level of experience in inquiry-based laboratory investigation classes and standardized test scores when student gender was controlled. Partial correlation analysis was used to examine the relationship while partialling out the effects of student gender. As a result of the gender examination, perceived level of experience in inquiry-based laboratory investigation classes remained correlated with standardized test scores. The correlation remained after controlling for gender. Given these results, the null hypothesis was rejected.

Interpretation of Findings

Research findings on science instruction that integrates experiments related to day-to-day life experiences reveal positive attitudes for learning science through exploration and discovery (Connors & Perkins, 2009). This teaching method can also improve test scores and academic skills by aligning an experience-based science curriculum with the types of questions found on state exams. For instance, Stephen (2007) investigated inquiry-based labs in botany and found that students developed: (a) conceptual understanding in science, (b) the ability to perform scientific inquiries, (c) a better understanding about inquiry, and (d) the ability to make connections to the real world. Although several factors contributed to the low achievement of Black students on standardized tests, an instructional model of inquiry-based teaching that incorporated multimedia tools in the classroom improved the performance of Black students on standardized tests (Monica, 2005).

The first research question in this study concerned the relationship between students' use of inquiry-based laboratory investigations in class and students' biology performance. The hypothesis predicted that there would be a relationship between perceived level of experience in inquiry-based laboratory investigation classes and standardized test scores. The null hypothesis stated that there would be no relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes. The first analysis conducted was a Pearson correlation. The findings were in favor of inquiry-based laboratory investigation classes.

As supported by the study results, the direct correlation between the perceived level of experience in inquiry-based laboratory investigation classes and standardized test scores revealed that an increase in LPVI scores was associated with an increase in Biology EOCT scores. In addition, as predicted, the null hypotheses were rejected. Hence, as supported by the work of Turner and Rios (2008), high school students demonstrate increased academic performance on standardized tests when biology instruction includes inquiry-based laboratory investigations. Also, the outcome of this study reaffirmed the successes identified by Monica (2005), Geier and Stephen (2007), Walker and Zeidler (2007), Colburn (2008), and Beamer (2008), whose studies provided evidence that a correlation of .12 indicated a direct correlation with students receiving inquiry-based labs in science classes and their standardized test performance. The studies further supported that an increase in LPVI scores was associated with an increase in Biology EOCT scores.

The second question examined the relationship while partialling out the effects of student gender. It was hypothesized that there would be a relationship between perceived level of experience in inquiry-based laboratory investigation classes and standardized test scores when controlling for student gender. The null hypothesis stated that there would be no relationship between standardized test scores and perceived level of experience in inquiry-based laboratory investigation classes when student gender was controlled. To test this hypothesis, a partial correlation procedure was conducted. The findings of the second analysis indicated that when student gender was controlled, perceived level of experience in inquiry-based laboratory investigation classes remained correlated with standardized test scores. A correlation of .12 indicated a direct correlation such that an increase in LPVI scores was associated with an increase in Biology EOCT scores. These results reinforced the alternative hypothesis and rejected the null hypothesis.

The outcome of this study supports the findings of Deborah, Ciara, and Courtney (2008) as well as Monique, Henry, and Frances (2011) who examined gender differences in Black youth with respect to school racial discrimination and academic engagement outcomes. Their findings indicated that although no significant difference was found between standardized test scores of boys and girls, the mean grade point average of the girls was significantly higher than the boys. The outcomes of these studies are further supported by Ketty and June (2010) who examined gender and ethnic differences using a performance-based assessment. Their results indicated that although all ethnic groups were well-represented in their study, no gender differences were found.

Evidenced in this study, after controlling for gender, students' perceived level of experience in inquiry-based laboratory investigation classes remained correlated with standardized test scores. The study builds upon the findings of previous studies which reported no detailed analysis on the effect of students' gender on standardized tests in biology. While providing support for inquiry - based laboratory investigations this study expands the findings of previous studies.

Lambert and Ariza, (2008) demonstrated that incorporating inquiry in earth science yielded a significant increase in science standardized test scores. Similar to this study, Lambert and Ariza (2008) supported that science instruction which integrates methods that provide a deeper understanding of inquiry-based laboratory investigation best positions students for academic success. To this end, the recommendations of this study include offering professional development in laboratory-based instructional strategies and methods of experimentation for science teachers. In addition, the curriculum should be modified to reflect a hands-on learning model in science classes.

National science education standards require that high school teachers plan inquiry-based investigations that engage students in combining process and critical reasoning skills leading to an understanding of science (National Research Council, 1996). This research study suggests a link between inquiry-based laboratory investigations and standardized-test performance of students. An inability to assess inquiry-based investigations in conjunction with a lack of resources and curriculum have been identified as major obstacles to incorporating inquiry-based investigations in instruction (Deborah, Ciara, & Courtney, 2008; Ketty & June, 2010; Monique, Henry & Frances, 2011).

As the study results indicate a need to change the traditional delivery of instruction, it is recommended that teachers be offered professional development opportunities to develop instructional practices that incorporate a more hands-on approach to science instruction. In addition, aligned with the Common Core Standards, curriculum modifications should reflect best practices that will have students acquire the skills needed to be college and career ready. Data should be shared with the school district, so that the findings of this study may be taken into account as curriculum is modified. Implementation of the recommendations posed in this study can yield positive academic and social changes at the school, district, state and federal levels.

Implications for Societal Change

This study has implications for societal change at the classroom, school, district, state, and federal levels. During the last two decades, there have been many policy changes with respect to high-stakes tests. The passing threshold on standardized tests has increased from minimum competency to proficiency (Lee, 2008). Consequently, the challenge for administrators and teachers lay in increasing student scores on standardized tests, as an indicator of successful academic achievement under NCLB. The data from Section 4 revealed a correlation between perceived level of experience in inquiry-based laboratory investigation classes and standardized test scores. A long-term outcome of this study may be a change from teacher-centered to student-centered pedagogy, in order to increase standardized test scores. The results of this study may also influence policy makers to reform curriculum standards. A change in curricula may also promote social change, as students become more competent and better able to succeed in life beyond secondary school.

Students who continue to learn through inquiry-based laboratory methods are likely to reap the benefits of this study through the possibility of their increased retention of knowledge and clarity of scientific concepts. Furthermore, our society develops a stronger intellectual foundation as its citizens are positioned to acquire stronger competencies in the field of science. Changing science instruction to reflect inquiry-based learning in the sciences may also be impactful in the international community.

Recommendations for Action

National data from the Program for International Student Assessment (PISA) in science showed that science literacy scores of United States students were lower than scores for 16 of 29 nations from the Organization for Economic Cooperation and Development (PISA, 2009). The results of this study revealed a correlation between perceived level of experience in inquiry-based laboratory investigation classes and standardized test scores. Further, after controlling for gender, perceived level of experience in inquiry-based laboratory investigation classes remained correlated with standardized test scores. For this reason, this study may provide insight to administrators, teachers and curriculum specialists who seek valid reasons to reform teaching practices in order to increase student achievement on standardized tests.

Results from this study will be shared with the research, planning and development department of the school district, as well as the principals of the schools where the study was conducted. A summary of the study will be provided to the teachers and administrators during a professional development workshop. Study results will also be disseminated to the parents and students within a six month period of time. An article about the study will be written in the school newsletter to ensure that all students are informed of the research findings. In addition, a handout will be created to publish key findings of the study. These handouts will be placed in the main office for public review. Further, there will be a presentation of the outcomes at a Parent Teacher Association meeting.

Recommendations for Further Study

The ability to infer causation is absent from the study due to the research design. As such, it is unclear whether perceived level of experience in inquiry-based laboratory investigation classes' causes higher standardized test scores or vice versa. Future research should include an experimental design which includes variables that are correlated with perceived level of experience in inquiry-based laboratory investigation classes and standardized test scores.

Reflection

Inquiry-based science instruction emphasizes student-centered activities oriented toward concrete observable concepts and utilizes questions that students can answer via investigations (Colburn, 2008). Constructivist education is a process of concept construction, which emphasizes the development of critical-thinking skills. From a constructivist perspective, students learn through inquiry, as opposed to memorization- the traditional way of learning (Vianna & Stetsenko, 2006). In another study of constructivist teaching methods in a science classroom, teachers trained in constructivist methods collected data through surveys and interviews. They reported a remarkable change in grades on standardized tests and improved critical-thinking skills in students

(Beamer, 2008). Geier (2007) argued that a standards-based inquiry curriculum had improved the performance of urban Black middle-school students on standardized tests.

The common theme among these researchers is the idea that students construct knowledge; they do not simply receive it. Constructivist education is a process of concept construction and emphasizes the development of critical-thinking skills. Inquiry in the science classroom not only emulates the principles of constructivism, but also assists students in constructing knowledge based upon their previous experiences. Incorporating inquiry into science teaching is a method based on the theory of constructivism. The focus of inquiry-based strategies hinges on student development of critical thinking skills and their acquisition of scientific knowledge by reflecting on lessons in relation to their previous experiences (Walker & Zeidler, 2007).

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Appendix A: Demographic Information

Place an X in one box per section.

Gender:

Female __________

Male_______________

<u>Race /Ethnicity</u>

White____________

Black or African American___________

American Indian or Alaska Native ________

Asian Indian _______________

Other Asian

Native Hawaiian or Other Pacific Islander___________

Hispanic or Latino Origin? Yes_____ / No___________

Other_________________

Appendix B: Student Survey

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
1. Students follow the step- by- step instructions in the laboratory manual.	1	2	3	4	5
2. Questions in the laboratory manual require the interpretation of data.	1	2	3	4	5
3. The instructor is concerned with correction of data.	1	2	3	4	5
4. Students are allowed to go beyond laboratory exercises and do experiments on their own.	1	2	3	4	5
5. Laboratory activities are used to develop concepts.	1	2	3	4	5
6. The instructor lectures to the whole class.	1	2	3	4	5
7. Students are asked to design their own experiments.	1	2	3	4	5
8. During laboratory students record information requested by the instructor or the laboratory manual.	1	2	3	4	5
9. Laboratory session raise new problems or result in data that can not be explained immediately.	1	2	3	4	5
10. The instructor or laboratory manual identifies the problem to be investigated.	1	2	3	4	5
11. Laboratory activities require students to solve problems.	1	2	3	4	5
12. The laboratory manual requires that specific questions be answered.	1	2	3	4	5
13. The instructor or laboratory manual					

requires that students explain why certain things happen.	1	2	3	4	5
14. Laboratory is used to investigate a problem that comes in class.	1	2	3	4	5
15. Laboratory experiments develop critical thinking skills in biology.	1	2	3	4	5
16. Questions in the laboratory manual require that students use evidence to back up their conclusions.	1	2	3	4	5
17. Students discuss their data and conclusions with each other.	1	2	3	4	5
18. The instructor or laboratory manual asks students to state alternative explanations of phenomenon.	1	2	3	4	5
19. During laboratory students, record information they feel is important.	1	2	3	4	5
20. Students propose their own explanations for observed phenomenon.	1	2	3	4	5
21. Students identify the problems to be investigated.	1	2	3	4	5
22. During laboratory students check the correction of their work with the instructor.	1	2	3	4	5
23. In discussion with the instructor, assumptions are challenged and conclusions must be justified.	1	2	3	4	5
24. Students usually know the general outcome of the experiment before doing the experiment.	1	2	3	4	5
25. The instructor gives information to students in small groups.	1	2	3	4	5

Adapted from Abraham, (1982) with permission.

Appendix C: Letter of Permission to Modify the Instrument

To Whom it may concern:

I have no objection to the modification requested in the attached letter from Usha Patke.

Michael R Abraham

David Ross Boyd Professor

Chemistry and Biochemistry

University of Oklahoma

Appendix D: Request for Permission to Modify the Instrument

The Richard W. Riley
College of Education and Leadership
WALDEN UNIVERSITY

Request for Permission to modify LPVI

Date: 03/15/2012

Usha Patke
4033 Saddle Brook Creek Drive
Marietta, GA, 30060

Dr. Michael Abraham
The University of Oklahoma
Department of Chemistry and Biochemistry
620 Parrington Oval, Room 208
Norman, Oklahoma 73019-3051
Email: mrabraham@ou.edu

Subject: Request for permission to modify the Laboratory Program Variables Inventory (LPVI) on 5 point Likert scale

Dr. Abraham:

I am Usha Patke, a doctoral student at Walden University. I am planning to do a doctoral study on inquiry-based laboratory investigations and performance of African American students on standardized tests. My Doctoral Research Supervisor is Dr. Patricia M. Marin.

I would like your permission to modify the Laboratory Program Variable Inventory (LPVI) published in your article, *Abraham, M.R. (1982) A descriptive instrument for use in investigating science laboratories, Journal of Science Education, 19(2), 155-165.* I will be using the LPVI to collect students' self-report on use of inquiry-based laboratory investigations. I will need your permission to . I will need your permission to modify the LPVI on 5 point Likert scale in my doctoral study in order to seek Walden University IRB approval for my proposed doctoral study. Please send me your signed letter of permission at the above address as soon as possible. Thank you very much for your prompt attention to this matter. Please contact me, usha.patke@waldenu.edu with any questions you may have.

Best wishes.

Usha Patke

Appendix E: Letter of Cooperation

Letter of Cooperation From a Community Research Partner

September 27, 2012

Dear Usha Patke,

Based on my review of your research proposal, I give permission for you to conduct the study entitled "Inquiry-Based teaching and the Performance of Black Students on Standardized Tests in Biological science" within the small learning school xxxxx. As part of this study, I authorize you to collect data. Individuals' participation will be voluntary and at their own discretion.

We understand that our organization's responsibilities include: providing the homeroom of 10^{th} graders to distribute the consent forms and collect the consent forms and conduct the survey for 30 minutes. We reserve the right to withdraw from the study at any time if our circumstances change. I confirm that I am authorized to approve research in this setting. I understand that the data collected will remain entirely confidential and may not be provided to anyone outside of the research team without permission from the Walden University IRB.

Sincerely,

XYZ

Appendix F: Assent Form for Research

Dear Student

My name is Usha Patke, and I am a Doctoral student at Walden University. The purpose of this study is to find out how different instructional methods used in science classroom help students to achieve. I am inviting all students enrolled in biology class and who have attended end of course test in Biology in April 2012, to join this important project. Participation is voluntary.

If you agree to be in this study, you will be asked to answer a questionnaire, which has 25 statements. The whole exercise will take approximately 20 minutes. The questions are to be answered individually. The Data may be collected only once. The link for the online confidential survey, Survey Monkey will be sent to your email ID provided below. Study risks are minimal and are no greater than those encountered in day-to-day life.

Privacy:

Everything you answer in the questionnaire during this project will be kept private that means that no one else will know your name or what answers you gave. If you have any questions, you can contact me at my cell #404 769 2723 or email me at uptake@atlanta.k12.ga.us. You can also contact the Walden University's Research Participant Advocate at 612 312 1210 or email my dissertation chair, Franklin CampbellJones at fcampbelljones@waldenu.edu. A copy of the letter is provided for your record. If you decide to participate in the study, please sign your name below and submit along with consent form in a self-addressed envelope of the researcher or return it to the school drop box provided in the counselor's office on each floor of the school.

The drop box will be locked and only I will have the key to access the drop box.

Name of Child	
Student email ID	
Student signature	
Researcher Signature	
Date :	

Curriculum Vitae

Usha Patke

Education

Ed.D. in Education: Walden University, MN

Area of Concentration: Administrative Leadership,
Dissertation: Inquiry-based laboratory investigations and student performance on standardized tests in biological science
Currently completing Doctorate (October 2013)

M.S. Osmania University 1978

Area of Concentration: Zoology

B.S. Osmania University 1976

Area of Concentration: Chemistry, Botany, Zoology

B.Ed. Annamalai University 1973

Area of Concentration: Education

Professional Experience

Instructor: Current High School
Biology Instructor: Honors biology & Gifted Biology, 2003-present
Georgia

Gifted Coordinator 2010 – Present

Certifications
Biology - T-6
Gifted in Field

Awards

Achievements
Teacher of the year finalist - 2010
Best Teacher award at the District level (India) – 1996

Professional Organizations and Memberships

American Federation of Teachers
National Science Teachers Association