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IMPACT OF PRACTICAL EDUCATION NETWORK ON STUDENTS AND TEACHERS IN THE GHANAIAN JUNIOR HIGH SCHOOL CLASSROOM

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IMPACT OF PRACTICAL EDUCATION NETWORK ON STUDENTS AND TEACHERS IN
THE GHANAIAN JUNIOR HIGH SCHOOL CLASSROOM

By

Jacob J. Babb

A REPORT

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

In Applied Science Education

MICHIGAN TECHNOLOGICAL UNIVERSITY

2019

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This report has been approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE in Applied Science Education.

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Abstract

The Ghanaian education system has a pervasive teacher-centered pedagogy, lack or absence of laboratory materials, poor-quality teacher training, and minimal support systems for teachers. Practical Education Network is an organization which addresses these problems by training science teachers through workshops about how to utilize locally-available, affordable materials in order to teach topics in the national curriculum in an inquiry-based manner. Three hundred and twenty-four students in six different Junior High Schools in the Greater Accra Region participated in a year-long, quasi-experimental study in order to test the impact that the PEN approach has on students' classroom environment, critical thinking skills, attitudes towards science, and standardized test scores. Additionally, teachers' ability to setup materials, facilitate the lesson, and deliver the objective was also examined. The data indicates that the PEN approach had a beneficial impact on students' classroom environment, attitudes towards science, and standardized test scores. The data also suggests that teachers were most comfortable with setup of materials, and least comfortable with delivery of the objective.

Keywords: inquiry-based science, attitudes towards science, standardized test scores

Chapter 1

Introduction and Research Questions

The Ghanaian science education system, like those in most developing countries, and just like all of its West African neighbors, has many hallmark issues to be solved. A pervasive teacher-centered pedagogy, lack or absence of laboratory materials, poor-quality teacher training, and minimal support systems for teachers at their schools are all problems that must be resolved for a healthier education system. The first issue on this list acknowledges the wide-spread teaching practice of a teacher-dominated, lecture-driven and rote-learning pedagogy (United Nations Educational, Scientific, and Cultural Organization [UNESCO], 2015). Much of this teaching style can be attributed to the establishment of formal education in Ghana over the last couple hundred years by British colonial powers, who themselves structured their education system in this way. Laboratory equipment is found in less than 10% of Ghanaian schools and even if they do have some supplies, they often are not managed properly, resulting in the teacher returning to lecture style teaching (UNESCO, 2015). Low teacher pay is an additional challenge, especially if one is raising a family. If materials for hands-on learning are not provided by the school system, teachers do not spend their own salary on these potentially costly resources. This lack of remuneration and resources can have a demoralizing effect on teachers of science.

Additionally, there is difficulty implementing the nation-wide curriculum due to a lack of teacher knowledge and training. The national science curriculum encourages hands-on learning and critical thinking skills, yet most teachers find themselves without

the necessary teaching materials and continued training in student-centered learning pedagogy to implement such a curriculum. There is also a mismatch between teacher training and the support mechanisms available in the classroom. Teachers receive some instruction on student-centered learning pedagogy during their teacher training and are provided with periodic workshops to support this practice. However, much of the knowledge is not put into practice once the teachers are at their schools, surrounded by others implementing traditional teaching styles and provided only limited science resources. In addition, over 11% of JHS teachers in Ghana are not trained teachers meaning they have not had any formal teacher training (Ghana Ministry of Education, 2016). In fact, in a third of countries with data in the Education for All Global Report, less than 75% of primary school teachers are trained according to national standards (UNESCO, 2015). These issues and many more pose a problem to the future of education in Ghana.

In regard to pedagogy, it is widely accepted in the science education community that the most appropriate science pedagogy must be knowledge construction for problem-solving and problem-posing (Anderson, Sjøberg, & Mikalsen, 2006). Extensive research in international science education shows that students who engage in inquiry-based learning that mirrors the practices actually followed by scientists and engineers are able to build a more cohesive understanding of science over time (NGSS Lead States, 2013). Unfortunately, students in Ghana are not commonly engaged in inquiry-based learning, but rather, are taught in a teacher-centered lecture style nearly all of the time. Potential proof of the dilemma may be seen in the 2015 West African Secondary School Certification Examination, where Integrated Science had the lowest pass rate of all the

core subjects in this terminal standardized test for Senior High School graduates (Ghana Ministry of Education, 2016). The low pass rates provide evidence that students are not attaining many of the pillars of science that are included in the national science curriculum, such as problem solving and critical thinking. This may be a result of science classrooms where teachers and students alike are trained in memorizing facts rather than understanding concepts.

Practical Education Network, or PEN, is an organization that addresses all of the challenges mentioned above. PEN provides a teacher training program infused with a learning-by-doing approach to promote hands-on science regardless of a school's resource constraints (Practical Education Network, 2018). For example, when the students are learning about the respiratory system they are often traditionally taught to memorize the function and location of the different organs within the system. The PEN approach is different, giving the teachers ideas for hands on activities that allow students to gain a deeper understanding of concepts like volume and pressure change within a system, in addition to learning the structures and functions normally taught in the traditional classroom setting (see *Figure 1* for a sample activity from the PEN Manual related to the respiratory system).

PEN has been training science teachers, who in turn train more science teachers with their methods. They have been operating in Ghana for several years and have received recognition from many international science education organizations. Teachers leave the trainings about using local materials for science with more knowledge of how to bring inquiry into their science classrooms and confidence to teach topics in the curriculum, which should in turn affect student learning in a positive way. This study

looked at students' attitudes towards science because of the strong relationship between student academic self-concept and academic performance in Ghanaian Junior High Schools (Bakari Yusuf & Balarabe, 2013). Critical thinking skills are also integral to science class achievement, and were looked at before and after hands-on

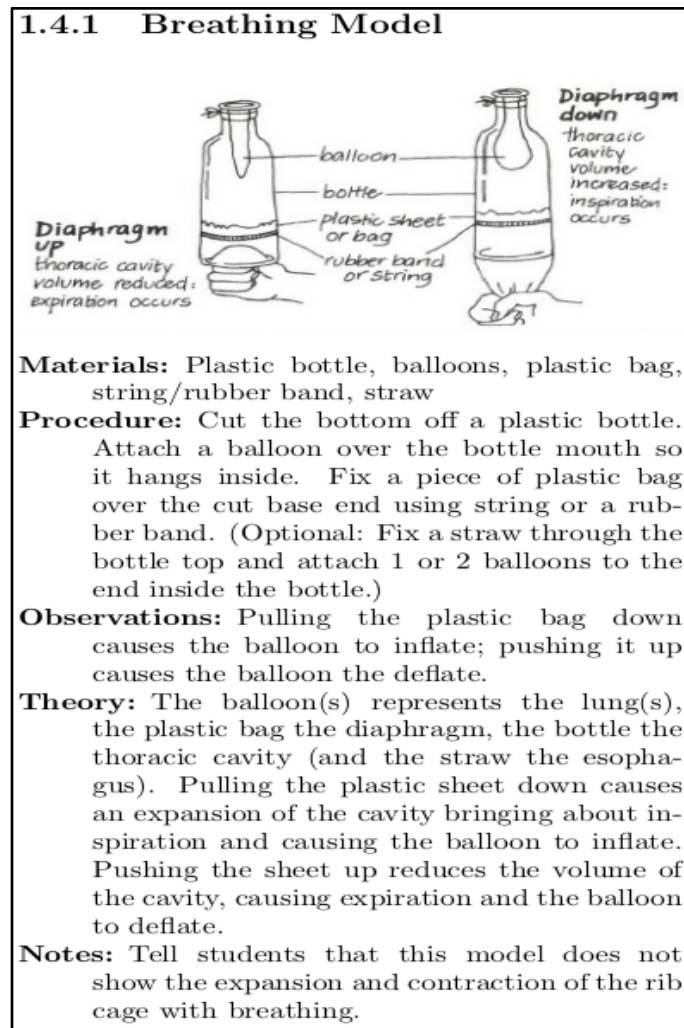


Figure 1. PEN Activity 1.4.1 demonstrates the Human Respiratory System using a Breathing Model made from local materials (taken from the PEN JHS Hands-On Science Resource Manual Version 1.0, p. 15).

learning in this study. I also aimed to see if teachers' continuous practice of hands-on inquiry-activities in the classroom improve their teaching performance in various skill sets. In this study, all of the above were considered to be factors playing into the performance of students on their standardized exams, the last factor examined in the study.

After teaching in the Ghanaian school system for two full academic years, I am keenly aware of the challenges facing the science classroom. The teaching style, lack of teacher knowledge and training, and limited resources are without a doubt the most apparent obstacles in increasing student performance in the science classroom. Knowing all that PEN does to address these issues, I thought it would be a great opportunity to collaborate and test the efficacy of the PEN approach on Ghanaian teachers through a quasi-experimental study. Ideally, teachers who have been trained by PEN will teach science in a different way and thus observe very different student outcomes than their business-as-usual counterparts.

Research Questions

The following five research questions were addressed in the study:

- 1) What impact does the PEN approach have on students' science classroom experience?
- 2) What impact does the PEN approach have on students' ability to think critically in the science classroom?
- 3) What impact does the PEN approach have on students' attitudes towards science?
- 4) What impact does the PEN approach have on students' standardized test performance?

5) After receiving PEN training, to what extent are teachers able to set up materials, facilitate student learning by answering any questions and keeping students on task, as well as deliver the main learning objective of the lesson?

Chapter 2

Literature Review

Inquiry-based Learning Through Hands-on Activities

Inquiry has a decades-long and persistent history as a central word used to characterize good science teaching and learning (Anderson, 2002). Inquiry-based learning has its roots in the great works of psychologists like Piaget and Vygotsky, who developed and popularized the theory of constructivism (as cited in Jones & Brader-Araje, 2002). Constructivism, as it relates to the classroom, can be summarized as the development of understanding requiring the learner to be actively engaged in meaning-making (Jones & Brader-Araje, 2002). In the science classroom, constructivist-minded views of learning necessitate shifting the focus from the teacher being the provider of meaning, to the student creating their own meaning through personal experience of phenomena. Constructivist theory aligns well especially with hands-on¹ science pedagogies due to the fact that the process of “doing science like a scientist” already demands an inquiry-based approach to learning. The National Science Education Standards states, “In the same way that scientists develop their knowledge and understanding as they seek answers to questions about the natural world, students develop an understanding of the natural world when they are actively engaged in scientific inquiry—alone and with others” (National Research Council, 1996, p. 29).

¹ In this study, the terms *hands-on activities* and *inquiry-based learning* hold the same meaning and are used interchangeably. This use of the terms is appropriate given that in the Ghanaian classroom, any form of instruction other than a lecture-style significantly shifts the students’ learning experience towards constructivism and is referred to as inquiry.

Arguably, one of the most tangible ways to nurture a mind which thinks like a scientist and effectively develops understanding of scientific concepts, is hands-on experimentation through the manipulation of apparatus or alternative materials. In Ghana, a simple activity for inquiry could be to observe different flow rates of water out of containers with different depths of water. This gets the students thinking about relationships such as pressure and depth, just like the scientists and engineers in the field.

Broad Look into Inquiry-Based Learning Outcomes

But does inquiry-based teaching and learning actually make a difference in the classroom? There are many studies in the science education literature that are able to give us a good introductory and generalized view of what has been learned about inquiry-based classrooms already, some that directly address hands-on instructional methods, and some that do not. Multiple studies of inquiry-oriented science curriculum programs in the 1980's showed substantial effect sizes in favor of the inquiry-oriented curriculum materials, and these effects were found on various quantitative measures like cognitive achievement, process skills and attitude toward science (Shymanksy, Kyle, & Alport, 1983). A research synthesis from 1984-2002 of inquiry-based science instruction in the K-12 classroom indicated a clear, positive trend in scientific conceptual learning, favoring inquiry-based instructional practices, particularly instruction that emphasizes student active thinking and drawing conclusions from data (Minner, Levy, & Century, 2009). Teaching strategies that actively engaged students in the learning process through scientific investigations were found to be more likely to increase conceptual understanding than strategies that relied on more passive techniques, which are often thought to be necessary in the standardized, assessment-laden educational environment.

Hands-on experiences, specifically with scientific or natural phenomena, were also found to be associated with increased conceptual learning. As a final research study to share, a comprehensive meta-analysis of undergraduate STEM education showed average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning (Freeman et al., 2014). The aggregate of the relevant research studying the effect of inquiry-based learning on science students of all ages overwhelmingly points towards benefits of such learning.

Classroom Environment

When the structure of the classroom environment² is set-up to be inquiry-based, involving methods such as hands-on activities, it can have very positive consequences. A couple major features of an inquiry-based classroom are experimentation and small group-work. A study examining the effect of teachers' adaptations of a middle school science inquiry-oriented curriculum unit on student learning highlighted that students have greater learning gains when the classroom is structured in a way that has students conducting experiments by themselves, rather than observing a demonstration by the teacher (Fogleman, McNeill, & Krajcik, 2011). A meta-analysis showed that small-group learning in various forms is effective in promoting greater academic achievement, more favorable attitudes toward learning, and increased persistence through STEM programs at the university level (Springer, Stanne, & Donovan, 1999). Another meta-analysis of over a hundred studies indicated that, on average, small group learning had significantly more

² In this study, classroom environment refers to the ways in which students engage in learning science, whether in a more inquiry-based, student-centered way, or in a more teacher-centered way.

positive effects than individual learning on student achievement (Lou, Abrami, & d'Apollonia, 2001). Student-centered environments are where teachers have been found to have the most impact.

Closely related to this study, when Ghanaian teachers were asked to describe the learning environment during their most successful experiences in the classroom, teachers' explanations were in accord with constructivism (Akyeampong, Pryor, & Ghartey Ampiah, 2006). The teachers gave their lowest approval to student activities like memorizing facts and repeating facts when asked. This is surprising as the most common mode of instruction in Ghana is by far a teacher-centered lecture at the chalkboard/marker-board. This could be indicative of the need for teachers to be properly trained in order to realize their constructivist-aligned attitudes.

Critical Thinking Skills

Critical thinking (CT) skills have been shown to be teachable. One study suggests that if teachers purposely and persistently practice higher order thinking strategies, such as through fostering inquiry-oriented experiments, there is a good chance for a consequent development of critical thinking capabilities (Miri, David, & Uri, 2007). The study found that by incorporating teaching strategies such as student question asking, self-investigation of phenomena, exercising open-ended inquiry-type experiments, and making inferences, students' CT skills and related capabilities were significantly advanced. A meta-analysis of research on teacher-student relationships also showed that, when used effectively, the constructivist learner-centered model has positive correlations (not causations) to improved critical thinking, among other outcomes such as class participation and self-esteem (Cornelius-White, 2007). Also at the university level,

another study showed that the students in an inquiry-based experimental group were 12 times more likely to spontaneously propose or make changes to improve their experimental methods than those in a control group who did not practice decision-making based on data. The students in the experimental group were also four times more likely to identify and explain a limitation of a model using their data (Holmes, Wieman, & Bonn, 2015).

Critical thinking must be continuously studied in different contexts, as there has been a global shift towards learner-centered pedagogies that promotes critical thinking, with teachers expected to help students actively construct knowledge through activities, group work, and reflection. The shift has occurred partly because some international organizations and national policy-makers believe the approach helps promote democracy, civic engagement, and economic development (UNESCO, 2015).

Attitudes Towards Science

There is plenty of research showing the link between hands-on inquiry and attitudes towards science. In one study, over 500 students in a Summer Science Exploration Program (SSEP) participated in inquiry-based learning through experimentation. Students engaged in answering scientifically oriented questions, gathering data (evidence) to develop explanations, evaluating their explanations in light of alternative explanations, and communicating and justifying their proposed explanations. Interview and survey data suggest that students maintained a more positive attitude towards science and a higher interest in science careers than students who did not go through the program (Gibson & Chase, 2002). In response to project-based learning in the Earth sciences, students were found to benefit from the instructional unit as

demonstrated by increased attitudes towards technology, science attitudes, and science self-efficacy (Baker & White, 2003). In another Turkish study, experimental groups who performed hands-on activities in the classroom scored higher on instruments measuring scientific process skills and attitudes towards science than those in the control groups who did not partake in inquiry-based teaching methods (Ergul et al., 2011). And finally, at the university level in Ghana, 79% of students who regularly used the available equipment for practical learning in a Chemistry class, agreed that the small scale equipment was feasible, fun, and easy (Hanson, 2014.) When examining the literature, it is not hard to find evidence of inquiry activities shaping students' attitudes in a positive way.

Test Scores

One of the biggest ways that hands-on inquiry learning has been shown to impact students has been in regard to student performance on standardized examinations. Engagement in inquiry-based learning during an urban reform program in Detroit Public Schools demonstrated that a standards-based inquiry science curriculum can lead to standardized achievement test gains in historically underserved urban students (Geier et al., 2007). Data from the National Education Longitudinal Study indicates that students who engaged in hands-on activities every day or once a week scored significantly higher on a standardized test of science achievement than the students who engaged in hands-on activities once a month, less than once a month, or never (Stohr-Hunt, 1996). Inquiry-based learning also produced higher scores than traditional teaching methods in an Iranian study (Abdi, 2014). Project-based learning is common form of inquiry in the classroom, which was implemented over three years with over 800 students in three

Texas Public Schools. It was found that previously low performing students showed the most significant growth in test scores compared to their high and middle performing peers (Hans, Capraro, & Capraro, 2014).

Teacher Training

The argument is being made for student-centered learning, but teachers must be on board and have the knowledge to implement such instruction. A nation-wide program in Kenya called Strengthening of Mathematics and Science in Secondary Education (SMASSE) had teachers implementing the Activity, Student, Experiment and Improvisation (ASEI) curriculum through a Planning, Doing while Seeing, then Improving (PDSI) approach—a student-centered teaching pedagogy—in an attempt to improve their teaching performance. Findings showed that teachers had a positive attitude towards the project and despite facing challenges, they worked hard to implement the ASEI/PDSI pedagogy. Teachers with a more positive attitude towards the program tended to apply the ASEI/PDSI pedagogy more often (Makewa, Role, & Biego, 2011). Using data from the National Science Foundation Teacher Enhancement program, researchers looked at the effects of professional development on teaching practice. They found that the quantity and quality of professional development in which teachers participate is strongly linked with both inquiry-based teaching practice and investigative classroom culture (Supovitz & Turner, 2000). In fact, the highest quality professional development was associated with the levels of inquiry-based teaching explicitly advocated for by science reformers. Teacher content preparation was also found to have a powerful influence on teaching practice and classroom culture. One literature review concluded that for successful science education reform to happen, long-term professional

development programs are needed, such as learning in networks and peer coaching (van Driel, Beijaard, & Verloop, 2001).

Inquiry-based Science Education in Ghana

The literature looked at in this chapter tells a story, which could persuade governments and non-governmental organizations (NGO's) to bring more inquiry-based interventions to the classroom. Narrowing our focus to Ghana, there have been some steps forward to change the teacher-centered classroom to a student-centered one in response to the research. The national science curriculum states many general aims, among them being to (a) develop a scientific way of life through curiosity and investigative habits, (b) use basic scientific apparatus, materials and appliances effectively, and (c) acquire the ability to assess and interpret scientific information and make inferences (National Syllabus for Integrated Science (Junior High School), 2012). Most of the efforts by the country to meet the aims have been through coursework and internships at teacher-training colleges and university programs, creation of science and mathematics directors at the district education offices, and school-level oversight of teaching practice.

Outside of this, other organizations have also contributed to trying to make the inquiry-based curriculum fully realized. The Ghana Association of Science Teachers (GAST) holds annual conferences for science teachers, which often include some practical science demonstrations for teachers to use for teaching topics in their classrooms, as found for example, in the GAST 2015 National Conference/Workshop Brochure (GAST, 2015). However, GAST does not have any monitoring and evaluation system in place to collect data on implementation of the practicals or the effects on

students, if the practicals are even done in the classroom at all. The Exploratory is an NGO now operating in Ghana that trains teachers to teach more practically to, in turn, inspire students to be more curious (The Exploratory, 2017). However, most of the data they been able to collect and publish has been either descriptive statistics on number of teachers, students, and schools reached, or data on student attitudes towards science, which has shown a positive impact. DEXT Technology is also a rapidly growing business in Ghana that sells their Science Set that contains materials for students to perform over 26 experiments (Dext Technology Ltd., 2018). They have won many international awards and gained international media coverage, but they are also without impact data looking at student performance or teacher training. Finally, PEN has also made significant contributions to science education in Ghana. PEN has trained nearly 3,000 science teachers how to use locally-available materials to conduct student-centered, hands-on activities in their classrooms. By extension, PEN has been estimated to have influenced around half-a-million students to learn science concepts in a hands-on way.

This impact study of PEN's approach addresses important gaps in the literature, particularly in the development sector. The United Nations (UN) Millennium Development Goal 2 focused on giving children around the world *access* to primary education. This goal was largely met, shifting the focus of the new UN Sustainable Development Goal 4 to address the *quality* of education, to "[e]nsure inclusive and equitable quality education and promote lifelong learning opportunities for all" (UNESCO, 2016). Thus, PEN's approach to train teachers in best science teaching practices for a quality science education is of great interest to education stakeholders in Ghana, who are trying to meet the new UN development goals. If the PEN approach is

shown to improve the quality of education in regard to students and teachers in Ghana, it could be a model for other West African countries, and perhaps the rest of the developing world.

Chapter 3

Methodology

In order to test the impact of practical learning through the use of locally available materials in the Ghanaian Junior High School (JHS) science classroom, a quasi-experimental study was designed and implemented. The study sought to measure the effect of practical learning on students' classroom learning environment, ability to think critically, attitudes towards science, and performance on standardized tests. It also measured how PEN training affected the teachers' pedagogy, including: their ability to set up materials, facilitate student learning by answering any questions and keeping students on task, as well as their ability to deliver the main learning objective of the lesson. There were three experimental classrooms where the treatment of practical learning was applied, along with three comparison schools in which the science class was conducted with no treatment (i.e., "business as usual"), making a total of six participating classrooms. The study took place in the Greater Accra Region of Ghana over the course of the 2017-2018 academic school year.

There were a few key people who performed vital roles in this study, facilitating it every step of the way. The *CEO* and Founder of PEN established connections with schools, administrators, teachers, and other human resources for this study. The *researcher* designed this study and communicated frequently with other key people on the ground for the duration. The *logistics coordinator (L.C.)* worked closely with schools and trainers to deliver materials such as measurement tools and practical learning

supplies. *Trainers* were collectively the three individuals hired for this study to facilitate the uptake of practicals in schools.

Participants

Teachers and students alike were the focus of this study, as their daily activities quite literally are the state of science education in Ghana. All six of the schools in this study were government schools. Teachers in government schools have completed Senior High School (SHS) in addition to at least a Teachers Training College program and at most a university degree in education. The teachers involved in this study were composed of five males and two females, ranging in age between late twenties and early fifties. The teachers had teaching experience ranging from 3 to 25 years. In all cases, the experimental teachers had more teaching experience than the comparison teachers.

The 324 students in this study were in Junior High School (JHS), Form 3, which is the final of three years of JHS. Most JHS Form 3 students range between the ages of twelve to fifteen years old. The gender ratio of the students was not collected for this study, however, most government schools within the Greater Accra Region have near equal numbers of boys and girls enrolled in JHS (Ghana Ministry of Education, 2016).

There are no significant differences between the comparison and experimental schools in this study in relation to the participants. However, out of the six total schools that participated, two of them (a comparison and experimental school, both in the same district as the PEN trainer) were in a rural area with fewer resources compared to the other four schools in the metropolitan area of Accra.

Measurement Tools

In order to measure the variables stated above, measurement tools were developed to capture data needed to address the research questions. Most were able to directly address the research questions, while a few were used for their anecdotal contributions. There were a total of six different measurement tools, giving information about students and teachers alike.

1) *The Basic Education Certificate Examination (BECE)* is the nationwide, multi subject standardized test that is taken at the end of the final year of JHS by all students, normally in June. The scores are used for placement of students to Senior High School (SHS) throughout the country. Official BECE Integrated Science results were obtained from all students participating in the study, both in the comparison and the experimental groups.

2) Questions from past BECE Integrated Science exams were selected to construct a *Pre/Post Test* (see Appendix A) that simulated the BECE exam. The test was composed of six multifaceted questions addressing topics ranging from electromagnetism to testing for starch in leaves. It was administered at the beginning and end of the study to both the comparison and experimental groups. They were marked by a part-time PEN staff member using the same criteria that is used by official examiners.

3) Students within the comparison and experimental groups were given a *student survey* (see Appendix B) to assess their perception of their classroom environment, critical thinking skills, and attitudes towards science at both the beginning and end of the study. It was administered by the L.C. at all the schools.

4) All six teachers (three comparison and three experimental) were given a *teacher survey* (see Appendix C) at the beginning and end of the study which addressed

the degree of inquiry in their classroom environment, communication about STEM with others in the school, challenges they face in the classroom, and the nature of any practical activities they do with their students. In some cases, it was administered by the L.C., and in other cases, by the trainer.

5) The three teachers in the experimental schools were observed each week during their implementation of the PEN lesson, by means of a *Teacher Monitoring Sheet* (see Appendix D). The observations were conducted by PEN trainers and focused on the teacher's ability to set up materials, facilitate student learning by answering any questions and keeping students on task, as well as delivering the main learning objective of the lesson.

6) Each experimental school teacher was given a *PEN Journal*. Every week the teacher was encouraged to write down qualitative observations and reflections: any challenges they may have faced, things that were easy to do and fulfilling, things they wish they could do better next time, etc. These journals were periodically monitored and collected at the end of the study.

Logistics

The activities in this study took form in three major phases. Each of the three phases has multiple activities which were carried out by different individuals. Figure 2 provides a schematic summary.

Phase 1

To date, PEN has trained over 3,000 teachers, most of whom are in the Greater Accra Region. Among those teachers, a few dozen have a particularly close relationship with PEN because of their frequent use of practicals at their schools and continuous

involvement in PEN events. From this pool of potential trainers, we scouted for schools to participate in the study, in which the trainers would be the facilitators in all activities. In the early months of 2017, the researcher made trips from his post in the Volta Region, which is a four-hour drive from Accra, to visit potential schools to participate in the study.

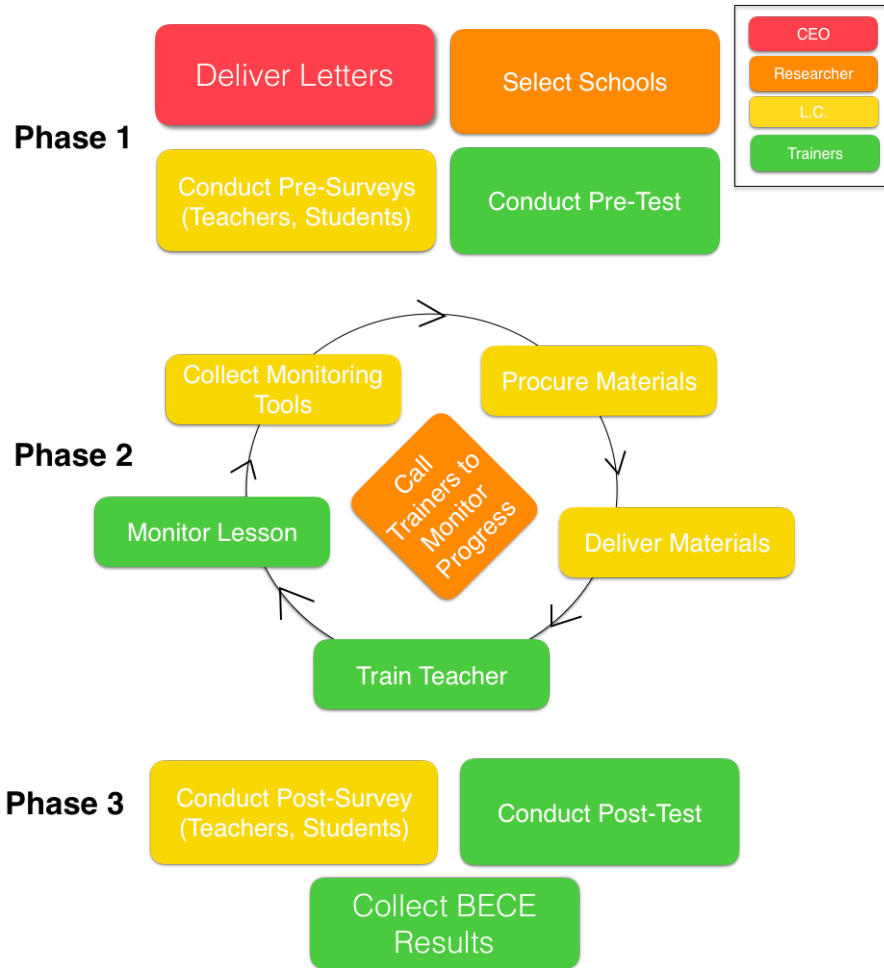


Figure 2. PEN Impact Trial 2017/8 Process Flow

Potential trainers were asked to identify two basic schools, other than the one in which they teach, within their district. The two schools were to be academically on par with each other based on past exam scores, and to be willing to participate in the study.

The researcher then traveled to meet the potential trainers in their district, to observe their selected schools in-person and to decide their feasibility to participate in the study based on a few additional criteria such as good attendance, a safe and sturdy building structure for the students, and the students' English language competency. After some deliberation on these matters with another part-time PEN employee, and considering funding, three PEN trainers were chosen to participate in the study.

Trainer 1 was a trainer for a previous, less involved, quasi-experimental study conducted by PEN during the 2016-2017 academic year. For this 2017-2018 study, he committed to oversee the comparison school, CS1, and to be actively involved in the training of the experimental school, ES1. Trainer 2 was also a trainer for the same 2016-2017 PEN study. For the current study, he oversaw the control school CS2, and was the trainer at the experimental school, ES2. The final trainer, Trainer 3, had never participated in a study before, but had been an active PEN trainee for a while. She was selected to oversee the control school, CS3, and was the trainer at the experimental school, ES3. This brought the total number of schools participating to six.

It is cultural custom in Ghana that if you are conducting a program within an institution, you must hand deliver an official paper invitation letter to the appropriate authority figures. Therefore, the CEO of PEN delivered the letters to the District offices before activities began.

An essential personnel in this study was the Logistics Coordinator, or L.C. In the absence of the researcher who lived and worked full-time in the Volta Region, the L.C.'s duties were numerous and vital for keeping the study off the ground. During the first week of October 2017, the L.C. printed all pre-surveys and pre-tests and delivered them

to the six schools. The L.C. was also in charge of conducting the student and teacher surveys, by reading the beginning prompt, invigilating while students and teachers filled the surveys, and collecting the surveys before returning them back to the PEN headquarters for scanning and storage. The pre-tests were given to the three trainers to administer to their comparison and experimental schools. The completed pre-tests were collected by the L.C. at a later time. The pre-tests were marked by a part-time PEN employee using an approved marking scheme, the scores were recorded in an Excel spreadsheet, then the tests were scanned, uploaded to Google Drive, and shredded. Student pre-surveys were scanned, uploaded to Google Drive, then shredded. Teacher pre-surveys were kept at the PEN office for collection by the researcher at the end of the study.

Phase 2

During the study, the most important duty of the trainers was training the Form 3 Science teachers at their experimental school. The trainer and the teacher were to meet twice in a week, every week, for the academic year—the first meeting each week being the trainer training the teacher in how to conduct a particular practical, and the second meeting being the teacher conducting their lesson while the trainer observed their performance using the Teacher Monitoring Sheet as a guide. The researcher made sure to call or text the trainers on a weekly basis at first, then on a bi-weekly basis, to check in with the trainer to make sure the trainings stayed on track. Sometimes if there were issues, the researcher would make suggestions to resolve them, or the researcher would contact the L.C. to make the appropriate changes on the ground.

During this phase, the L.C. would follow the national science syllabus to identify what topics the various schools were to be teaching about in that particular school term. He then identified the practicals in the PEN manual that addressed those topics to be taught soon by the teachers, and visited local stores to buy the appropriate teaching materials. After collecting the locally-available teaching materials, he organized them and delivered them to the three trainers at an agreed upon time. When delivering the teaching materials, he would also pick up data that had been collected such as past Teacher Monitoring Sheets and student pre-tests.

Phase 3

The final phase of the study involved the dissemination and collection of the student post-survey, student post-test, teacher post-survey, PEN journals, all Teaching Monitoring Sheets, and the official BECE science results of the students. During the last week of May 2018, all of these measurement tools were administered and collected with the exception of the BECE exams, which were taken nationwide during the first week of June.

The L.C. printed materials and scheduled a date and time to disseminate the student post-survey and teacher post-survey. He was to read the prompt, invigilate while the participants took their survey, collect them and take everything back to the PEN headquarters to be collected by the researcher at the end of the study. He also printed and delivered the student post-tests to the three trainers. The trainers then were to identify suitable times to administer the post-test to students in both the comparison and experimental schools. The trainers were to read the prompt, invigilate while the participants took their test, and then put them aside for pick up by the L.C., to be taken

back to the PEN headquarters where the researcher would come to collect them at the end of the study. The L.C. also collected the PEN journals and Teacher Monitoring Sheets from the trainers, to be collected by the researcher at the end of the study.

The official BECE exams were marked by official examiners hired by the West African Senior School Certificate Examination (WASSCE). Official scores were released to the schools in January 2019. It was the trainers' duty to be in communication with school administration at both of their schools in order to receive the official scores for the Form 3 students that were part of the study once they were made available. The scores were delivered to the researcher for analysis.

Data Loss

The pre student survey data for all schools was collected, then scanned by the L.C. and then uploaded onto the Google Drive folder by the CEO, all in the absence of the researcher who was not physically present during most of this study. The researcher was later only able to find five uploaded pre student surveys for CS1, compared to eighty-two student post surveys for CS1. After the researcher interrogated the L.C. and the CEO, it was agreed upon that the most likely cause for this data loss was an unremembered mishap during the period of scanning and uploading. The researcher tried to compensate for this loss by using statistical tests that correct for very different sample sizes.

There were plans to assign each student in the study to a PEN number, in order to conduct student-level analysis. However, master lists that matched student names and PEN number were either not kept or were lost for CS1, ES1, and ES3. In addition, during the post data collection, it was reported by trainers and the L.C. alike that students forgot

their PEN numbers and were not able to be provided with them due to some master lists being unavailable. Many students wrote down their best guess as to what their PEN numbers were, but the researcher is not confident in the accuracy of this method. It is for these reasons that the researcher did not conduct student-level analysis.

Survey, Test, and PEN Journal Issues

As shown in *Figure 2*, the L.C. was in charge of student and teacher surveys, while the trainers were in charge of student pre/post tests. However, a different story played out. During pre-data collection, the L.C. administered both surveys and tests in CS1/ES1, CS3/ES3, and he left the test with the classroom teachers in CS2/ES2. During post data collection, the L.C. administered both surveys and tests to CS1/ES1, and gave all surveys and tests to the trainers to administer in CS2/ES2 and CS3/ES3. These changes of duty did not seem to affect the data that was collected in any meaningful way. However, mislabeling of teacher surveys, as well as failure to give the survey to the correct teachers, caused some issues with teacher survey data. This caused the researcher to take a more qualitative, anecdotal approach to data analysis of these surveys. PEN Journals were also misused by two of the teachers to mostly record what they had done, rather than the intended purpose of the journals of sharing challenges and ideas about the lessons. One teacher lost their PEN Journal, so the researcher conducted a post study interview to capture some of her thoughts.

Phase 2 Logistical Issues

One common complaint of trainers and experimental teachers alike, was that they were not provided with the adequate amount of teaching materials needed to conduct the practicals. The researcher repeatedly asked the L.C. to increase the amount of materials,

yet the trainers still reported having to buy some of their own materials to supplement. There was also the issue of the materials being shared with the comparison school in the case of CS1/ES1. The structure of these schools was unique in that they were housed on one school campus. The population in the area is so great that there are two different schools, with two different administrations, on one campus. Even though they are separate, they naturally work together and share resources often. Once the comparison teachers heard that the experimental school had teaching materials, they asked to also receive some, to which the trainer and teacher obliged. When the researcher later found out about this and queried the trainer, he said he gave them some of his personal science teaching materials, and that he never trained the teacher how to use them.

It was also expected that trainers meet every week for the whole school year to do the training and the actual lessons. In reality, the unpredictability of the Ghanaian classroom took over, and the teachers and trainers were not able to meet regularly. Out of the thirty-six weeks of the academic calendar, the most any teacher was able to deliver a lesson was a total of twenty-two weeks. Some teachers even delivered multiple lessons in one given day to try to make up for lost time. The researcher encouraged trainers and teachers to meet every week, but school administration, culture and sports events, and miscellaneous teacher duties also got in the way.

Another major issue was that the science teachers were not always the ones teaching the lessons. The ES3 teacher had external meetings to attend on two of the days that she was supposed to deliver a PEN lesson. Instead of skipping the lesson, the trainer decided to step in and teach those two lessons. For one lesson with ES3, the L.C.

conducted a lesson on the digestive system mostly by himself. This did not serve the purpose of the study well, but the researcher was not aware until after it occurred.

Data Analysis

Each research question was thoroughly investigated by analyzing the data collected through the six aforementioned measurement tools. Basic descriptive statistics were conducted for data collected from all measurement tools except for the PEN Journal and teacher surveys. Data were analyzed using four major methods that compared data from the experimental and comparison groups after the pre data collection, and after the post data collection. These methods included: (a) difference in means, (b) observation of whether there was a switch in which group had the highest mean, (c) an unpaired T-test for two independent means at a 5% significance level, and (d) a test for effect size, specifically Hedges-g. In these analyses, the data for the entire population of comparison school students were analyzed in comparison to that of the entire population of experimental school students. As significant findings became apparent, a more detailed analysis of the differences between paired experimental and comparison schools was also done. For the final research question, regarding the teachers, only descriptive statistics and qualitative assessment were employed, because of the nature of the measurement tools and the low sample size of teachers.

The T-test was the signature statistical test in this analysis, used to analyze data for research questions one through four. It is worth noting that an unpaired T-test was used because of the inability to collect matched pre/post data for individual students, and because in some cases, there were drastically different sample sizes between groups. For the unpaired T-test to be significant, each set of data studied had to meet two conditions:

there had to be no statistically significant difference between two groups after the pre data collection, and then subsequently there had to be a statistically significant difference between the two groups after the post data collection. The Hedges-g test for effect size was then an additional test to further quantify the magnitude of the difference between two groups. A Hedges-g score ≥ 0.20 signifies a small effect size, ≥ 0.50 a medium effect size, and ≥ 0.80 a large effect size. Data analysis specific to each research question is discussed below.

Research Question #1

This question was addressed using data from the first section of the student pre/post survey, which was composed of eight questions and named “Classroom Environment and Activities” (see Appendix B). Since all of the questions in this category are Likert-type questions, it was convenient to calculate the mean for each question as the unit of analysis to compare the results between the collated data from the comparison and experimental groups. Means were calculated along with other descriptive statistics such as frequency and percentage. For questions 3, 4, 6, 7, and 8, higher Likert scale values were associated with a more practical-based learning environment; thus a higher mean would indicate a more inquiry-based classroom. Questions 1 and 5 had higher Likert scale values associated with a less practical-based learning environment, meaning that a higher mean would indicate a less desirable classroom setting. Question 2 measured use of exercise books, which can be used in a variety of ways, inquiry-based and not. Therefore, the values did not hold significant meaning.

The null hypothesis for research question #1 was that the PEN approach did not have any impact on the students’ classroom experience. The more questions in this

section that showed a greater improvement by the experimental group, after using the four analysis methods, the greater the confidence of rejecting the null hypothesis. This would indicate that the PEN approach had a beneficial impact on the students' classroom experience.

Research Question #2

Research Question #2 was addressed using data from the second section of the student pre/post survey, which was composed of ten questions and named, "Critical Thinking." This section was composed of eight multiple choice questions (MCQs) and two open-ended questions. The open-ended questions were coded for level of critical thinking. A score of 1 meant there was no critical thinking exhibited by the student, while a score of 4 meant there was a high level of critical thinking. After coding the mean was calculated for each question. Given the nature of the MCQs, they were marked either correct (a score of 1) or incorrect (a score of two). Basic descriptive statistics such as frequency, percentages of correct answers, as well as means were calculated. Given that more correct answers would produce a mean closer to 1, a lower mean in the case of the MCQs would mean that a group performed better, exhibiting greater critical thinking skills.

The null hypothesis for research question #2 was that the PEN approach did not have any impact on the students' critical thinking. The more questions in this section that showed a greater improvement by the experimental group, after using the four analysis methods, the greater the confidence of rejecting the null hypothesis. This would indicate that the PEN approach had a beneficial impact on the students' critical thinking.

Research Question #3

This research question was addressed using data from the third and final section of the student pre/post survey, which was composed of seven questions named “Attitudes.” Since all of the questions in this category are Likert-type questions, it was convenient to calculate the mean for each question as the unit of analysis to compare the data between the collated comparison vs experimental groups. Means were calculated along with other descriptive statistics such as frequency and percentage. Higher means were associated with more favorable attitudes towards science, while lower means were associated with less favorable attitudes towards science.

The null hypothesis for research question #3 was that the PEN approach did not have any impact on the students’ attitudes towards science. The more questions in this section that showed a greater improvement by the experimental group after utilizing the four analysis methods, the greater the confidence of rejecting the null hypothesis. This would indicate that the PEN approach had a beneficial impact on the students’ attitudes towards science.

Research Question #4

Research Question #4 involved two measurement tools, the student pre/post test and the students’ official BECE scores, both of which consisted of nation-wide, standardized science questions. Both measurement tools were analyzed the same way by grouping classrooms into three pairs: CS1/ES1, CS2/ES2 and CS3/ES3, and additionally collating the data from the three pairings to provide a dataset comprised of the entire comparison vs experimental populations, making four groupings for comparison in total. Analysis focused on comparing changes in the comparison and experimental groups’ scores after pre-data collection and post-data collection. The researcher employed four

methods of analysis: (a) difference in means, (b) observation of whether there was a switch in which group had the highest mean, (c) an unpaired T-test for two independent means, and (d) a test for effect size, specifically Hedges-g.

The West African Examinations Council has a unique way of score reporting for the BECE which differs from the percentages that were used for the pre/post exams.

Figure 3 below gives the score reporting system that was used for the BECE.

In preparation for analysis, the BECE scores were grouped in the same way as the pre/post test, into the three pairs of schools (CS1/ES1, CS2/ES2, and CS3/ES3).

Subsequently, the data from these groups were collated to create a dataset comprised of the entire comparison vs experimental populations. Since the BECE was taken one time by all students, analysis compared these scores between the comparison and experimental scores; there was no pre/post aspect to the analysis. The researcher examined

(a) difference in means, (b) an unpaired T-test for two independent means, and (c) a test

BECE Score	Percentage Point Equivalent
1	75-100
2	70-74
3	65-69
4	60-64
5	55-59
6	50-54
7	45-49
8	40-44
9	0-39

Figure 3. BECE Score Reporting Scheme

for effect size, specifically Hedges-g. Additionally, the frequencies of scores (ranging 1 through 9) in the collated comparison vs experimental group were plotted in order to better see the distribution within each group. Finally, teachers' PEN Journals were looked at for qualitative anecdotes which shed light on test performance.

The null hypothesis for research question #4 was that the PEN approach did not have any impact on the students' standardized test performance. The more instances in which a particular comparison and experimental grouping indicated a greater improvement by the experimental group, after using the four analysis methods, the greater the confidence of rejecting the null hypothesis. This would indicate that the PEN approach had a beneficial impact on the students' standardized test performance.

Research Question #5

The final research question was primarily addressed by analyzing the data collected from the Teacher Monitoring Sheet, which was used by the three trainers to document the performance of the three experimental teachers in regard to their teaching skill-sets, during every hands-on lesson over the course of the academic year. Some qualitative data from the PEN Journal was also used to provide additional insight into this question.

The Teacher Monitoring Sheet, which tracked changes over the year, had 10 questions, each one measuring a skill which served as an indicator³ for particular skill-sets. First, a mean for all indicators in each skill-set was calculated to produce a total of three different skill-set means for each observation of a teacher: (a) Preparation and Setup

³ Indicators measured teachers' ability in a particular skill-set. For example, for the section measuring *Preparation and Setup of Materials*, one question asks, "Was the teacher able to split the students up in groups that are efficient for the lesson?"

of Materials; (b) Facilitation of Student Learning; and (c) Delivery of the Objective.

Using these skill-set means, a line graph was plotted showing the change in means over time for each skill-set, for each experimental teacher. It was quickly determined that there was no obvious trend over time for any of the skill-sets for any teacher. The mean for each indicator for all of a teacher's observations was then calculated, and was collated with the means of other indicators in the same skill-set, to produce a total of three different skill-set means for each teacher for all of their observations. The collated means for each skill-set were then compared within individual teachers, and among the three teachers in order to reveal which skill sets were the most difficult or easy for teachers.

The PEN Journal was used in order to collect information about the experimental teachers' classroom experiences throughout the year while doing hands-on practicals in the classroom. The researcher was able to use these journals to identify anecdotes relevant to the research question at hand, which were able to provide a more detailed picture and make better meaning out of the data from the Teacher Monitoring Sheet.

Chapter 4

Results

The purpose of this chapter is to present the results from the data analysis, according to each research question. Results from research questions 1, 2, and 3 are reported as the collated data from the various schools within the comparison and experimental groups. Research question 4 results are reported from individual school pairs, along with collated data. Research question 5 results include weekly data from only the experimental teachers. The discussion of these results is found in the subsequent Chapter 5.

Research Question #1

The student survey included eight total questions serving as indicators of students' experience in the science classroom. The results of the analysis from over 300 student pre/post surveys, capturing a year of potential changes, are presented in *Figure 4* below. The values in the figure show the difference in pre/post student survey Likert-scale means for each of the eight survey questions in the section.

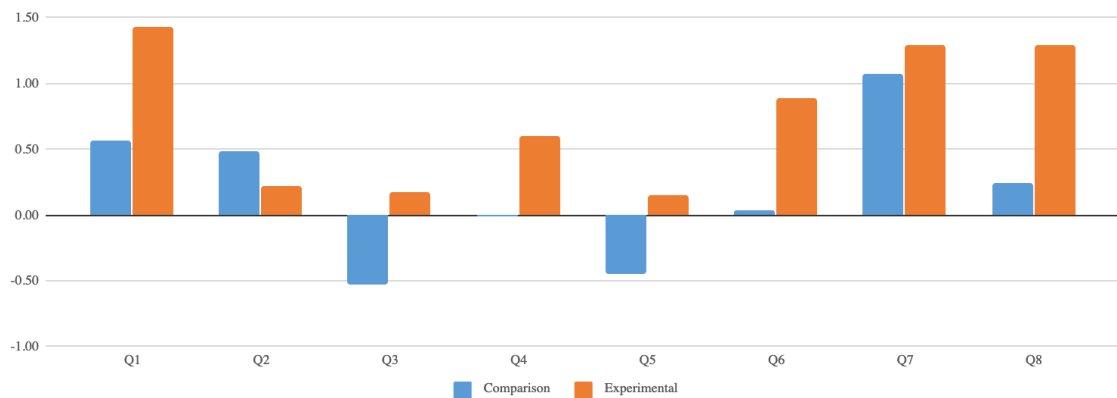


Figure 4. Classroom Environment and Activities Difference in Means on Student Survey
(Collated Comparison and Experimental Schools)

The major points of interest are the questions directly measuring frequency of classroom activities supporting inquiry-based learning; that is, questions 3, 4, 6, 7, 8 (See Appendix B and Table 1 for content of survey questions). All of these questions showed a greater increase in the mean of the responses of the experimental group than the comparison group. The difference in the means of the two groups for questions 4, 6, 7, and 8 were also found to be significant at a 5% significance level; that is, there was no statistically significant difference between the means after pre data collection, and there was a statistically significant difference between the means after post data collection. Question 3 revealed greater improvement for the experimental group and loss for the comparison group, but the difference was not found to be significant. *Table 1* shows some more points of interest for Effect size and the switching of higher means from pre to post data collection in the student survey.

Although limited, qualitative data from the PEN Journals completed by the experimental teachers reinforces this quantitative data on the classroom environment. The ES2 teacher wrote in his PEN Journal in relation to a lesson on the formation of shadows that, “Group work made pupils to bring their ideas together to carry out the practicals...pupils were able to relate it to eclipses.” The ES1 teacher highlighted the inquiry-based environment during his lesson on rectilinear propagation of light saying, “students asked questions on the sun and lunar eclipse formations and related it to the card being moved.”

The results in *Figure 4* and *Table 1*, especially relating to questions 4, 6, 7, and 8 clearly suggest that more hands-on, practical activities and small group work took place

in the experimental classroom. Notes from the PEN Journal give a more direct account of some of the inquiry activities in the classroom.

Table 1				
<i>Summary of Significance Tests Results for Classroom Environment and Activities Section of the Student Survey</i>				
<u>Question</u>	<u>T-test Significance (p<0.05)</u>	<u>P-Value</u>	<u>Hedge's g (Effect Size)</u>	<u>Switch in Relative Values of Comparison and Experimental Group Means</u>
Q4: How often do you use local items such as bottles, batteries, and rubber bands in your science class?	Yes	0.000267	Small effect	No
Q6: How many times did you have practicals in your science class?	Yes	<0.00001	Medium effect	Yes (Experimental came to lead)
Q7: This month, how many times did you work in small groups with other students in your science class?	Yes	0.028891	Small effect	No
Q8: This month, how often did your science teacher bring in materials from outside the classroom to teach (such as bottles, batteries, rubber bands)?	Yes	0.000338	Small effect	Yes (Experimental came to lead)

Research Question # 2

The student survey had a total of ten questions related to students' ability to think critically, eight multiple-choice questions and two open-ended, coded questions (see

Appendix B). The characteristics of a critical thinker assessed in the survey are listed according to their corresponding question in *Figure 5*, while the results of the analysis, specifically the differences in scores from pre to post, are presented in *Figure 6*.

9) Judge the credibility of sources
10) Identify conclusions, reasons, and assumptions
11) Judge the quality of an argument, including the acceptability of its reasons, assumptions, and evidence
12) Develop and defend a position on an issue
13) Ask appropriate clarifying questions
14) Plan experiments and judge experimental designs
15) Define terms in a way that is appropriate for the context
16) Be open minded
17) Try to be well informed
18) Draw conclusions when warranted, but with caution

Figure 5. Characteristics of a Critical Thinker Measured in the Student Pre/Post Survey

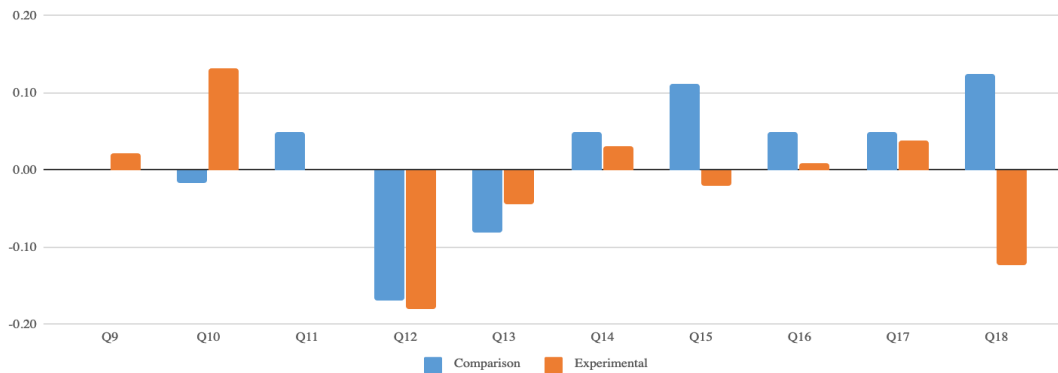


Figure 6. Critical Thinking Difference in Means from Pre to Post Student Survey (Collated Comparison vs Experimental)

The data represented in *Figure 6* does not seem to reveal any strong trend towards greater overall improvement in critical thinking of one group over another. Most of the questions saw the comparison group either increase in critical thinking skills more (questions 11, 14, 15, 16, 17, and 18), or sustain less of a loss over time (question 12), than the experimental group, with the exception of questions 9, 10, and 13, which showed the opposite, favoring the experimental group. The experimental group increased critical thinking skills more than the comparison group in Question 9 and 10 only, and had less of a drop of the mean than the comparison group in question 13. Question 10 was the only question within this section which yielded a significant t-test result that indicated a greater increase in the experimental group's scores on the question related to identifying conclusions, reasons, and assumptions.

Research Question #3

The student survey's final seven questions captured changes in students' attitudes towards science over time. All of the questions were Likert-type questions that addressed attitudinal factors related to the science classroom. For instance, Question 19 stated, "Science is my favorite subject". *Figure 7* shows the results of the analysis for research question #3.

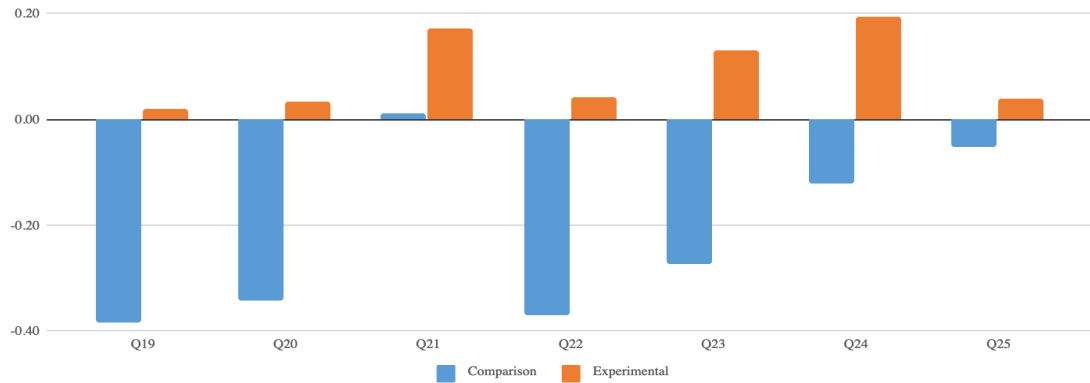


Figure 7. Attitudes Towards Science; Difference in Means from Pre to Post on the Student Survey (Collated Comparison and Experimental)

Figure 7 shows that all the questions in this survey section saw a more positive change in students' attitudes towards science in the experimental group compared to the comparison group. In fact, for all questions except for question 21, the comparison groups' attitudes towards science decreased, while the experimental groups' attitudes towards science increased. It is also true that in all of the questions except for question 21 that the experimental group mean was lower than the comparison group mean in the pre survey collection, and then switched to be higher than the comparison group mean after the post survey collection. However, despite such consistent changes in the survey results of the experimental group over the comparison group, none of the questions in this section were found to have a statistically significant difference between the two groups' change in attitudes toward science.

Research Question #4

Research question #4 was answered by studying the data of a pre/post test comprised of past BECE questions, as well as the official BECE results of the

participants at the culmination of the school year. *Figure 8* below contains four different comparisons between the experimental and comparison groups in relation to their performance on the pre/post test. Each experimental/comparison pairing of comparable schools is considered (i.e., CS1/ES1, CS2/ES2, and CS3/ES3). Finally, the total aggregate of scores of all comparison and experimental schools is shown to give a broader perspective.

Figure 8 shows a greater increase in mean test scores from pre to post of the experimental group than the comparison group, in each pair of schools, as well as in the collation of experimental and comparison group scores. With the exception of CS1/ES1, every other grouping saw the experimental group mean lower than the comparison group mean after pre data collection, and then switch to have the experimental group mean higher than the comparison group mean at the end of post data collection. The only case

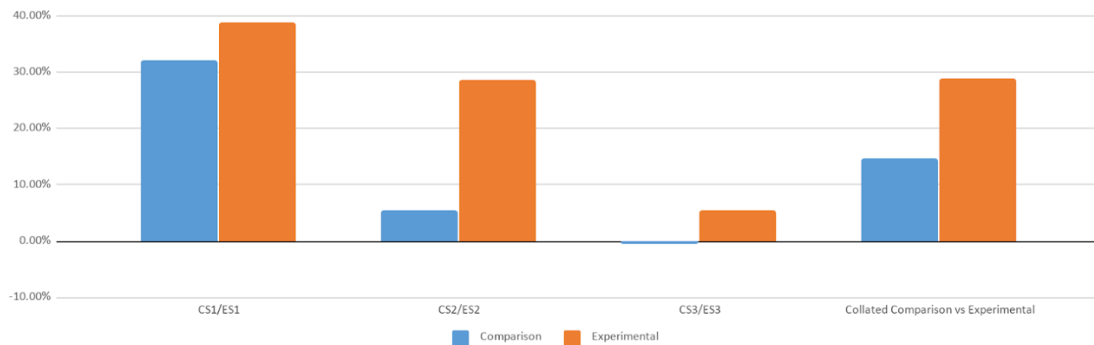


Figure 8. Percent Increase in Mean Test Scores by Paired Schools and Collated Comparison vs Experimental

where the T-test indicated statistical significance was for the total comparison vs experimental data set in which the experimental group (28.78%) increased mean test scores by nearly double that of the comparison group (14.6%). This pronounced

difference may be due to the significantly larger sample size in this particular comparison. The test for Effect size using Hedge's g also showed a medium effect for the T-test performed on the collated post data.

The results from the culminating official BECE are represented in *Figure 9* and *Table 2* below. Two things are important to note: (a) all final year JHS students took the BECE exam on the same week in June, 2018 and all the scores compared here are from this single event, and (b) as shared in *Table 1*, a score of 1 is the best possible BECE score, which means that in *Table 2* below, a lower mean represents better performance by a group.

Figure 9 shows the distribution of official BECE scores in the collated comparison and experimental groups. Given that 1 is the best possible score, it is clear that the experimental group had a higher frequency of scores in the superior score categories (1 through 5) in every case except for 3. The inferior score categories (6 through 9) revealed higher frequencies of scores in the comparison group. Furthermore, the best score category of 1 was composed of only participants in the experimental group while the worst score category of 9 was composed of only participants in the comparison group.

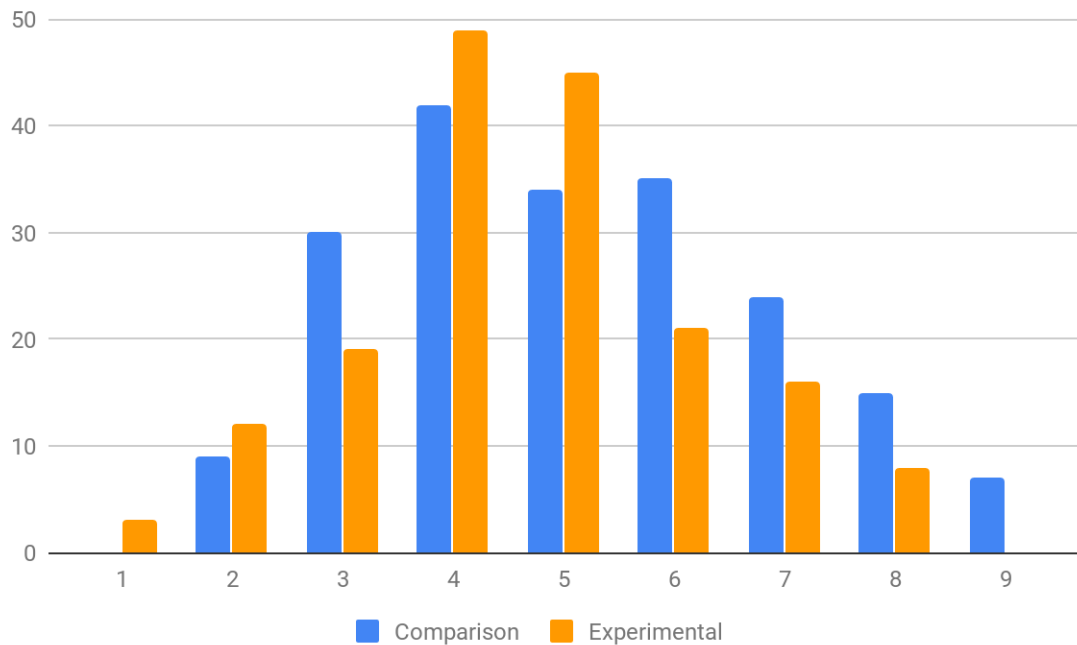


Figure 9. Frequencies of BECE Scores According to Scoring Categories in Collated Comparison and Experimental Groups

Just as for the pre/post test data, *Table 2* presents the data for paired schools, as well as the collated data for the comparison vs experimental groups. Perhaps the most important result in *Table 2* is that the entire population of experimental students had a higher average mean as compared to the comparison group. This exam difference in means according to a T-test and Hedge’s *g* for effect size, was found to be significantly significant with a small effect size. The experimental group also scored a higher BECE score in the case of paired schools CS2/ES2 and CS3/ES3, with only CS3/ES3 showing a statistically significant difference in the means. Interestingly CS1 had a higher average score than ES1, which was also found to be a statistically significant difference between the means with a small effect size.

Table 2		
<i>Means of BECE Scores by Paired Scores and Collated Comparison vs Experimental (Lower the mean the better the performance)</i>		
<u>Group</u>	<u>Comparison</u>	<u>Experimental</u>
CS1/ES1	3.98	4.4
CS2/ES2	6.73	6.36
CS3/ES3	5.88	4.93
Collated Comparison vs Experimental	5.14	4.66

Some qualitative data also adds to the findings on test scores. The ES3 teacher reported in an interview just after the study, that her science students had the best test scores out of all the other cluster groups in her school. The ES2 teacher wrote in his PEN Journal repeatedly on different occasions that “75%, 80%, 90% of the students successfully answered oral or written evaluation questions.”

Research Question #5

This research question was addressed using mostly the Teacher Monitoring Sheet, while also utilizing a few pieces of qualitative data from the Teacher Survey and PEN Journal. The Teacher Monitoring Sheet captured experimental teacher performance in a number of areas on a 10-point Likert-scale, with a score of 10 being the best performance possible. Means were calculated for each individual indicator for all of the observations of a teacher during the 2017-18 school year, then collated to create skill-set means for each of the three teachers. The three teachers (with trainers observing) conducted lessons at variable frequencies: the ES1 teacher conducted 15 lessons, the ES2 teacher conducted 22 lessons, and the ES3 teacher conducted 16 lessons. *Figure 10* below displays the cumulative performance of the three experimental science teachers, specifically their

mean scores in each of the three skill-sets (Preparation and Setup of Materials, Facilitation of Student Learning, and Delivering the Objective) relating to the inquiry-based lessons they conducted.

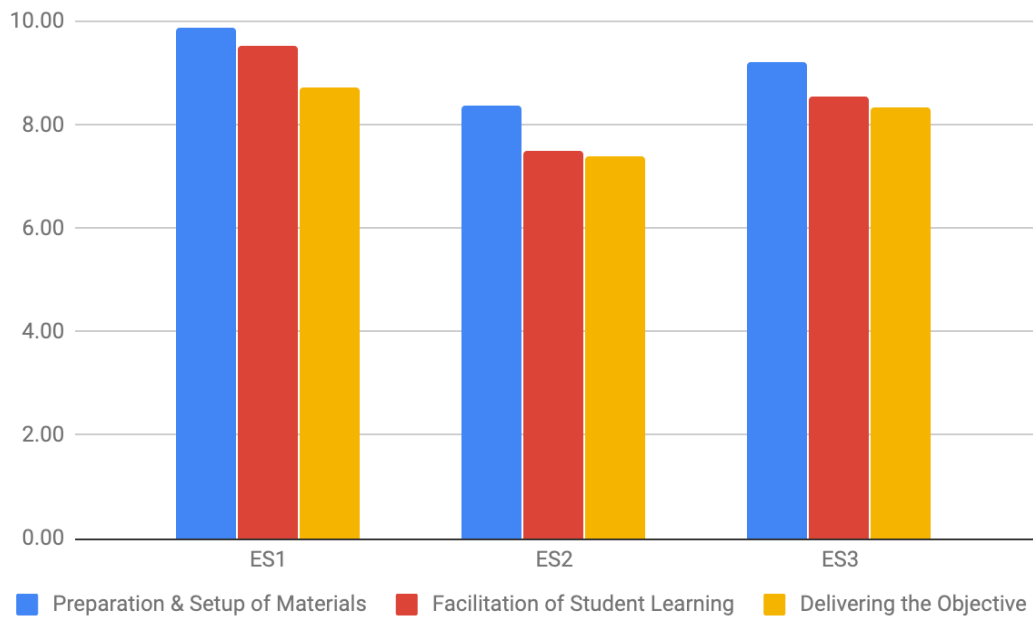


Figure 10. Distribution of Experimental Teacher Skill-sets Means

Figure 10 shows two major findings about how the teachers performed in conducting hands-on, practical activities during the 2017-2018 academic year. First, all three teachers showed the same hierarchy of different skill-set performance; that is, all teachers performed the best at preparing and setting up materials, then facilitating student learning, and finally delivering the objective. Secondly, the teacher who performed the best considering all of their skill-sets together, was the ES1 teacher, followed by ES2, then finally the ES3 teacher. Means for all teachers' skill-sets were comfortably above a 5, which is considered in Ghana as average performance. All of the scores also show a

relatively low variability considering the 10-point Likert scale. However, there seems to be a notable difference between teachers, especially between the lowest score of 7.39 (ES2) and the highest score of 9.87 (ES1).

An anecdote from the PEN Journals revealed some difficulties that experimental teachers went through, which could partly explain the outcomes seen from the Teacher Monitoring Sheet data. In regard to delivering the objective, the lowest-performing skill set for all three teachers, the ES1 teacher stated in his PEN Journal that, “Class size was too large, it became a large class, was not able to reach every group for general comment. The general comment was given to the class.” The entire quote can be interpreted to mean that the teacher was overwhelmed by the large class size and therefore decided to revert back to the teacher-centered method of giving a general comment to the class rather than have the groups make meaning themselves.

Chapter 5

Discussion and Conclusion

Key Findings

This study measured the impact of PEN's approach over the course of one school year on students' classroom environment, critical thinking skills, attitudes towards science, and standardized test scores. Teachers' preparation and setup of materials, facilitation of student learning, and delivery of the objective of the lesson were also measured. Data was collected through six measurement tools which included a student survey, student pre/post test, official BECE student examination scores, a teacher survey, a teacher monitoring sheet, and a PEN Journal.

The PEN approach was shown to affect some aspects of the classroom to be more aligned with an inquiry-based classroom, increasing use of local materials, the frequency of practical-based lessons, and prevalence of group work. Students' critical thinking skills as a whole did not seem to be affected by the treatment. There was a beneficial, but not statistically significant, impact on attitudes towards science, with the experimental groups' attitudes improving more than the comparison group for every question in the survey. Experimental students' test scores showed statistically significant improvement (28.78%) compared to the comparison (14.60%) from pre- to post-test. Additionally, experimental students' BECE scores were significantly higher than their comparison peers. All the teachers seemed to have performed best at the preparation and setup of materials, and have the most difficulty in delivery of the objective of the lesson.

Inquiry Activities in the Classroom

The experimental classrooms exhibited a more inquiry-based classroom, which makes sense given the nature of the study, in which the classroom lessons were manipulated for the experimental group. Statistically significant gains for the experimental group on four of the eight questions on the student survey related to classroom activities are perhaps a direct consequence of the PEN approach, as they measured use of local items, and the frequency of practicals, group work, and outside materials being brought into the classroom. Question 6 of the student survey measured the frequency of practicals in the science classroom, and makes the strongest case for impact of PEN on the classroom environment, given the significant gains that were found. Question 8, which measured the frequency in which science teachers brought in materials from outside the classroom to teach science, also showed gains, but exhibited a small effect size. With respect to the frequency of group work, although the experimental group saw a greater improvement, both saw gains over the course of the year. This could be an indicator that small group work was a convenient way for the comparison schools to implement inquiry-like activities in the classroom without any laboratory equipment or materials. Question 3 measured the use of laboratory equipment, and while the experimental group did not see much gain, it did see a small increase compared to the comparison group, which decreased over the school year. Perhaps the experimental group was motivated to do at least some practicals with laboratory equipment they could find because of the practicals they performed with the PEN-provided materials, while the comparison group had no reminder to strive for any laboratory equipment and therefore

saw a decrease in use. Finally, the teacher survey reinforced the reality of an inquiry-based classroom by indicating a greater increase in reported frequency of use of local materials and laboratory materials, as well as frequency of practicals.

In regards to the classroom environment, one interesting finding was that despite showing greater gains in inquiry-based activities, the experimental group increased the use of the chalkboard, which is considered part of a teacher-centered pedagogy, more than the comparison group. In fact, the experimental group actually switched from having the lower mean in this area in the beginning of the study, to having the higher mean at the end. The most likely explanation for this could be that the experimental teachers did in fact use the chalkboard more than the comparison group during the classroom time that they were not performing practicals, which was most of the time. While experimental teachers did in fact do more practicals over the course of the school year, the practicals tended to be inconsistent, and the teachers may have continued teaching in the traditional manner during the majority of the class time not spent doing these activities. It could also be that the experimental teachers were more engaged overall, using the chalkboard in addition to practical activities.

Critical Thinking

There was no major apparent difference in the critical thinking skills of students in the two groups. In fact, on seven out of the ten questions the comparison group performed better over time than the experimental group. On the remaining three questions, the experimental group improved more than the comparison group, or had a less significant drop in critical thinking, only one of which was found to be statistically significant. Pertaining to these three questions, Question 12 showed a major reduction of

critical thinking by both groups, and while question 18 showed a major improvement by the comparison group and loss of performance by the experimental group, the two groups still finished the school year having virtually the same means. Question 10 measured students' ability to identify the differences between conclusions, reasons, and assumptions. This question stood out because of it being one of the few which saw a greater improvement by the experimental group, was statistically significant, and saw a switching of the means; in fact, it was the only question where there was a significant switch in higher performing means from the pre to post survey. It could be the experimental group students may have excelled at this question more than the others because the hands-on activities they did actually improved their ability to differentiate between conclusions, reasons, and assumptions. However, this seems to be unlikely because different critical thinking skills tend to be related, and if there was not an improvement in the other questions in this section, it is highly unlikely question 10 had any special quality to it.

Given the outcomes shown in this section of the student survey, it appears that there was no strong trend favoring either the comparison or experimental group, and therefore critical thinking skills of students did not appear to be affected by the PEN approach.

Student Attitudes Towards Science

The survey section measuring attitudes towards science showed a significant trend, that for every question, the experimental group showed greater increases in attitudes towards science than the comparison group. Every question except one had the experimental mean lower than the comparison in the beginning of the study, then switch

to become the higher mean at the end of the study. What is significant is how in these questions, the comparison group mean decreased, in many cases drastically. On the other hand, the experimental group saw an increase in the mean over the course of the year for every question, albeit sometimes the gain was minimal. This information indicates that without the presence of regular hands-on learning in the comparison group classroom, attitudes towards science naturally decreased over the course of the school year. In contrast, regular hands-on learning was able to improve student attitudes towards science, or at least prevent it from dwindling in the experimental group.

Student Test Scores

Perhaps one of the most impactful findings in this study was the greater increase of test scores of the experimental group (28.78%) over the comparison group (14.6%) from pre to post. There was an increase in the mean test scores for every one of the paired schools, as well as for the collated scores of the experimental and comparison students compared against each other, with the latter being statistically significant. The end-of-the-year official BECE results also indicated significantly better performance⁴ by the collated experimental group (mean of 4.66) compared to the collated comparison group (mean of 5.14). These results of higher test scores for the experimental group have significance because of the importance placed on standardized testing in the Ghana education system in order to move ahead in the educational system.

Teachers' Skill-Sets

⁴ Refer to *Figure 3*. A score of 1 is the best while a score of 9 is the worst.

The Teacher Monitoring Sheet produced results showing the differences in skill-sets among experimental teachers. For every teacher, performance was best for preparation and setup of materials, then facilitation of student learning, and finally the lowest performance was delivering the objective. The fact that this is true for every teacher brings into consideration that either teachers are naturally the most skilled at preparation and setup of science materials more than the other skills, the PEN approach prepares the teachers best at this skill-set, or that the other skill sets are inherently more difficult. There is no way to know for sure about PEN's impact on teaching skills, as there was no comparison group for this research question. It is also important to note that, according to the field notes taken, no experimental teacher had less than 15 years of teaching experience, which may explain why there were mostly higher scores (greater than 7) and also low variability of scores. A common complaint in the field notes and PEN Journal was that the teachers were not provided with adequate teaching materials, yet they were still able to perform the skill of preparation and setup of materials the best, which also could be a testament to their teaching experience.

Connections to the Literature

The results from this study add evidence to the existing literature on the benefits of inquiry-based learning while also providing new information and novel insights specific to Ghana. In relation to the classroom environment, the PEN approach aligned with the Springer, Stanne and Donovan's (1999) findings of their meta-analysis of the effect of small group learning on STEM undergraduates in promoting greater academic achievement and more favorable attitudes towards science. Albeit the data in this study on group work is limited, the PEN approach did show parallels to the findings of Lou and

colleagues (2001), which indicated that small group work produced greater student academic achievement than a traditional teacher-centered approach. Teachers in the PEN study also had more success in the student-centered way. For example, the ES2 teacher wrote in his PEN Journal that his lesson on Diffusion "was successful because the group work had encouraged participation and therefore about 90% of the class comprehended the topic". This success in a constructivist setting also was reported in the Ghanaian classroom from Akyeampong et al.'s (2006) study. The local materials that were brought into the classroom environment boosted the students' motivation to learn, despite high numbers of students in the classroom setting.

One area where this study seemed to break from the existing literature is in teaching for critical thinking. Cornelius-White (2007), Miri et al. (2007), and Holmes et al. (2015) all were able to observe changes in critical thinking skills as an outcome of an inquiry-based classroom from the primary school level through to the university. However, the students in this study did not respond in the same way. In fact, the comparison group even showed a greater improvement over the course of the year than the experimental group in most cases. The only case where the experimental group saw a greater increase in the mean, was in the question addressing the ability to differentiate between conclusions, reasons, and assumptions. There does not seem to be any similar anomaly in the selected literature addressing student growth in the area of critical thinking.

The literature has lots of indications of inquiry-based learning affecting more positive attitudes towards science. Science summer camps (Gibson & Chase, 2002), new instructional units with hands-on activities in the classroom (Baker & White, 2003; Ergul

et al., 2011), and practical learning at the university level in Ghana (Hanson, 2014) all were able to increase attitudes towards science in various ways. This study falls in line with the past research on the matter, particularly in PEN's ability to reliably maintain a more positive attitude towards science, even if the attitudes do not happen to increase substantially from a given treatment.

The PEN approach can also add to the literature in regards to improving standardized test scores. All the students in this study could be classified as underserved students if we were comparing them to other countries around the world, particularly developed Western countries. Just as cited in Geier et al. (2007), as well as Han et al. (2014), the approach of making an under-resourced classroom, like the classrooms in this study, an inquiry-based one can have very beneficial effects on test scores. Lower-performing students in Ghana have shown that they can respond very well to a more student-centered learning environment in regards to test scores. Additionally, a profound difference can be seen between the 28.78% increase in experimental group exam scores in this study, compared to the average 6% increase observed in a comprehensive meta-analysis of STEM undergraduates (Freeman et al., 2014).

Just as teachers in the nationwide SMASSE program in Kenya faced challenges, but worked hard to have good science pedagogy and developed positive attitudes (Makewa et al., 2011), the teachers in Ghana adapted well to the PEN approach. The teacher survey for ES2 in the beginning stated that the teacher was facing challenges obtaining laboratory equipment in order to do practicals. In the post survey the teacher did not share any challenges other than that there is too much material to cover in the curriculum; it could be inferred that the teacher was able to discard the idea of needing

laboratory chemicals to do good science, once they saw how the same concepts can be taught with local materials. Supovitz & Turner (2000) brought to light the link between professional development and inquiry-based teaching practice. This study can be seen as a year-long professional development for experimental teachers and through the student survey, it was found that the experimental group did indeed have a more inquiry-based classroom. Literature also suggests that successful science education depends on teachers' learning in networks and having peer coaching (van Driel et al., 2001). The "communication" section of the teacher survey also indicated through limited qualitative analysis that the PEN teachers showed a greater level of communication between other science teachers than the comparison teachers.

Limitations

This study has several limitations that must be brought into discussion. The first being that there was not a Teacher Monitoring Sheet used for the three comparison teachers in order to measure true impact of the experimental treatment. Another measurement tool, the teacher survey, was not executed well. In the end, only two out of the six total schools (CS2 and ES2) were able to produce complete pre and post teacher surveys. The ES1 and ES3 pre surveys were not able to be collected, and the CS1 post survey was not able to be collected. These missing pieces of qualitative data made it difficult to utilize the teacher surveys in any powerful way. Another limitation of the study was the inability to do student level analysis, as was originally planned. This is a result of the designated PEN numbers for each student not being accurately collected, or not collected at all. A student level analysis could have provided more detailed insight, into how the PEN approach impacts individuals over time. The limitation that

encompasses all the previously mentioned issues, is a lack of strict monitoring and evaluation during the study, resulting in the loss of potentially useful data. The researcher would have liked much more attention to detail when it came to data collection, but could not enforce it while living so far away from those responsible for the data collection. The argument could be made that the Ghanaian school culture does not place much emphasis on thorough documentation, which could be the source of the lost information.

Research question #5 “After receiving PEN training, to what extent are teachers able to set up materials, facilitate student learning by answering any questions and keeping students on task, as well as deliver the main learning objective of the lesson?” did not include data from a comparison group. Since the measurement tool for this question, the Teacher Monitoring Sheet, was not administered to comparison group teachers, there is no way to truly measure the impact of the PEN approach compared to a “business as usual” classroom. However, with this being said, the Teacher Monitoring Sheet was an informative tool that was able to be analyzed thoroughly, and describe similarities and differences amongst the experimental group teachers.

The Teacher Survey and PEN Journal were not designed to directly address any particular research question and difficulty was also experienced during implementation, probably due to a lack of immediate oversight on the ground. Some Teacher Surveys were not collected with no reason being given as to why, while another schools’ Teacher Survey was rendered unusable due to the teacher being transferred to another school. One teacher lost her PEN Journal, while another teacher listed procedures of the activities rather than sharing challenges or benefits of the lessons. However, the CS2 and ES2 Teacher Survey and the PEN Journals of all the teachers (including the one teacher

interviewed), were able to be analyzed qualitatively and provide a more detailed, anecdotal picture that support the quantitative findings addressing research question 5.

It was observed that the CS1/ES1 school pairing had the experimental test scores (38.98%) increase more than the comparison scores (32.13%), yet the difference between the two schools' averages was the smallest out of any pairing. This unusually high performance by the comparison school could very well be because of the sharing of materials by the experimental trainer and teacher. The comparison school teacher requested materials from the experimental teacher and trainer, and were provided them. Perhaps the prevalence of hands-on materials in this comparison classroom helped them achieve higher exam scores than the other comparison schools.

The least performing teacher according to the Teacher Monitoring Sheet was ES2. It has already been mentioned that all the experimental teachers had a lot of teaching experience, ES2 had 25 years, the most out of all the teachers. The most probable cause for the ES2 teacher performing the worst out of the three was most likely due to the trainer's erratic and sometimes misinformed use of the Teacher Monitoring Sheet. For the first eight weeks, the trainer filled in the measurement tool backwards, believing that a 10 meant the teacher performed terribly, and that a 1 meant the teacher performed exceptionally well. The trainer also seemed to have extreme variability when filling out the sheet. For example, the final 7 weeks of the study, the trainer recorded the following marks, starting with week 16: 10, 3, 8, 8, 5, 10, 8. The validity of these marks are questionable, because the teacher in question had the most years of teaching experience out of all the experimental teachers.

Further Research

This research study provides valuable information into the effects of science teacher trainings in Ghana on teachers and students alike. However, much more insight could come if key changes were made and another study was subsequently implemented. To start, it may be worthwhile to reconsider the critical thinking aspect—how teachers could better teach to improve critical thinking, and how best to measure it. It could be that while the students in the experimental groups did in fact do more hands-on learning, there was no specific teaching pedagogy to better inculcate critical thinking skills in the students. Also, the measurement tool could have been unfit to accurately measure critical thinking skills of these JHS students, as the English could have been too difficult or unfamiliar to them to properly respond to the questions. Both better pedagogy and a new measurement instrument in their native language could be helpful in further research.

Another major suggestion for further research would be to have a larger, trained, and experienced network of trainers and logistics coordinators for better monitoring and evaluation, to make sure very detailed and credible data was collected from beginning to the end of the study in even more schools. This would produce a higher quantity of quality, usable data, that could be able to uncover unseen benefits and shortfalls of the PEN approach that would be of interest to stakeholders in the Ghanaian STEM community, such as government as a whole, the Ministry of Education, other non-governmental organizations and also outside funders who wish to invest in education in Ghana.

A final suggestion would be to study the impact of the PEN approach in new areas, such as the other nine regions of Ghana, and perhaps other Anglophone countries in West Africa. It would be of great interest to Ghana as a whole to see the effects of

more inquiry-based learning on students of different socio-economic and cultural backgrounds in various parts of the country, instead of the more homogeneous setting of the Greater Accra basic school. Perhaps there would be changes to be made in the implementation of the PEN approach according to different types of school settings throughout the country. Differences could be even more pronounced in different countries in West Africa, meaning that PEN would have to take these differences into consideration to make their method more effective depending on location.

Conclusion

This report highlights the impact that the PEN approach of inquiry-based learning, using locally available materials, has on students' classroom environment, critical thinking skills, attitudes towards science, and standardized test scores. Teachers' preparation and setup of materials, facilitation of student learning, and delivery of the objective of the lesson were also measured in response to PEN training. The data indicates that the PEN approach had a beneficial impact on students' classroom environment, attitudes towards science, and standardized test scores. The data also suggests that teachers were most comfortable with setup of materials, and least comfortable with delivery of the objective. The significantly positive impact of PEN's approach on student test scores, as well as ability to reverse the trend of decreasing student attitudes towards science, holds great promise for getting more stakeholders to support the cause for more practical student learning. Based on the inconclusive evidence for students' critical thinking, PEN should find better ways to teach for and measure this important skill in science education. Further research should include a larger, and more

highly-trained network of trainers and logistic coordinators to further measure the impact of the PEN approach in the rest of Ghana and eventually other West African countries.

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Appendix A

PEN CONTROL TRIAL PRE/POSTTEST

[60 marks]

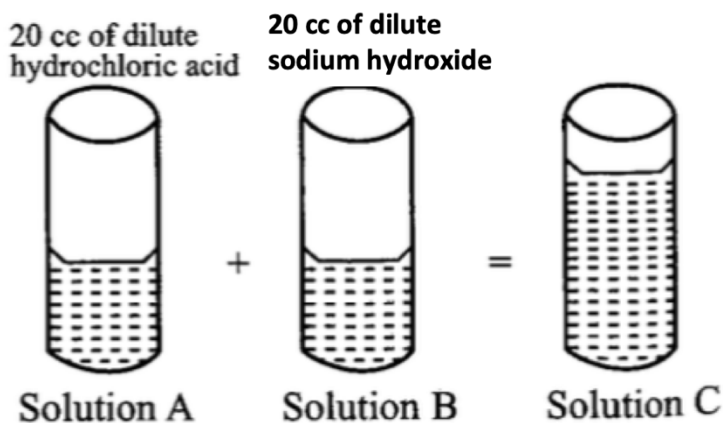
This paper is in one part.

*Answer **all** of the questions in your answer booklet. You have one hour.*

Credit will be given for clarity of expression and orderly presentation of material.

Question 1

In an experiment, equal volume of dilute hydrochloric acid (solution A) and dilute sodium hydroxide (solution B) are mixed together to form solution C.



- What is the volume of solution C?
- Red litmus paper and blue litmus paper are dipped in turns into solutions A, B and C.

State the observation you will make in all six cases. Present your answer in the table below.

	Red Litmus Paper	Blue Litmus Paper
Solution A		
Solution B		
Solution C		

- Give the name of the reaction that took place between solution A and solution B.

iv. Identify solution **C**.

v. State what will happen when solution **C** is heated.

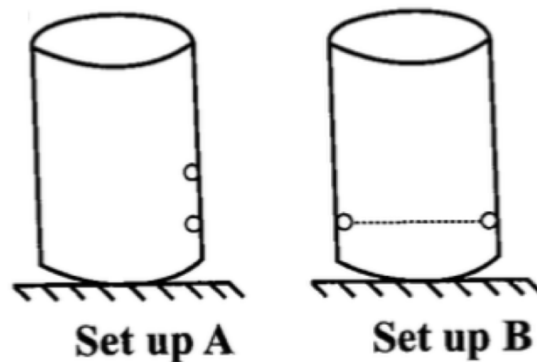
Question 2

i. Explain the term *electromagnetism*.

ii. Given a nail, insulated wire, key (or switch) and a battery, show by means of a circuit diagram how the nail can be magnetized.

Question 3

In an experiment, a pupil took two empty Milo tins and made holes in their sides as shown in the diagram above. The pupil then filled the Milo tins with water.



i. Draw and label the diagrams to show what the pupil will observe in set-up **A** and set-up **B**.

ii. Explain the observations in set-up **A** and set-up **B**.

iii. What is the aim of set-up **A**?

iv. What is the aim of set-up **B**?

Question 4

i. State the *laws of reflection*

ii. Draw a ray diagram of light incident at an angle 40° on the surface of a plane mirror.

Question 5:

i. What is an *electrical conductor*?

ii. List **two** substances which are conductors.

iii. List **two** substances which are insulators.

iv. Draw the circuit symbols for

a. Dry Cell

b. Resistor

c. LED

Question 6

The table below gives the steps that were followed in an experiment to test for starch in a green leaf freshly taken from a tree.

	<i>Stages in the test for starch</i>
A	Leaf is put into boiling water for 1 minute.
B	Leaf is dipped in alcohol warmed in a hot water bath.
C	Leaf is washed in cold water.
D	Leaf is dipped into iodine solution.

i. State the reason for carrying out each of the activities in stages **A**, **B** and **C**.

ii. What happens when the leaf is dipped in iodine solution?

iii. Give the colour changes of the leaf from the beginning of the experiment to the end of the experiment.

iv. Why is the alcohol warmed indirectly in a water bath?

v. Explain what will be observed if the test is carried out on a leaf taken from a plant and kept in a dark room for 1 day.

Appendix B

Student Science Survey

Thank you for completing this survey! Answering these questions will allow us to know more about your education and how to make it better. Please know that the answers you give will not be marked correct, incorrect, or affect your scores for science class. Your teachers, parents, or friends will never know the answers you give on this questionnaire. Please answer the questions thoughtfully and honestly so that we can help you and other students in Ghana. Once again, thank you, and feel free to ask me any questions you may have as you go through this survey. Let's begin.

Classroom Environment & Activities

1) How often do you use a *chalkboard* in your science class? (1 is least often, 5 is most often)

1 2 3 4 5

2) How often do you use *exercise books* in your science class? (1 is least often, 5 is most often)

1 2 3 4 5

3) How often do you use *lab equipment* such as microscopes, pipettes, and test tubes in your science class? (1 is least often, 5 is more often)

1 2 3 4 5

4) How often do you use *local items* such as bottles, batteries, and rubber bands in your science class? (1 is least often, 5 is more often)

1 2 3 4 5

5) How often do you use the *textbook* in your science class? (1 is least often, 5 is more often)

1 2 3 4 5

6) *This month*, how many times did you have practicals in your science class?

never once twice three four or more I don't know

7) *This month*, how many times did you work in small groups with other students in your science class?

never once twice three four or more I don't know

8) *This month*, how often did your science teacher bring in materials from outside the classroom to teach (bottles, batteries, rubber bands)?

never once twice three four or more I don't know

Critical Thinking

9) If you are confused about a topic in science, and want to find out more information, which of the following is the best source of information?

- a) a friend
- b) the internet
- c) the textbook
- d) I don't know

10) A classmate tells you "I think there are 20 girls in class today", even though they have not actually counted the students. The classmate is _____

- a) drawing a conclusion
- b) making an assumption
- c) providing a reason
- d) I don't know

11) Three different scientists do an experiment the same way but their results are slightly different. Scientist A collected 3 pieces of evidence, Scientist B collected 100 pieces of evidence, and Scientist C collected 15 pieces of evidence. Whose work will you believe?

- a) Scientist A
- b) Scientist B
- c) Scientist C
- d) I don't know

12). A student does not have school fees and decides to skip school the first 2 weeks of school to make money for school fees. Some say he is doing a good thing. Others say he is not. What do you think? Defend a position on the issue and tell us why.

13) If you don't understand a question that your teacher asks, what will you do?

- a) think about the meaning in your head
- b) raise your hand and ask your teacher to repeat the question
- c) ignore the question
- d) I don't know

14) Acids turn blue litmus paper red. Bases turn red litmus paper blue. You see your classmate applying acidic lemon juice to red litmus paper. They tell you they are testing to see if lemon juice is an acid. Do you think they are doing a good experiment? If not, what should they do?

15) The word "matter" has many meanings. Which of the following expressions use "matter" related with science class?

- a) "It doesn't matter"
- b) "the president spoke on the matter"
- c) "gas is a state of matter"
- d) I don't know

16) You and your classmates walk to school the same route every day. One day a classmate says they know of a new, quicker and better route to school. What will you do?

- a) try the new route to school to see if it's better
- b) continue walking the same way you have always walked to school
- c) talk to a different friend, telling them it is not a good idea
- d) I don't know

17) Which of the following describes *best* how you can pass your exams in school....

- a) attend school every day
- b) read extra material before class
- c) learn what is asked of you in class
- d) I don't know

18) Friends tell you that malaria is caused by the sun whilst your teacher says it is mosquitos that cause malaria. What should you do?

- a) Conclude your teacher is correct but still remain open to other ideas
- b) Listen to your friends only
- c) Listen to your teacher only
- d) I don't know

Attitudes (circle one)

19) Science is my favorite subject...

Strongly disagree Disagree Agree Strongly Agree I don't know

20) I enjoy being in science class...

Strongly disagree Disagree Agree Strongly Agree I don't know

21) I think it is useful to know about science for my everyday life...

Strongly disagree Disagree Agree Strongly Agree I don't know

22) I think I will choose to study General Science when going to Senior High School (SHS)...

Strongly disagree Disagree Agree Strongly Agree I don't know

23) My friends and I enjoy talking about science after class...

Strongly disagree Disagree Agree Strongly Agree I don't know

24) I believe that I am smart enough to understand science...

Strongly disagree Disagree Agree Strongly Agree I don't know

25) I am amazed about things I learn in science class...

never rarely sometimes often always I don't know

Appendix C

Teacher Survey

Circuit: _____

District: _____

Date: _____

Thank you for being part of our study! By completing this survey, we will potentially be able to improve the state of science education in Ghana. Please note that your identity will never be made available to anyone outside of this study. Also note that you will not be judged and the responses that you give will not affect the status of your job as a teacher at your school. I ask that you respond to this survey in a thoughtful and honest manner. So TAKE YOUR TIME, thank you for participating and please ask me any questions you may have.

Classroom Environment & Activities

1) How often do you use the *chalkboard* in your Form 3 science class? (1 is least often, 5 is most often)

1 2 3 4 5

2) How often do you use the *textbook* in your Form 3 science class?

1 2 3 4 5

3) How often do you utilize student *exercise books* in your Form 3 science class?

1 2 3 4 5

4) How often do you use *local materials* like bottles, batteries, and rubber bands in your Form 3 science class?

1 2 3 4 5

5) How often do you use *lab equipment* like microscopes, pipettes, or test tubes in your Form 3 science class?

1 2 3 4 5

6) *This month*, how many times did you have practicals in your Form 3 science class?

never once twice three four or more I don't know

7) *This month*, how many times did you have students work in groups in your Form 3 science class?

never once twice three four or more I don't know

Communication

8) I feel supported by my local community of STEM (Science, Technology, Engineering, and Maths) teachers.

strongly disagree disagree neutral agree strongly agree

9) Each term, how many times do you reach out to another STEM (Science Technology Engineering & Maths) teacher to discuss STEM-related content?

zero one two three four or more I don't know

10) If you reached out to at least one other STEM teachers, what do you talk about? (Check all that apply)

- Practicals
- Science Content
- School community (teachers, schools, students)
- Other
- I do not reach out to other STEM teachers

Challenges in the Classroom

11a) Please circle all of the challenges you may face in making your classroom one that utilizes student-centered learning, group work, and includes practicals on a regular basis.

- I don't have the proper training to teach with those methods
- I forget the skills I was taught in previous trainings
- The curriculum has too much material to cover
- My classroom size is too large for practicals
- I can't afford materials for practicals
- I can't access materials for practicals
- I lack ideas for activities to do
- I'm not comfortable explaining science concepts in this style of teaching
- My school environment encourages teacher-centered instruction
- I have difficulty reaching out to my STEM community (Science, Technology, Engineering, and Maths) for help/resources

11b) If you have in mind any challenges that are not listed above, please list and explain them all in the space provided below.

Practicals

12) *This month*, have you done at least one practical in your Form 3 science class? If no, please leave this portion blank. If yes, please list and describe the practicals that you have done.

Thanks again for your participation!

Appendix D

PEN Trainer name: _____

Circuit: _____

District _____

Topic of lesson: _____ Date of lesson: _____

Preparation and Setup of Materials

1. Did the teacher seem intellectually prepared to deliver the content for the lesson?

1 2 3 4 5 6 7 8 9 10

2. Was the teacher able to split the students up in groups that are efficient for the lesson?

1 2 3 4 5 6 7 8 9 10

3. Was the teacher able to distribute the materials in a way so that the students were able to identify what they needed for the lesson?

1 2 3 4 5 6 7 8 9 10

Facilitation of Student Learning

4. Was the teacher able to answer most of the questions posed by students?

1 2 3 4 5 6 7 8 9 10

5. Did the teacher stay engaged in the activity by walking around the classroom and inviting all possible questions?

1 2 3 4 5 6 7 8 9 10

6. When there were no questions from students, was the teacher able to invoke questions from the students regarding the activity?

1 2 3 4 5 6 7 8 9 10

7. When there were problems with the materials at hand, was the teacher able to successfully fix the problem?

1 2 3 4 5 6 7 8 9 10

Delivering the Objective

8. Did the teacher accurately explain to most of the groups the theory behind the lesson?

1 2 3 4 5 6 7 8 9 10

9. After choosing a random student of your choice, was he/she able to tell you the theory behind the lesson?

1 2 3 4 5 6 7 8 9 10

10. Did the teacher get every students attention at the end of the lesson and deliver an accurate summary of the theory behind the lesson that was delivered?

1 2 3 4 5 6 7 8 9 10