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The Effects of Mobile Devices & Maker Projects on Middle School African American Students’ STEM Knowledge Base & Interest

Allen L. Savage Sr.
University of Missouri-St. Louis, savageals@yahoo.com

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Allen L. Savage

M.Ed., Higher Education, University of Missouri-St. Louis, 2017
M.A. Inorganic Chemistry, Washington University-St. Louis, 1978
B.A. Chemistry, Westminster College-Fulton, 1974

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Advisory Committee

Keith W. Miller, Ph.D.
Chairperson

Charles Granger, Ph.D.

Carl Bassi, Ph.D.

Helene Sherman, Ed.D.

Abstract

The nature of future employment is rooted in the sciences, technology, engineering, and math (STEM). Educating the current and future workers will require the inclusion of STEM education, especially in the K-12 classrooms. African Americans run the risk of being left behind in future STEM jobs due to their poor STEM representation throughout institutional education. In general, African American students have a poor attitude towards and poor academic performance in STEM.

This research was explored using ubiquitous smartphones and a unique form of student-centered learning called maker education to increase the attitude and STEM knowledge of African American middle schoolers. A mixed-method approach was utilized through a pre- post- questionnaire, comprised of three Likert-type scales for Attitude: Interest, Difficulty, and Importance, and a knowledge base multiple-choice portion to investigate the study quantitatively, supplemented by direct observation and focus groups to investigate it qualitatively. Twenty-nine African American students from four St. Louis, Mo., middle schools were divided into two groups, one of 24 treatment and one of five control participants. The research setting for both groups was a local Boys and Girls club. The treatment group completed two maker-ed interventions with smartphones, while the control participants completed two similar interventions without smartphones or maker activities (see Appendix F). The qualitative data were thematically coded, and the quantitative data were statistically analyzed for significance. The knowledge base of both the treatment and control groups showed no statistically significant difference, either before or after the interventions, which supported the null hypothesis $H1_o$. The Likert scales suggested a slight increase in African American middle schoolers' attitudes in both treatment and control groups, but it was not statistically significant, supporting null hypothesis $H2_o$. The thematic analysis of the observation and focus group data was logically inconsistent with the Likert-scales data in that it suggested a strong increase in attitude in both groups. More research is warranted in this area to increase African Americans in STEM.

Keywords: African American, science, engineering, math, technology, STEM, career, mobile device, attitude, mixed-method analysis, constructionist theory, Maker education

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

The Effects of Mobile Devices & Maker Projects on Middle School African American Students' STEM Knowledge Base & Interest

Chapter I: Introduction

Background

Creating an environment in which African American (AA) students can excel and develop a sense of motivation and a positive attitude towards science, technology, engineering, and math (STEM) is an elusive, much sought-after goal in secondary education STEM courses. The driving forces acting as the vanguard for this endeavor include a desire to improve diversity in the STEM field talent pool, as well as the awareness of an ever-increasing gap between STEM-capable workers and STEM required jobs (Arik, & Geho, 2017; Bozick, Srinivasan, & Gottfried, 2017; Christensen, Knezek, & Tyler-Wood, 2014). One untapped reserve of potential for the STEM field labor force in this country is that of the African American workforce. This American ethnic group is significantly underrepresented in all areas of STEM education in K-12 and higher education, and the existing tech labor field (Diversity.nih.gov, 2018). Therefore, it is not surprising that African Americans represent only a small percentage of the STEM workforce. Moreover, those AA students who desire to pursue a STEM career are often discouraged somewhere along their educational pathway and generally will shun STEM-related majors in higher education, or will start but not complete a major, or will even drop out of college completely.

Like most youth in their age bracket, secondary school AA students are very adept at using mobile devices, such as personal cell phones, tablets, pads, and their respective apps (Harper, Burrows, Moroni, & Quinnell, 2015; Krishnamurthi, & Richter, 2013; Sharples, Taylor, & Vavoula, 2005). The use of mobile devices and their applications is exponentially increasing in U.S. schools. However, costs, technical issues, and lack of stakeholders' preparedness have been shown to hinder the schools that contain most AA students from incorporating mobile device technology into their teaching curriculum. Furthermore, other complications for incorporating mobile devices in STEM courses for AA students are many, and their interactions are convoluted. AA schools do not have the infrastructure, the trained staff, or both to formulate an aggressive and effective STEM education component. Decision-making about what platform, device, and operating system can be a daunting process to the typical AA K-12 school administration. In a majority of cases, the finances are just not in place for procurement of the necessary components of a successful STEM education program.

Some progressive administrators and educators have sought remedies for the above impediments. One such remedy is to form alliances with other likely instructional cohorts, such as after-school programs, community-based STEM clubs, and civic private organizations, and public programs. These and other such entities can assist in the STEM education and motivation of AA secondary students. Many such institutions have found that offering STEM instruction in after-school, summer, or weekend programs has helped them fulfill their own mission goals while creating an interest in STEM in their targeted student population.

These programs that generally take place outside of the classroom include makerspaces, DIY clubs, and public Fab-Labs. Some may be as simple as a field trip to a local drainage basin to search for microbes or as complex as designing a 3D printed model car. Some programs involve tailored "do it yourself" maker activities, such as aeroponics gardens or building and launching unmanned vehicles, UAVs, and maker activities tend to use materials and tools that are readily available and cost-effective. A quick search of websites such as YouTube.com or InstrucTables.com reveals an abundance of such maker activities utilizing everything from a discarded soda can to the hard drive from outdated laptops. By utilizing such maker-based ventures and activities, some have made a noticeable increase in STEM awareness, interest, and knowledge amongst those who participate in these STEM programs. Interest in integrating this type of classroom learning into traditional educational STEM classes is increasing. And although there are no well-formed strategies yet identified that can be used as generalized, flexible templates, the promise of the development of such is clear.

Overall problems faced by African American society are more pervasive than STEM education, but this particular field offers the potential of lifting a whole ethnic community out of poverty. Many ethnographers are interested in studying African Americans in STEM fields, and there has been a surge of studies of African Americans' STEM interest and achievement at the K-12 levels since 2010. A particular type of STEM, maker education, is also on the increase. With the decreasing price of technology, increasing instructional access to the internet, and an increasing interest in the general public in community Makerspaces, Maker Fairs, Fab Labs, and online Maker social media, the prospect of using maker education to teach STEM to underprivileged groups, such as African Americans, has become more appealing. Likewise, since the start of this century, mobile devices, such as tablets and smartphones, have become pervasive at all levels of the social stratum, so much so that a homeless person who may not have a home, a job, or an automobile most probably has a smartphone. Smartphones are increasingly impacting every segment of society, including healthcare, religious institutions, governmental agencies, financial management, and lagging behind education. Therefore, it is predictable that the under-utilized tools of maker education and mobile devices might be tried, separately or jointly, as a solution to the poor representation of African Americans in STEM.

Statement

Although much research has been published which attempts to describe and define the lack of African Americans in pursuit of a STEM education, less has been published on the use of mobile devices as tools for STEM learning, and only a scant amount of research can be found in the literature on adapting this method to African American secondary school students in disadvantaged school districts. Likewise, the maker movement has proven its effectiveness in suburban majority-white schools, but only a fraction of the research has been conducted within schools serving disadvantaged students.

There also exists a gap in the knowledge presented in the literature that investigates how effective the use of socially ubiquitous devices, such as mobile phones, in conjunction with modified maker education, increases STEM knowledge and attitude in African American Students. Specifically, an area of research of interest is investigating whether mobile device-assisted maker activities can increase the number of disadvantaged AA students exposed to STEM coursework in middle schools and, consequently, increase their knowledge of and interest in STEM. This issue was addressed by investigating mobile devices and maker education in educating AA middle schools STEM education. The need for such research is apparent, given the relative lack of literature published on this area. However, there has been a recent upswing in the number of researchers investigating the use of mobile devices in education in general, and the inclusion of maker spaces in the classroom setting. Specifically, the effects of including personal cell phones in an after-school maker style STEM program on the academic knowledge, interest, and attitude of AA middle schoolers, was explored.

Purpose

Our purpose was to explore whether mobile device-assisted Maker activities can be used to increase STEM knowledge, interest in, and the positive attitude of AA middle school students towards STEM fields. The research used an explanatory sequential mixed method design and collected quantitative data followed by an in-depth collection of qualitative data. In the first quantitative phase, participants were solicited from four underprivileged schools within a large midwestern urban district, with a majority African American student population. The chosen research site was a nonprofit membership organization, a boys and girls club, in which all four participating schools had a prior association in an ongoing aeroponics activity. The participants completed two quasi-experimentally designed maker activities using cellphones during an after-school STEM program.

The schools were all part of a STEM after-school program that utilizes hydroponics to teach horticultural skills, cooking, and nutritional awareness. A three-session STEM component was added to this ongoing program, which investigated whether mobile device-assisted maker activity experience can increase the subject knowledge base, interest, and the positive attitude of African American middle school students in STEM. The four schools were divided into two groups, a Monday evening group, and a Tuesday evening group; both met on the same three consecutive weeks for 1½ hour-long sessions. The format of the sessions was designed such that the participants gathered for a meal at 4:00 pm, with open socialization during the meal. A pre- test and a post-test were given respectively on the first and last day of each group session. At 4:30 pm during each session, the instructor offered a 15-minute PowerPoint presentation concerning the evening's scientific concepts. The control group was then separated from the treatment group and taken to a separate laboratory area with traditional science instruments. The participants then completed the project with as little assistance from the instructor or other adults as possible. The session ended promptly at 5:30 pm.

As a follow-up to the quantitative phase of this study, a qualitative aspect was carried out to explore African American students' attitude towards the interventions and STEM in general. The researcher observed the participant's interactions and responses until they left the research site premises. The researcher led a focus group with each participant school within two weeks after completing the last session of the study.

Importance

Without a large, viable STEM workforce, the literature is very certain that the U.S. may lose its position as the world leader in technology and innovation (Cordero, Porter, Israel, & Brown, 2010; Diversity.nih.gov., 2018).

A mixed methods research design was used even though a quantitative approach, using a purely positivist stance could have been used, but too much valuable information about how the participant's feelings towards STEM and any measurement of how the study experience impacted those feelings would have been lost. Likewise, a viable qualitative approach could have been designed using pre-and post-interviews and contrasts of this research design with existing, successful STEM programs. However, this approach would likewise fail to consider the outcomes of mobile device-maker activities on academic performance.

The most obvious benefits for potential stakeholders reside in the participants themselves, their participating schools, teachers and administrators, and the nonprofit boys and girls organization, which welcomed an opportunity at STEM activities. The parents are also potential beneficiaries of such a program since was designed to increase the knowledge base and the interest of their child in an ever-growing and financially viable field of employment. Future higher education and technical career institutions may also find it desirable to have incoming clientele better versed in STEM education. Since STEM occupations are on the rise whereas the pool of qualified STEM workers is not keeping up, the country's labor pool as a whole will benefit from a more diverse, informed, and motivated STEM worker pool.

Research Questions and Hypothesis

Pursuing a solution that would increase African American students in the STEM field was the primary motivation for the use of a mixed-methods research design. One reason for choosing a mixed-method design was its ability to triangulate the desired results using converging quantitative and qualitative methods (Schoonenboom, Johnson, 2017). The research questions raised that gave rise to this study were:

RQ1: To what extent do mobile device-assisted maker activities affect the STEM knowledge base of African American students at the secondary education level?

RQ2: To what extent do mobile device-assisted maker activities affect the STEM attitude of African American students at the secondary education level?

The quantitative portion of the research generated two null hypotheses:

Null Hypothesis 1, H1o. The use of mobile device-assisted maker activities has no effect on the STEM knowledge base of African Americans at the secondary education level.

Null Hypothesis 2, H2o. The use of mobile device-assisted maker activities has no effect on the STEM attitude of African Americans at the secondary education level.

The respective one-tailed alternative hypotheses are:

Alternative Hypothesis 1, H1a. The use of mobile device-assisted maker activities will increase the knowledge base of African Americans in STEM activities.

Alternative Hypothesis 2, H2a. The use of mobile device-assisted maker activities will increase the attitudes of African Americans in STEM activities.

Overview of the Research Design

A sequential explanatory mixed-method study consisting of a quantitative pre-, post-, questionnaire, qualitative direct observations of the participants, and qualitative focus group responses was used to answer the questions on achievement and attitude. A 26-item questionnaire that was designed to measure attitude and achievement was given at the start of the study to all participants in both treatment control groups, and again at the end of the study. Both groups studied the microscopic structure of plants grown in an aeroponic system referred to as the Green Tower system (Flaga, n.d.), and quantified the chlorophyll content of the leaves. The treatment group received and assembled a maker device called a Foldscope (Cybulski, Clements, & Prakash, 2014) with a smartphone accessory for the first intervention, while the control group received a standard student microscope. For the second intervention, the treatment group constructed an Arduino-based smartphone colorimeter to quantify chlorophyll extracted from spinach leaves. In contrast, the control group received a paper comparator to estimate the chlorophyll content extracted from the leaves. Throughout the study, from the time the participants arrived until they left the premises, periodic observations were made of the affects and behaviors of both groups and documented using notebook transcriptions.

Four 30-minute focus group meetings were held during the lunch period time at each school building, in which both treatment and control groups participated. By responding to seven leading questions, the participants shared how the study affected their interest in and attitude about STEM education, the use of smartphones as a learning tool, and their feelings about maker education activities.

The participant sample was drawn from the population of students in the four schools whose classroom teacher had already established or was in the process of establishing a Green Tower Aeroponics system in their classroom and also held periodic projects at the Boys and Girls Club research site. Volunteer participants were recruited using informational flyers provided to both the student and the parents or guardians of the student (see Appendix E). No attempt was made to limit the study's attendance by race, gender, or grade level, although only the AA participants were considered in the analysis of the data. The sample proved to be a total of 63 participants, with 29 AA participants completing the study. A more detailed description of the research design can be found in chapter three of this paper.

Definition of Terms

Attitude is a personal construct that defines how positive a participant values STEM as a component of study, career, and preference. It is comprised of three components: Interest, Difficulty, and Importance. There is no negative aspect of attitude for this paper.

Arduino is an open-source microcontroller on a simple, inexpensive, versatile circuit board for constructing user-designed devices. It is coupled with a user-friendly integrated development environment (IDE) software package. (Galadima, 2014; Smith, 2011).

Constructionism, according to Flores; "is the term Papert created as a play on the theory of constructivism as well as the words "to construct," or "making." Papert's Constructionism assumes constructing one's knowledge, just like constructivism, using code as a language to invent or to inquire" (2016, p. 2).

Difficulty, is defined for purposes of this study as the educational personal construct that demonstrates how African American students find STEM education hard to deal with or understand.

Foldscope is a low-cost, paper microscope that is effective enough to be used in serious microbiology research (Cybulski, Clements, & Prakash, 2014).

Green Tower refers to the Tower Garden Aeroponics System invented by a Disney horticulturist and very popular in k-12 schools (Blank, 2018).

Importance, for this study, is a personal construct that defines how much a participant values mobile devices and maker education in the studying of STEM.

Interest is defined as a personal construct that measures how curious the participant is in pursuing STEM education.

Maker Education was defined by the Maker Movement's father, Dale Dougherty, as a hands-on approach to STEM learning, which incorporates the solving of specific problems with pro-active construction of "do-it-yourself" devices (Dougherty, 2012).

Mobile Device is a small, handheld, computing device, generally with internet or Bluetooth capabilities, such as a smartphone, tablet, or i-pad computer.

STEM Education is generally a multidisciplinary teaching method that combines Science, Technology, Engineering, and Math tools to solve real-world problems.

Assumptions, Limitations, and Delimitation

Likert scale questionnaires have as a strength the ability to conduct proven statistical testing and are generally user-friendly. One weakness of such a tool is that respondents may get bored or find the questions uninteresting and begin to offer unreal or false responses. The 26-item questionnaire used in this study may have been too long for a middle school respondent. On the other hand, focus groups as a research tool offer the advantages of being time-saving and effectively obtaining open, freely offered sentiment and emotional responses. They have the disadvantages of being comparatively expensive (in this a significant financial burden was amassed by providing food and incentives for the four participating groups) prone to moderator bias. The researcher was also the focus group moderator and may have introduced some degree of bias, although every attempt was made to keep objectivity in interpreting the focus group data.

Apparent underlying assumptions were that the chosen schools had characteristic student populations for disadvantaged urban schools and that a significant portion of the participants would remain throughout the study. Another assumption was that the pre-post- questionnaire respondents and focus group participants provided truthful, honest, forthright responses. Lastly, it is assumed that the researcher's observations were made without bias, uniformly and consistently throughout the length of the study.

The study design afforded several limitations that could not have been controlled within the constraints of the study. The questionnaire was designed to require a specific range of answers which limited the participants' responses. The target population was restricted to a small middle school district, serving disadvantaged students in a moderate-sized, midwestern city in the United States.

Some of the internal threats to the quantitative portion have to do with the school district's resources and statistics: educator training, experience, and willingness to participate; the turnover rate in-school educators and their use of STEM labs teaching tools. The quasi-experimental design limited the randomness of the results and thereby the generalizability. The small size of the sample of participants in both the treatment and control groups also limits the generalizability. Finally, the limited time frame, subject selection, and the small number of intervention activities meant that the conclusions may apply only to similar populations and similar circumstances.

The setting was in conjunction with an after-school program interested in increasing the level of STEM activities offered. This was a deciding factor in the choice of interventions made, along with the given session timeframe, and the limited mobile device interaction.

The delimitations were the participants were of a certain demographic; age, gender, family status, and economic status. The participating schools were also limited in their representation of African American students. Therefore, they do not represent all AA students who may seek to enter into STEM education. Other delimitations were the choice of interventions chosen, the budgeted amount per participant, the study's length, and the time frame of each session.

Summary

A gap exists in the literature regarding mobile devices in conjunction with maker activities as a STEM educational format. This may be primarily due to the availability of resources, training, interest, and to the educators in disadvantaged, majority African American school districts. This study sought to use mobile devices and inexpensive maker activities to breach this gap. The following chapters will present a review of the available literature (Chapter II), a detailed discussion of the research design used and how the study was conducted (Chapter III), the research results (Chapter IV), and an interpretation of the investigator's findings (Chapter V).

Chapter II: Literature Review

Introduction

A significant amount of research has been put forth in the immediate past on African American students in secondary school and their effectiveness and attitude towards STEM-related classes (President's Council of Advisors on Science and Technology, 2010). This review attempts to investigate the factors that have been shown to affect the knowledge base and interest of African American students in secondary level STEM classes, particularly those that influence knowledge advancement and interest improvement. Many key descriptors were initially used to select preliminary sources, which yielded a substantial body of literature. Eventually, to narrow the search, the following key descriptors were chosen: African American in STEM, efficacy in STEM, interest in STEM, Maker Education, STEM in after-school settings; STEM laboratory, and Mobile-device use in public education. A literature search on the theory of connectionism, and related theories of education, was included. A search of Google Scholar produced 17,500 results; 7,840 written since 2014. A search using these key descriptors of UMSL Summons produced 7,419 peer-reviewed and scholarly results, 2,158 written since 2014. The literature reviewed is grouped into one or more of the following topics: African American in STEM, mobile devices in public school STEM classrooms, and African American high school students' use of Maker Education in STEM. A second search of Google Scholar using the key descriptors, Makerspace, education, digital fabrication, and diversity narrowed the results to 1,720; 1080 since 2014. Finally, a search of Google Scholar of the bracketed terms: "Makerspace," "digital fabrication," "secondary education," and "diversity" yielded 56 results; 39 since 2014.

Seymour Papert's constructionism publications were foundational to the theoretical framework for this research, especially as formulated in the Maker movement of Dale Dougherty and his followers. A Google Scholar search of the terms: Papert, Dougherty, Constructionism, secondary education, diversity, African American produced 5910 results; 3060 published since 2014.

Search Strategy

The literature search revealed four significant and one minor area of interest in answering the research questions. The first area to be investigated was African American secondary school students' perception of STEM, STEM courses, and STEM careers. Then attention was given to the achievement levels of African American students in STEM courses in secondary education. The third area searched was the utilization of mobile devices (such as smartphones, tablets, laptops, and other tech devices) in STEM classrooms and the propositions of existing methodologies. The last significant area of literature searched was that supporting the use of the theory of Constructionism and STEM maker education in school districts. Finally, a less aggressive search was conducted concerning STEM in after-school programs, clubs, and activities, especially relating to African American secondary students.

An estimate of the number of sources reviewed for relevancy was close to three hundred, of which about one hundred ten were selected for inclusion as references for the groundwork of this paper. Greater than 75 % of the selected sources were published within the last ten years.

A Brief History of STEM education, Mobile devices, and Maker education

The confluence of STEM, mobile devices, and maker education in our k-12 schools is a relatively recent incident, basically occurring around 2005 – 2010 (Laouris, & Eteokleous, 2005). A Google Scholar search for journals was conducted on several terms related to this study, including but not limited to "STEM Education," "African American" + "STEM Education," "African American" +"Maker Education," "Mobile devices" + "STEM Education," "Maker Education," "African American " + "Maker Education," "Middle school" + "Mobile devices," etc. An examination of the results shows that all of these areas increased rapidly between 2005 and 2010 and then slowed in the number of articles produced over the last two decades. It is understood that these search results were not exclusive; for instance, "STEM" may have been taken to mean the "stem of a plant" or "stem cells" in a biological system. It is also conceded that over the first decade or so of this century, the literature used multiple terms with the same or similar meaning to the searched keywords. Some publications were therefore overlooked. However, it was assumed that the results were indicative of the rate of change in STEM publications. Table 1 shows the results of keyword combination searches using Google Scholar, a specialized search engine for academic publications. The parameters for this and other searches are a custom time range of 2000 - 2019, sorted by relevance, excluding patents and citations. This search information is also shown graphically in (Figure 1). As expected, the number of peer-reviewed articles concerning STEM education, in conjunction with mobile devices and maker education, increased at an ever-increasing rate for the first two decades of this century. But the rate of articles concerning

African Americans and STEM education, mobile devices, and maker education took a longer period to increase and increased at a decreased rate.

Table 1

Google Scholar Search for Specific Key Words and Combinations

Key Word(s) Searched.	Year					Total
	2000	2005	2010	2015	2019	19 years
Mobile + Definition	11	145	673	1,680	2,160	4,669
Mobile + Education	43	156	274	543	635	1,651
Mobile Devices + STEM	122	501	1,150	3,740	5,180	10,693
African American + STEM Education	20	48	238	926	1,580	2,812
Elementary School + STEM Education	13	91	537	2,020	4,250	6,911
Middle School + STEM Education	4	76	424	1,580	2,980	5,064
High School + STEM Education	19	128	821	2,810	5,470	9,248
Higher Education + STEM Education	18	123	702	2,580	5,340	8,763
Maker Education + STEM Education	5	10	10	168	558	751
African American + Maker Education	0	0	1	7	29	37
Total	255	1,278	4,830	16,054	28,182	50,599

Note. Retrieved 02/04/2021

mobile learning was viewed (Wilson, & Fenlon, 2007). Almost immediately, other providers of android type smartphones rapidly followed suit, and within a few years, these devices were ubiquitous worldwide. What made the smartphone format so vastly different from its predecessor, the cellphone, is that it offered wide-ranging functionality that existed at the time, but only by purchasing multiple devices; Global Positioning Systems; Gaming, Music, and Video apps, Personal Digital Assistants; Email capabilities, social media management, Gyroscopic, and Navigational sensors, to name a few (Bressler, Bodzin, & Tutwiler, 2019; Kaimara, Poulimenou, Oikonomou, Deliyannis, & Plerou, 2019; Soegoto, 2019).

A significant portion of the literature is devoted to determining whether smartphones are the right mobile device to be included in today's k-12 teachers' tool kit. Hochberg, Kuhn, & Müller provide the majority opinion that smartphones make an excellent addition to today's classroom, by studying their effectiveness in the physics classroom (2018).

The history of maker education was the most fluid of the three educational tools presented in this section. For this study, maker education is defined as a STEM education tool that incorporates the elements of hands-on inquiry. The learner constructs a creative product that is needed to solve specific problems (Dougherty, 2012). As for the act of "making" to solve problems, it is as old as civilization itself, beginning most likely when the first humanoid used a stripped-down twig to catch termites. Making as a tool to problem solve diminished in the latter part of the nineteenth century, when industrialization and technology made it impractical to "do it yourself (DIY)" for items that could be easily and cheaply mass-produced. Nevertheless, a century later, that same technology has produced tools, such as 3D printers and CNC machines, that have made "DIY" once again practical. Although Dougherty is considered the Father of making, the word "maker" can be traced back to Chris Anderson, who defined it as "the web generation creating physical things rather than just pixels on screens" (Anderson, 2013). Anderson and Dougherty were influencing the direction that Making would take, away from Piaget and Vygotsky's social-cognitive construction of knowledge (Troxler, 2013). towards a more individualized construction of knowledge through actual hands-on, trial and error, methods. The act of Doing It Yourself, in real-time and real space, is where knowledge and understanding meet for the Maker. Even if the Maker is more concerned with the product than the knowledge that comes from the making, she will obtain the knowledge all the same and at a level higher than from rote learning, or being an apprentice to a "master."

This assumption is that the participants in making activities will gain valuable knowledge and understanding of STEM education by utilizing the principles of making while investigating scientific principles. To understand why STEM education and its variants are intimate components of modern, western educational systems and why STEM may be a major driving force in the U.S. labor pool, we need to go back to the last world war. When the first Atomic bomb conclusively ended WWII with mind-wrenching new science, it started a worldwide, lasting fervor over understanding the principles of science and technology (Jolly, 2009). In this country, the education system has ridden an on-again, off-again roller coaster with math and the sciences, trying a sundry of teaching tools, methodologies, and theoretical frameworks. Some were discarded early, and some were retained and expanded, seeking, as it were, the "philosopher's stone" of science and math pedagogy. Therefore, there existed few defined or consorted efforts to increase STEM in k-12 schools. Indeed, the literature shows that it was more like multiple attempts, often disjointed, all with the same common goal of increasing STEM outcomes, but few obtaining it (Catterall, 2017). Emphasis has slowly but surely shifted from the rote learning technique of the 3-R's to the higher order of thinking of active learning now used in STEM subjects: Science, Technology, Engineering, and Math (Kressler, & Kressler, 2020; McDonald, 2016). By the 1980's public interest in STEM jobs accelerated due to the attraction of higher salaries and a concerted effort between the government and industry to advocate for more STEM graduates. One teacher quoted, "My goodness Johnny does terrible in math; but now he is doing math through the use and help of technology, and he is forging ahead"("Technology and the At-Risk Student," 1988). If African American students cannot compete in the STEM job marketplace, then perpetual poverty and a deep sense of low self-esteem are likely outcomes.

Early into his presidency, partly in response to the ever-increasing perceived need for qualified STEM workers and partly in response to this dismal outlook on the black community, Barack Obama established the President's Council of Advisors on Science and Technology (2010). This Council called for training 100,000 STEM workers, and the creation of 1,000 STEM schools by 2020. The resultant Every Student Succeeds Act (ESSA) Law of 2010 replaced the noneffective No Child Left Behind Law of the previous administration: "Not since Brown v. Board of Education (1954) has a single piece of legislation had a greater effect on the landscape of education than No Child Left Behind (NCLB) (2002)" (Edwards, 2015). Although Edwards was overly optimistic, and although the stated goal has been woefully underachieved, the ESSA effort generated a renewed effort to increase STEM education effectively in low-income urban school districts all over the country. Unfortunately, this effort has failed to increase STEM has not significantly closed the gap between African Americans and their white counterparts (Glennie, Mason, & Dalton, 2016; Barton, Tan, & Greenberg, 2016). As a consequence, African Americans still make up less than 6% of U.S. STEM field professionals (Bozick, R., Srinivasan, S., & Gottfried, 2017; Landivar, 2013).

It is believed that STEM education in the later 20th and the early 21st centuries will be the foundation of a new level of jobs and careers for decades to come, many of which will make current service-based, labor-based, and manufacturing-style jobs obsolete. (Barley, Bechky, & Milliken, 2017). The early and mid-20th century jobs, such as institutional manufacturing jobs, automotive jobs, were structured on paying employees a "middle-class" wage in return for long-term service and valuable experience. However, near the end of the twentieth century, those jobs rapidly disappeared from the U.S. workforce and were systematically shipped offshore to other countries. It was then more evident that a new education paradigm was required to face the needs of the twenty-first century.

The literature revealed that the benefits of the utilization of "novel" teaching methodologies, such as mobile devices and makerspaces in the k-12 classroom, greatly outweigh the detriments. The benefits are measurable and include increased interests in STEM activities and STEM knowledge. It suggests that the STEM gap that exists between white males and nearly all other minorities in this country, women, Hispanics, LBGTQ, and, especially, African Americans, can be closed, or at least lessened, by such teaching methodologies. Various factors potentially contribute to this gap, from financial, to societal, to teacher profiles. However, the generally accepted view is that the gap does exist, and therefore, it should be addressed (Liu, Scordino, Navarrete, Ko, & Lim, 2014;

Pollara, & Broussard, 2011). The literature does contain a small percentage of the research that discounts that a gap exists when certain appropriate variables are acknowledged as significant (Riegle-Crumb & King, 2010). There is also literature that shows that mobile devices in the classroom may offer no or little academic advantage, and maybe detrimental since some students might use them for personal motives and create a distraction source for others (Synnott, 2017).

African American Perception of STEM Education

In general, African American students believe that the U.S. school system has failed them, and therefore have an impoverished perspective of ever succeeding in life (Anderson, 2018) This is driven by poor quality education, underrepresentation in gifted and STEM classes, and a stricter code of punishment than other groups (Anderson, 2018). The literature consensus is that African Americans, especially students, have an unfavorable opinion of STEM courses, in particular of the fields of science and math secondary education courses. (Russell, & Weaver, 2008; Stephen, Bracey, & Locke, 2014; Zerega, 2015). The overwhelming reasons given are those of poverty, making technology unattainable in African American households, the lack of STEM-savvy family members who may offer academic assistance, lack of STEM education in prior classes, and a belief that STEM is just too "hard" or "uncool." Both Edwards (2015) and Gonzalez & Kuenzi (2012) studied factors that contribute to African American students' decisions to pursue a STEM-focused education. Both agreed that parental support, early exposure to STEM, and fostering a STEM career are important. Gonzalez and Kuenzi also stated that poor schools, unqualified teachers, lack of funding, and microaggressions towards minorities contributed to a decision to steer clear of STEM classes (2012).

The impact of teachers' and administrators' perceptions on how their African American students would perform in gifted classes (which include math and the physical sciences) also greatly influences the students' self-evaluation (Sermons, 2016). Other researchers have determined that the way to increase student interest is to develop an educational tool that will spark the interest of the student (Beckett, Hemmings, Maltbie, Wright, Sherman, & Sersion, 2016; Beckett, Hemmings, Maltbie, Wright, Sherman, Sersion, & Jorgenson, 2015; Sais, Nadelson, Juth & Seifert, 2017). Still, other researchers have concluded that existing inexpensive technologies might be adaptable as effective tools to increase STEM experiential labs in high poverty schools (Honma, 2017; Kim, Gerber, Chiu, Lee, Cira, Xia, & Riedel-Kruse, 2016; Susilo, Liu, Rayo, Peck, Montenegro, Gonyea, & Valdastri, 2016) but first further research must be conducted to measure outcomes to show their viability. Responses to these challenges in this area have been developed in the form of STEM classes in robotics, computer coding, and virtual learning programs (Beckett, Hemmings, Maltbie, Wright, Sherman, & Sersion, 2016; Palmer, Maramba, & Dancy, 2011; Somyürek, 2015; Stephen, Bracey, & Locke, 2014).

Other research has revealed that mentoring by properly trained mentors in the STEM field of interest has improved the perception and interest of African American students before attending higher education, and has improved African American students' retention rates in STEM majors (Kendricks, Nedunuri, & Arment, 2013). Minority student perceptions of the impact of mentoring to enhance academic performance in STEM disciplines has been also studied (Mulqueeny, Kostyuk, Baker, & Ocumpaugh, 2015). Furthermore, a comprehensive longitudinal study by Beckett et al. (2015) incorporated a STEM-based lab kit for low economic status students in Cincinnati, called

CincySTEM. The findings suggest that project-based learning experiments significantly increase the student's attitude towards STEM classes. Beckett, G. H., Hemmings, A., Maltbie, C., Wright, K., Sherman, M., & Sersion, B. (2016)

Since STEM education almost invariably incorporates mobile devices, such as smartphones, electronic tablets, and pads, researchers have also studied were such devices perceived as helpful or harmful. Many believed that there would be massive cheating due to using the internet during assessments. Others believed that the smartphone's mere presence in the class would cause disruptions due to incessant ringing or notification beeps, or multitasking, or social media usage during class time (Campbell, 2006; Synnott, 2017). Campbell's findings show that this "misperception" about mobile phones are only partially true, with most negativity due to a perceived improper social setting, similar to a person answering a mobile phone in a theater upsetting someone a few rows behind him. An investigation of student perceptions of mobile phone use for learning was conducted at Boise State University by a group of faculty members of several disciplines. The group first distinguished mobile learning (mLearning) from electronic learning (eLearning) as mLearning is spontaneous, connected, and informal, while eLearning is interactive, hyperlinked, and formal. mLearning is best defined as computer-assisted creative problem-solving, as opposed to eLearning which acts as a knowledge base, consisting of online references, pdf files, training videos, etc. In the Boise State study, students were allowed to use mobile devices to access otherwise inaccessible information, create solutions to problems, and tabulate and analyze data sets. Then the participants were surveyed to determine their interests and perspectives of mLearning activities. A course blog was also included to collect student perspectives.

Pre-course surveys hinted that even though the participants were part of Generation M (mobile, multi-taskers, born between 1980-99 (Tabor, 2016, p 83)), almost 30% did not have high utility expectations of mLearning in their field of endeavor. Although post-course that value dropped significantly, almost 20% persisted in having low perceptions of mLearning. Tabor (2016) did not pursue whether or not variables such as age, gender, preexposure to technology, race, or class were factors in student perception. However, since Tabor's population included a 26% persons of color student population, also a 25% Mormon population, it should be assumed that both are factors in these statistics.

Inquiry-based hands-on use of technology seems to have the effect of changing the perspective of the student positively (Barraza Castillo, Cruz, & Vergara Villegas, 2015). The improvement of STEM interest and knowledge has been investigated significantly during the last 25 years, with mixed results. The level of student interest is important because, as anecdotal evidence has shown, you can lead a student to knowledge, but you cannot make him think -- unless he wants to (Hoffer, 2012). Hoffer also believed that there is a pervasive perception among students of all races that STEM careers are difficult to attain. It can be shown that this perception, which is held even more so by African American students, is dispelled by proper hands-on STEM exposure. Hoffer recommended three classroom enhancements that will improve students' perception of STEM education; (1) use more inquiry-based hands-on learning, (2) incorporate interdisciplinary approaches to STEM learning, and (3) use teachers who have been trained in teaching STEM. Many teachers have the same perception as the student that STEM is difficult. The following quote reflects much of the misconceptions about the mental acumen required for the pursuit of STEM careers, held by our public-school teachers, and echoed by their students, especially African American students:

> The teachers' attitudes provide the K-12 engineering educationcommunity with an interesting paradox. Teachers are overwhelmingly positive about engineering in the abstract, extolling the virtues of engineering education and careers. However, when it comes down to their students, they believe that many—and especially females and minorities—cannot succeed in the engineering world (Douglas, Iversen, & Kalyandurg, 2004).

This academically prejudiced viewpoint has persisted, even unto the first quarter of the 21st century, and no reduction of it amongst current pre-service teachers has been seen (Kennedy, & Odell, 2014; Lewis, Pitts, & Collins, 2002).

African American Middle School Students and Maker Education in STEM

A relatively new movement in education is the Maker Movement; "..there is a growing national recognition of the maker movement's potential to transform how and what people learn in STEM.."(Peppler, & Bender, 2015). Maker Educator, Dale Dougherty, states that "we all are makers: as cooks preparing food for our families, as gardeners, as knitters" (2012). Dougherty reminds us that humans have always had an inquiring mindset. Therefore, maker education hearkens back to a time when people made what they needed, and knowledge grew because people interacted with their surroundings. Making requires you to fashion the needed object out of items not intended to be used together. Therefore, building a robot from scratch is not the same as building a robot from a kit. It goes beyond the motor skills required for the assembly stage because it requires problem-solving at various steps and increases enjoyment and satisfaction

(Vandevelde, Wyffels, Ciocci, Vanderborght, & Saldien, 2016). The Makerspace movement in education may be a way for African American students to bridge the gap between themselves and their white counterparts, by making their cognitive abilities the limiting factor (Barton, Tan, & Greenberg, 2016).

Other methods of increasing minorities in STEM has included utilizing augmented reality (Davis, Grant, Bowles, & Jeffries, 2015; Barraza Castillo, Cruz Sanchez, & Vergara Villegas, 2015; de Ravé, Jiménez-Hornero, Ariza-Villaverde, & Taguas-Ruiz, 2016; Mulqueeny, Kostyuk, Baker, & Ocumpaugh, 2015; Davis, Grant, Bowles, & Jefferies, 2015). Researchers have reported that augmented reality increased African American students' self-efficacy in engineering classes. (Barraza Castillo, Cruz, & Vergara Villegas, 2015).

Utilization of Mobile Devices in the Public-School STEM Classroom

In a sense, there has always been "tech" in the classrooms of our public schools. As far back as the pre-Socratic age, when alchemist searched for the philosopher's stone using mortar and pestle up to modern times where electronic scales, digital projectors, and now, even fusion reactors are found in school labs, educators have always tried to provide the most advanced tools available to teach mathematics and the sciences (Tweney, 2021). Since the advent of relatively cheap and ubiquitous mobile devices, high tech in public schools has become a dominant learning instrument. The smartphone is the most familiar type of mobile device, including tablets, i-pads, smartwatches, personal exercise devices, digital cameras, digital game boys, personal navigation devices (such as GPS), and even archaic graphic calculators and pagers. A generalized definition of a mobile device for this paper is any computing device capable of being held in hand or carried in a pocket, possesses its operating system, and is wireless capable. They can be equipped with cameras and video recorders that can be used to measure light intensity and composition, vibration detectors, proximity meters, magnetism gages, electrical meters, sound level meters, voltage, and electrical resistance sensors, GPS, compass, and gyroscopic orientation apps, as well as several other items that can be useful to STEM investigations. (Khan, Xiang, Aalsalem, & Arshad, 2012; Lane, Miluzzo, Choudhury, & Campbell, 2010). It is generally accepted that most mobile devices use Google Android or Apple iOS operating systems. Therefore, many programs or apps are capable of running in one or both of these environments.

The question arises whether the use of mobile devices such as those mentioned above, along with maker activities, can increase interest and the knowledge base of students in STEM education. The laboratory, in particular, the STEM laboratory, offers a unique learning experience that cannot be gained by classroom pedagogy alone (Ney, Maisch, & Marzin, 2009). Ally (2005) and Strayhorn (2015) agree that today's smartphone, equipped with wireless technology and massive computing capabilities, cannot be ignored as a teaching tool for 21st-century students. Ally suggests that the use of mobile devices is ideal for today's classrooms; "Mobile learning facilitates personalized learning because learning (and collaboration) from any place and at any time allows the learning to be contextualized" (p. 6, 2005).

Hwang & Tsai provided a detailed review of research revolving around the use of mobile device-assisted learning from the first decade in the 21st Century (2011). Their results show that research regarding mobile devices in classroom learning is increasing across the field in both k-5 and higher education. However, secondary education (grades

6 through 12) lagged behind higher education and elementary (Table 1, p 3, 2011). This may be due to the tensions that exist within this age group to use their smartphone for socialization instead of solely for academic concerns. Early teens often feel that peer associations are the most critical component of their lives. Therefore, they would find a lack of availability of their smartphones due to academic use, an undesirable imposition. Also, the study showed that while westernized countries' education was more inclined to research mobile devices in learning during the first half of the studied decade, the small country of Taiwan contributed to 42 % of the journal articles published in the second half of the decade. The reason given in the article was a push for more "national programs for e-learning" from the government of this nation (p. 5). Overall, the trends showed that mobile devices' use is decisively and rapidly increasing in STEM education. Hwang & Tsai's publication was cited more than six hundred times, and many of those citations were cited over one thousand times themselves, indicating that interest in this field is greatly accelerating.

The second decade of the 21st century continued to demonstrate an increased interest in mobile devices in k-12 learning in many disciplines, STEM being one. Some researchers have furthered this type of work by constructing STEM activities based on mobile devices and studying their effectiveness in a public-school learning environment. One such study is called the CincySTEM ITEST project, an NFS grant-funded partnership between the local school district, local colleges, universities, and business and other stakeholders. (Beckett, et al., 2015) CincySTEM was implemented in an urban high school and concluded that digital devices could help low-income minority high school students achieve a greater appreciation of STEM. One interesting aspect of CincySTEM was that it developed a low-cost, user-friendly mobile laboratory called the F-Set backpack designed for ease of digital access and the capacity for interfacing with mobile devices, tablets, and cell phones.

Minecraft and Lego are two high technology, commercialized, construction kits that have become popular in STEM education (Somyürek, 2015; Sias, Nadelson, Juth, & Seifert, 2017). They have as a core concept that learning at all levels can be greatly facilitated by the use of interactive gaming on mobile devices and with the use of hands-on projects, such as building robots. They have been incorporated into various disciplines, such as computer programing to English language learning, to history and, of course, STEM education (Cruz, Carvalho, & Araújo, 2017; Deaton, 2017); (Fowler, Pirker, Pollock, de Paula, Echeveste, & Gómez, 2016).

These kits can easily incorporate mobile devices as both control and engineering tools. As a testament to the popularity of these types of tools, one researcher said, "Learning through construction kits offered opportunities to deepen the students' understanding of various concepts with hands-on exploration and design, resulting in fun and enjoyment" (Somyürek, 2015). A study performed on mobile devices to build specialty designed robots at the elementary level exceeded the maker shortcomings of commercial kits like LEGO in that empirical creativity was required (Sais et al., 2017). In general, the literature suggests that the use of mobile device-based STEM education is an ever-increasing, unyielding field of study. It is the intention of this study to show that this concept may be successfully applied to African Americans in urban underprivileged middle schools.

Of the literature reviews and meta-analyses that have been published on the use of mobile devices in k-12 classes, some common findings were that the learning pedagogies were designed only to use the mobile device as a knowledgebase, thereby bypassing the full power of the device as a tool for constructionist inquiry and analysis (Aguayo, Cochrane, & Narayan, 2017; Crompton, Burke, & Gregory, 2017). Aguado, Cochrane, and Narayan also investigated the key themes of publications with topics of mobile devices as a learning tool. Five major groupings of 330 themes, grouped as a 3-tiered association, were identified, some of which would impact the purpose of this study. Their major groupings are (1) philosophical and theoretical frameworks; (2) mobile learning research; (3) pedagogies and learning methodologies; (4) mobile learning affordances; and (5) key issues in mobile learning (p 33, 2017). Under Group 1, the situated learning frameworks were of interest to this study as to where the socio-cultural background of mobile device users and systems thinking principles. Group 2 investigated mobile device design-based research themes, understanding and evaluating the research's purposes and categories of research directions, which also impacted this study. In Group 3, the access and equity theme, barriers and enablers themes, and the "Bring Your Own Devic"e theme were of interest to their study. Finally, in Groups 4 and 5 the themes of mobile learning and effective/culturally-responsive theme, face to face and offline components of mobile learning, and teacher/practitioner support themes were of interest to the investigator of this study, especially those further defined in the references of a referenced article (Bannan, Cook, & Pachler, 2016; De Michelis, De Paoli, & Bandini, 2017).

Mention should be made here that some researchers are leery of mobile device benefits, such as smartphones, in the classroom. Roschelle (2003) examined the effectiveness of mobile devices as a tutor, tutee (as in coding), and tool and found that certain challenges currently impedes the effectiveness of these devices: lack of a universal pedagogical platform divorced from the social media applications; a better definition of what wireless networking is in the context of teaching; and the need for more effective pedagogical applications that better fit the needs of the educator and student alike. Mentzer (2011) found that, without proper instruction, some students could spend hours wandering amongst the endless sea of information available without really improving their understanding of problem-solving designs. Likewise, other research found conflicting conclusions about the effectiveness of mobile device use in the classroom (Bartholomew, et al., 2017) and also in student attitude towards using mobile devices in learning (Lin, et al., 2019; Tossell, et al., 2015). I contend that with proper planning and guided utility, the mobile device can be a valued and effective tool in today's STEM academic environment.

Theoretical Framework Literature Review

The pursuit of a viable mechanism to retain students of color in STEM fields has been highly researched (Palmer, et al., 2011). One contemporary movement that has found a social following of informal learners is Maker Education (Dougherty. 2012), popularized on the world wide web by "Do it Yourself-ers" in electronics, husbandry, construction, and natural living. Maker education is based on the notion that humans are built for making or constructing what is required from their environment, not just accumulating knowledge about their environment. This philosophy is the root of Papert's educational theory of Constructionism (Papert, 1999). Papert believed that children, and indeed all people, best understand their environment by creating, testing, and revising their knowledge base. He proposed that the computer be made as available to every student, like pencils and paper (this was when computers cost tens of thousands of dollars.) Papert devised his theory of Constructionism based on the belief that guided communal inquiry would "allow young learners to construct their knowledge of various subjects through personal inquiry and creativity." (Flores, p.1, 2016).

Making education holds the potential for improving both the achievement levels and efficacy of African Americans in STEM. It essentially extends the beliefs of Papert past the field of computer hardware and software into everything from paper to quarks. The use of Papert's Constructionism and Maker Education theory as foundations for improving African American students' involvement and understanding of STEM is believed to be an appropriate design for investigating the effects of mobile device-based laboratory instruments. The "making" of inquiry analysis and evaluation tools utilizing inexpensive, available materials and mobile devices in a structured communal learning situation is rapidly growing. However, there is not yet a profound amount of research on the matter (Flores, C. 2016). The use of the same framework and strategies for African Americans may produce desirable results.

The belief that the literature does not universally embrace the learning style advocated by the Constructionists and Markers is presented here. Many believe it to be ineffective, and some even say it may result in negative outcomes (Kirschner, et al., 2006; Moreno & Mayer, 2004). Kirschner et al. made a convincing case that unless a student has a sufficient prior knowledge base or experience when confronted with a problem, she is likely to do poorly compared to someone guided by the teacher. (2006). Mehalik, Doppelt, & Schuun (2008), furthered this perspective by showing how a system design approach, Learn by Design, emphasized an internship phase for students before a problem-solving inquiry task showed superiority over purely problem-based learning. It also is twice as effective in content knowledge increase as traditional scripted inquiry and appears to help close the equity gap between low-achieving African American middle school students and white students; "the science knowledge test gains for African American students in the design group are eight times higher than the inquiry group" (see p 78).

A mention should be made here of Sherry Turkle (2007), who makes an extreme case that solid, tangible making has the added advantage of evoking very powerful imageries and emotions which help anchor concepts learned from the making, as opposed to online, virtual, or intangible making.

Finding the Research Gap in The Literature

Although there appears to be a significant amount of study of the lack of African American students in STEM, and the use of mobile devices in STEM classes, and the potential for laboratory STEM using Maker Education (Chin & Callaghan, 2013; Glennie et al., 2016; Jackson et al., 2017; Strayhorn, 2015; Vandevelde et al., 2016), little has been investigated combining all of these methods. Therefore, a gap in the literature exists in the current research of the effects of blending mobile devices with maker activities on secondary education African American students' knowledge base and attitude in STEM classes. The ensuing results will attempt to investigate this gap. To do so, an appropriate research design and methodology were formulated. The following chapter will present the chosen methodology.

Chapter III: Methodology

Introduction

Since the purchase of education technology is usually prohibitive for school districts serving disadvantaged students, many may be left behind in this new educational pedagogy. One proponent of making technology available to everyone is Dale Dougherty, the acknowledged father of the Maker education, the originator of MAKE Magazine, and creator of Maker Faire. Dougherty says that although our educational needs are changing rapidly, our schools are still using methods that are older than the nation itself (Delkic, 2018). Maker education takes various and diverse knowledge bases and offers them to everyday "Do It Yourself-ers", in open-source, free to all, activities. These are presented in such a way to be easily adapted to the typical k-12 classroom. The research design outlined here was to demonstrate that the use of the ubiquitous mobile devices found throughout our culture, in combination with maker education activities, may help these school districts bridge the gap between them and more affluent districts.

Chapter III presents the research methodology used in an exploratory, sequential, mixed-methods study of whether mobile device-assisted maker activities can increase the STEM knowledge of and the attitude of African American middle school (AAMS) students towards STEM education. thereby attempting to close the gap between AAMS and other racial groups.

This chapter will demonstrate in detail how the use of constructionism learning theory and maker education apply to the research design and methodology, and the research questions. The research plan, the study participants, research setting, site layout, and adult leaders, variables of the study, study instruments, data collection, data analysis, and issues of ethics and human subjects concerns are presented. A final summary of this chapter will also act as an introduction to the next chapter on the results.

Research Plan

This research plan presents the "hows" that support the "whys" of the study. It will lay out a plan to seek data to answers the research questions explained in the literature review and to show why this study fills a significant void. It contains the approach or design that the study pursued to reach its goal, the particulars of the sample, such as how it was chosen, and what does it represents. Also, it outlines the data collection and analysis strategies that were used in this study.

Research Questions and Hypotheses

Two questions shaped the research plan:

RQ1: To what extent do mobile device-assisted maker activities affect the STEM knowledge base of African American students at the secondary education level?

RQ2: To what extent do mobile device-assisted maker activities affect the STEM attitude of African American students at the secondary education level?

The null hypotheses that were tested and that correspond to these research questions are as follows:

Null Hypothesis 1, H1o. The use of mobile device-assisted maker activities has no effect on the STEM knowledge base of African Americans at the secondary education level.

Null Hypothesis 2, H2o. The use of mobile device-assisted maker activities has no effect on the STEM attitude of African Americans at the secondary education level.

Research Design

A mixed-method approach was used, which contained elements of comparative, quasi-experimental research, survey research, and direct observation research. It is comparative because the sample has been split into a treatment group and a control group. It is quasi-experimental because the participants were chosen and assigned to the two groups by voluntary convenience sampling. It includes a survey, a pre- post-test questionnaire, a collection of focus group responses, and direct observation of the participants' behaviors.

The research design is best classified as a sequential explanatory mixed-method design. The decision to use a mixed-methods design was driven by several considerations. First, the format of the research questions themselves. Since the overall research question has both a quantitative and a qualitative component, it requires both approaches. The quantitative question RQ1 sought to determine what effect the proposed interventions had on the knowledge base of the participants. This was investigated by measuring the increase in the participant's knowledge base of the subject matters presented in a multiple-choice questionnaire format, (see Appendix E, Figure E9, questions 18 through 26), before and after the interventions.

The qualitative question RQ2 was addressed by the opened-ended questions that evolved through iterations of coding of the observation notes and the responses given by the participants during four focus group sessions (see Appendix A, Table 6). Since quantitative designs emphasize objective data, and qualitative designs deal with subjective data, a mixed-method design was used.

Johnson, Onwuegbuzie, & Turner, in their pursuit, to define mixed method research listed 19 definitions for mixed-method from the literature, and from them formulated the following basic definition;

> Mixed method research is, generally speaking, an approach to knowledge (theory and practice) that attempts to consider multiple viewpoints, perspectives, positions, and standpoints (always including the standpoints of qualitative and quantitative research) (2009).

Creswell and Clark (2014), say that qualitative designs can rely upon multiple viewpoints and follow a pragmatism worldview.

Generally, mixed methods research has the advantage of being able to collect a broader data coverage. Mixed methods are also useful in those research methodologies where neither a qualitative or quantitative approach will provide complete coverage of the stated problem. Therefore, a mixed-method design has an advantage over both a quantitative and a qualitative approach, in that it provides more extensive coverage of the studied subject matter.

Implementation of the mixed-method approach first randomly separated 10% from the sample population to form a control group. This group completed each of the two maker activities without the use of the mobile device/maker project format, using a typical middle school lesson plan instead (see Appendix C). The remaining 90% sample population comprised the treatment group, which completed the interventions utilizing mobile device-assisted maker activities. A 26-item paper and pencil questionnaire, consisting of three 5-point Likert Scales, and a 9-item multiple-choice section, was administered to both groups at the beginning of the study and again at the end (see Appendix E, Figure E9, for the instrument used). The pre-post data was analyzed using SPSS and Excel software, and the results were interpreted in consideration of the quantitative RQ1 and RQ2.

Additionally, observations were made of both groups during the intervention portion of the study, and four focus groups were held, one for each school, within two weeks after the study interventions. The results of both the observation notes and the focus group data were coded and thematically analyzed, and the results were interpreted in light of RQ2, along with the three 5-point Likert Scales mentioned above (Maguire, & Delahunt, 2017). Statistical testing was used to analyze the quantitative data; descriptive statistical testing, Student's t-test, Cronbach's alpha, Analysis of Variance (ANOVA), Analysis of Covariance (ANCOVA), Correlation Analysis, and regression analysis

Demographics of the Target Schools. The study population consisted of African American students from four St. Louis middle schools, three public, one private. St. Louis is a small, midwestern city with a population of 300,500 (141,000 African American) that has been declining in both population and wealth since 2000. Of the total population19% live at or below the poverty level, while 25% of African American residents live in poverty. According to data from the National Center for Education Statistics, the school district's students are 47% African American, 43% Caucasian, 4% Hispanic, and 3% Asian. The building stock is old, 84%, built more than 50 years ago, which is indicative of the financial status of the district. The number of families living in poverty was twice as high as the city general population at 38% with 49% receiving

SNAP benefits. The students come from households with a median income of less than $34,000. In 2019 the district was listed seventh from the bottom of all school districts in the state of Missouri. (Snyder, De Brey, & Dillow, 2019) Table 2 compares the demographic data for the four schools to the district averages for statistics that may influence the outcomes of the study.

Table 2

School Demographics Compared to District Averages

School Programs		School 1	School 2	School 3	School 4	District
Type		Public	Public	Private	Public	Public
After School Care		No	Yes	Yes	No	
Post Activity Transportation		No	Yes	No	No	
USDA Food Program Eligible		Yes-100%	Yes-100%	USDA Food Program Eligible	Yes-100%	
Free Breakfast Offered		Yes	Yes		Yes	
Free Lunch		Yes	Yes		Yes	
Student /Teacher Ratio		20 / 1	09 /1	10 / 1	12 / 1	15 / 1
ESOL		No	Yes	No	Yes	
Special Ed		Yes	Yes	Yes	Yes	
Student Diversity	African American	97.9%	100.0%	24.0%	67.4%	77%
	White	n/a	n/a	60.0%	20.2%	15%
	Other	1.5%	n/a	14.0%	12.4%	8%
	Male	51.0%	48.0%	45.0%	24.0%	
	Female	49.0%	52.0%	55.0%	76.0%	
	Other	n/a	n/a	n/a	n/a	
Total Students		336	75	211	258	268
MAP	English Language Arts	8.7%	50.0%		38.5%	23.1%
	Mathematics	4.7%	34.70%		21.80%	18.9%
	Science	6.4%	29.6%		33.7%	17.7%
Academic Growth	English Language Arts	50.2%	n/a		n/a	49.5%
	Mathematics	51.5%	n/a		n/a	49.4%
Proportional Attendance		79.1%	80.3%		85.3%	77.7%
bullying Incidents		0.1%	n/a		n/a	0.2%
Out of School Suspensions		0.30%	0.0%		8.1%	2.0%
Teacher Profile	% Teachers with Advanced Degrees	n/a	20.0%	90.0%	32.8%	44.9%
	Avg Years of Experience	4	8		7	8
Students per Teacher		15	12	15	13	15
Aft. School STEM		n/a	Coding	math, science, robotics clubs maker space	n/a	

A close examination of this data reveals that all of the public schools in this study have a majority African American student body (from 67.4% to 100%). The one private school has about 24% African American that makes up its student body. Also, the public schools all have 100% participation in the USDA food program with both free breakfast and free lunch programs, while the one private school has the program available, but no statistics on how many of their students participate. The student population of three of the four schools was within +/- 25% of the district's average total student population, except School #2, whose total student population was 75, compared to 268 for the district average. The MAP results for three of the four schools were all greater than the district average, except for School #1, which was significantly lower. This school also had the lowest teacher experience, with no reporting on the percentage of teaching staff with higher degrees. Also, it is revealed that the one private school, School #3, is the only one reporting significant after-school STEM-related activities: math and science clubs, a robotics group, and a Makerspace. The only other school that reported any after-school STEM-related activity was School #2 with some after-school coding.

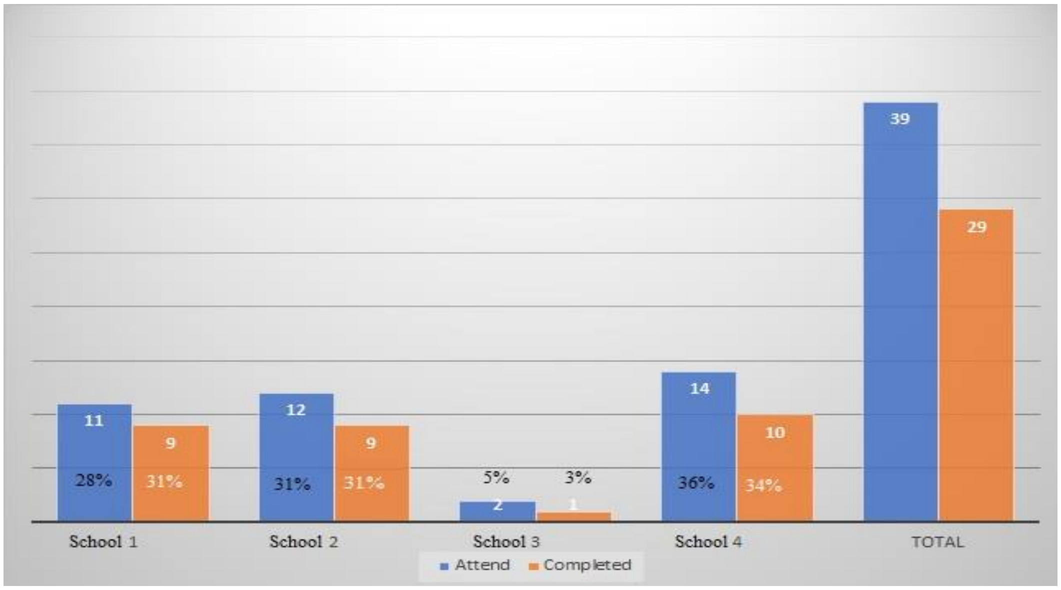
Research Setting. The setting of the study was a local Boys and Girls Club whose impact on the youth of St. Louis has been evident for nearly seven decades. Initially started as a sports club to keep youth off of the streets and out of trouble, the institution has broadened its mission "To produce physically active, well-educated and hopeful young people with families at the center of our efforts" ("Mathews-Dickey Boys & Girls Club", 2020). The building used consisted of a large, institutional-style building, with multiple rooms, such as a computer room, gymnasium, cafeteria, individual offices, and classrooms. A large cafeteria room and a moderately sized classroom were used for this study. Other portions of the building were used by non-participants while the study was in session, but no exchanges with the study took place.

The Green Tower Program at the Boys and Girls Club was started in conjunction with a local representative of the Tower Garden® system, which is a self-contained aeroponics growing system. Initially, the program was started at the Boys and Girls Club as a way to supplement nutrition and then was later introduced into local schools. All of the participating schools either have an active Green Tower program in their school or are in the process of developing one. Although the program had elements of maker education, it originally included only activities of horticulture and culinary skills. The STEM study allowed the program to be introduced to a more science-based format.

The focus group meetings were held at the participating schools, generally during the lunch hour. For each of the four schools, the meeting was held within an unused classroom. As with the after-school sessions, a light meal of pizza, fruit, and a drink was served during the meeting time to participants. At each focus meeting, the contact teacher from that school was present to act as a facilitator for the meeting.

Recruitment of Participants. The participants were recruited through the contact teacher at each of the four schools. Each of these teachers was either already teaching a STEM class, had established a Green Tower Program in their classroom, or was in the process of establishing the Green Tower Program. Recruitment consisted of a two-phase methodology. First, about a month before the study began, an informational flyer was given to all potential participants in the classroom, and a different flyer, designed for parents and guardians was sent home by way of the student. The second phase began two weeks later, where labeled informational packets, complete with a more detailed description of the study, application, accent, and consent forms were distributed by the contact teachers. (See Appendix E) Each page of the materials in the packet had a randomly computer-generated number to help keep track of the applications and packet materials while maintaining confidentiality. The randomly generated numbers were then sorted to the control group or the treatment group at a ratio of one to five, in anticipation of a 20% control group and an 80% treatment group. This same number was used when the participants picked up their pre/post questionnaires, intervention #1 and #2 packets, and all other materials that could have identified them (See Appendix F). The students were instructed that all appropriate consent and accent forms had to be returned with proper signatures before the beginning of the study. For the most part, those who participated complied with these instructions, and those who did not completely comply were not included in the study data. An Excel file that identified the names of the participants with their identifying information was maintained by an impartial person who had no other relationship to the study. Figure 2 shows the distribution of participants who completed the study, per contributing school. The greatest number of students who completed the study came from School #4 (34%), with schools #1 and #2 contributing about the same (31% and 31%, respectively) and School #3 contributing the least (3%).

Figure 1
Distribution of Participants Who Completed the Study



Sampling

The sample for the study consisted of volunteers from the four target schools which lends itself to convenience sampling. A total of 69 students signed up initially for the study. The data was expunged those who did not present the properly signed consent or assent forms (15), participated for less than two of the three days (10), or did not complete both pre and post-tests (6). The data was further cleaned of those who were not African American (9), leaving a sample population of 29 African American participants, which represented an overall participation rate of 42%. Of these 24 participated in the treatment group and five participated in the control. Both students, their guardians, teachers, and all institutions were asked for their consent (and assent) for participation in the study(see Appendix E). The consent (assent) form clearly stated the intent of the study, the methodology and procedures used, confidentiality protection of the study, and how to contact the researcher for any questions that arose (see Appendix E). The forms also clearly explained that the student was under no obligation to participate, nor to remain in the study once included. To assist in keeping all students confidential to the researcher, all forms were distributed to the students and their parents in their classroom and explained by their teacher, and all forms were collected in the same manner.

The demographics of the African American participant data used in this study are found below (Table 3). As can be seen, there is a large discrepancy between the number of participants in each group. Both groups contained a medium age of 12, and a grade of 6^{th}, and were majority female. The treatment group had the largest number of its students coming from School #2, while the majority of the control participants came from School #4. It is noted that the control group had no students from School #2. This is because of the small number of persons in the Control Group relative to those in the Treatment Group.

Table 3

Demographics of the African American Participants by Group

	Treatment (%)	Control (%)
Number, N	24 (83)	5 (17%)
Age, 10 and less	1(3%)	1 (3%)
11	7 (24%)	1 (3%)
12	8 (28%)	2 (7%)
13	6 (21%)	0 (2%)
14 and greater	2(7%)	1 (3%)
Grade, 5	1 (3%)	0 (0%)
6	14 (48%)	3 (10%)
7	6 (21%)	1 (3%)
8	3 (10%)	0 (0%)
9	0 (0%)	1 (3%)
School, #1	7 (24%)	1 (3%)
#2	9 (31%)	0 (0%)
#3	1 (3%)	1 (3%)
#4	7 (24%)	3 (10%)
Gender, female	15 (52%)	3 (10%)
Gender, male	9(31%)	2(7%)

Site Layout

The four participating schools were divided into two equal groups. One group met on three consecutive Mondays, from 4:00 pm – 5:30 pm, and the other group met on three consecutive Tuesdays, of the same weeks. Each session began with 30 minutes for eating a light meal, socializing with other students, and asking questions or talking with the instructors. The study setting was two classrooms at the local boys and girls club. The treatment site is a large meeting room where participants were seated at 10 - 60" circular tables, each with a maximum seating of six participants, although rarely did any table have the maximum setting. Tables were an average of six ft from each other and were arranged in an arc around the instructor's projector screen. At one corner of the room the PowerPoint screen was situated as to be visible to all participants, and against an adjacent wall were located the Green Towers used in the interventions. Along this same wall were located the participant's STEM kits, which contained all the required materials for the activities. This arrangement allowed the instructor to face all of the students as needed, and for ease of pathway of the observer and student, as seen in Figure 3a. The control group of the students was placed in a separate room joined by a corridor. (see Figure 3b) This classroom was equipped with two traditional 30" x 72" rectangle tables and with a wall-mounted blackboard located on a perpendicular wall. Two Green Towers used in the study were located on the opposite wall. The target group's second Monday session had to be changed due to and programming issue at the boys and girls club, and it was moved into the smaller classroom (Figure 3c) for that session only.

Figure 3a

Treatment Group Meeting Room

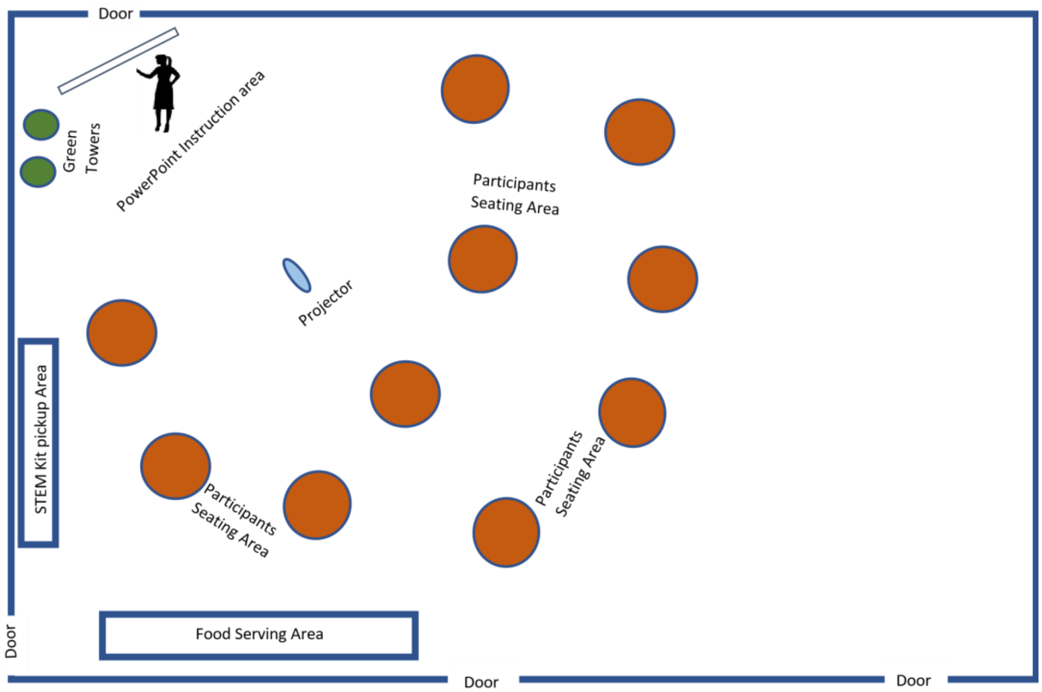


Figure 3b

Control Meeting Room

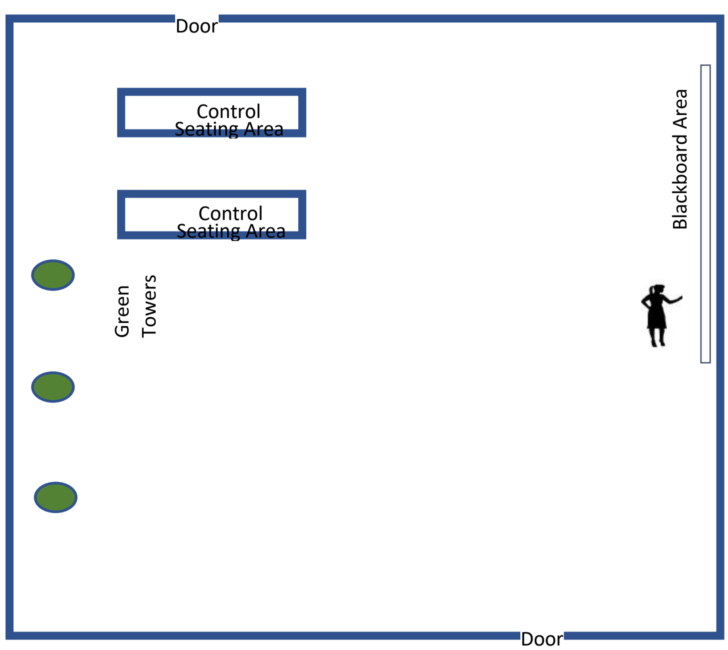
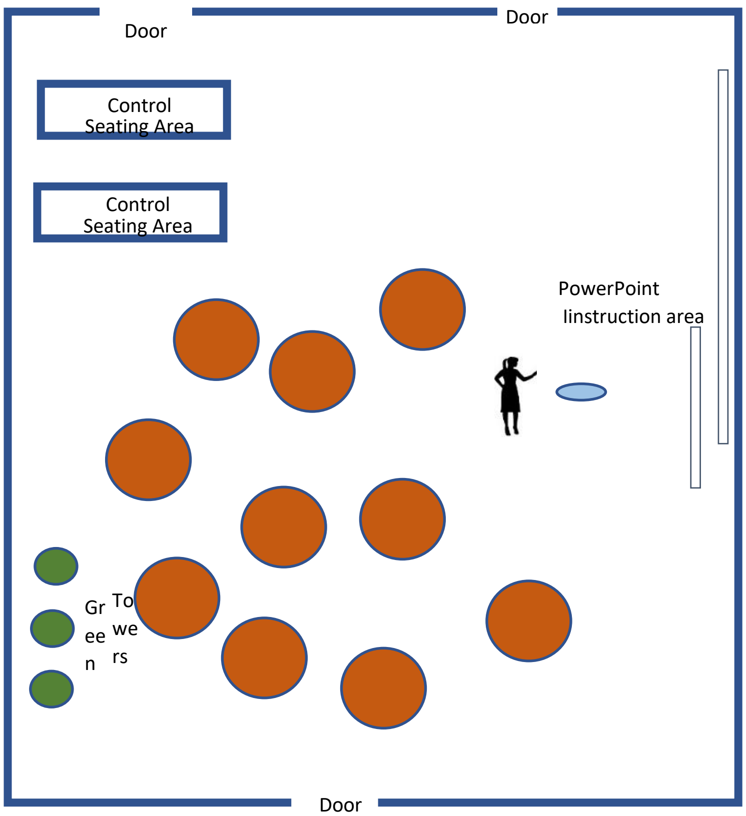


Figure 3c

Treatment/Control Combined Arrangement



On the first session for each group the pre-questionnaire consisting of a 3-question demographic data section, a 17 question 5-point Likert section, and a 9-question, five items multiple-choice subject knowledge section. At the end of the last session for each group, the same questionnaire was again given as the post-questionnaire. Of the participants who attended the study(N=65), only participants who completed both the pre-and post-questionnaire and had met the earlier mentioned aspects were included in the final analysis (N=29). The explanations for such a large decrease in the data set include several factors; participant's absence, incomplete permission forms, and questionnaires that were incomplete or not turned in. Observations were made by the researcher throughout each session, including the initial meal portion, and also afterward during the time that participants waited in the corridor and on the parking lot of the site for the arrival of their transportation.

Activities of the Instructor and Adult Leaders

Apart from the principal investigator, there were several types of adult leaders who interacted in some capacity with the participants of the study.

The Instructor

The Instructor for the study, who is referred to as Ms. Instructor, was a female lecturer for the University of Missouri, St. Louis, Department of Educator Preparation and Leadership, and has extensive experience in curriculum design, STEM program design, science education, and inquiry-based education. She was a co-sponsor of the Green St. Louis Machine, for the Boys and Girls Club where the study was held and has experience teaching lower secondary science classes in St. Louis area public schools with demographics similar to those of the school is in the study. Before the beginning of the study, Ms. Instructor met with the principal investigator to develop, review, and prepare each of the three study sessions, and after each group session, to critique, assess, and compare valuations.

The Site Coordinator

The site coordinator, who is referred to as Adult Leader #1, was the administrator of the Boys and Girls Club and offered assistance in providing approval of site usage, transportation of the participants from the four schools to the site, and provided setup and janitorial services for the study. She also approved the use of the site personnel as meal preparers/servers, which proved to be very helpful, freeing up the researcher for observation.

The Green Tower Representative

The Green Tower Representative, who is referred to as Adult Leader #2, acted in a multitude of capacities. First, she is an official representative of the Green Towers that were used during the study and supplied the towers for use in the study. Second, she acted in an advisory capacity for Tower-related concerns. Third, the four schools used in the study all had purchased a Tower from her, and she consulted with each of them in an advocatory capacity regularly and therefore was familiar with some of the participants. This was helpful in that she was able to assist in classroom management. She also coordinated the meal preparation and distribution. Finally, Adult Leader #2 acted as a Table helper when required.

The Table Helper

The Table helper, who is referred to as Adult Leader #3, were science teachers (and one administrator) of most of the participants from the four schools. They acted as Table helpers, answering participant's questions that did not require Instructors' input. Since they were teachers of most of the participants, they also provided classroom management and helped keep order. Some of the Adult Leader #3 also provided their observations to the researcher at the end of a session. The number of Adult Leaders #3 varied from each session, from two to five.

The Photographer

Although not a part of this study, the Boys and Girls Club had their photographer, hereby referred to as Adult Leader #4, who took photos of the sessions for their purposes. Before the study, it was explained to the site coordinator that any photography was totally separate from the study, with its consent and assent documentation required, and the photographer could not directly interact with the study participants and is only mentioned here because some noted observations were of the participants' reaction to and opinions of this adult leader.

Focus Group Settings

Two weeks after the end of the after-school portion of the study the researcher began holding 30-minute volunteer focus group sessions at each of the four schools to assess the participant's attitude towards STEM in general, and the after-school STEM study in particular. The room was always a vacant classroom during the scheduled lunch hour. A lite lunch was provided since the students gave up their lunch break to participate. All focus group sessions were completed within two weeks of the final session.

Variables in Mixed Methods Design

The quantitative phase of the research design was presented first, and will answer the research question, RQ1, "To what extent does the introduction of mobile device assist maker activities to have on the knowledge base of African American students in after-school programs?" Several variables of interest have been identified. First, the between-groups independent variable that we call treatment and control will have two levels (those without mobile device-assisted maker activities and those with a mobile device-assisted maker activity), that influence the dependent variable of increase in the Knowledge base and the Attitude of the participant. A repeated-measure dependent variable called "difference of score" calculated in SPSS was used to determine the effect of the two interventions on the absolute change of each participants' pre-test scores compared to post- test scores.

The qualitative portions of the research consisted of direct observation of the students and a concluding focus group. Notes from both were compiled and coded, and thematically analyzed. A relational study of the independent variables, the dependent variable, student Attitude was attempted.

Assumed confounding variables between the two groups; school size, ranking, finances, and location; and educator race, ethnicity, lab partners, or even the placebo effect, influenced the selection of the inference statistics. Extraneous variables, such as the composition of activity partners or groups, the teacher and or table helper, the time of day of the class, and the group dynamics within the class, were considered on an as-needed basis.

Data Collection

The data was collected using a pre- post- Questionnaire, two mobile device-equipped maker activities, direct observation, and four focus group meetings. The data collection methods are explained below based on the research questions.

Pre- Post- Questionnaire

The 29-item paper and pencil pre- post- questionnaire used were developed by modifying 30 items from a 5-point Likert Biology Attitude Questionnaire (Prokop et al., 2007). The 29-item questionnaire consisted of a 3-item demographics section, a 17-item, three dimensions, a 5-point Likert section, and a nine 5-item multiple-choice section (Appendix E-9). The questionnaire was administered by the session instructor at the start of the first session of each day session (Monday and Tuesday) to both treatment and control groups. This generated all the raw demographics and pre-test quantitative data. On the last day of each session (Monday, and Tuesday), the study session instructor again administered the questionnaire to both treatment and control groups (no demographics questions were answered this time); this generated the raw post-test data. It was intended that the data from the pre-post questionnaires would provide the demographic data for the participants and their schools, and test the research null hypotheses, $H1_o$ and $H2_o$.

Direct Observation

Observations were made using the method known as "direct observation" as a partially participating observer, as discussed in (Ciesielska et al., 2018). Direct observation occurs in real-time when the object of observation is happening. Ciesielska et al. define a partially participating observer as one who "takes part in the interactions, but not in the type of activity that is specific to the studied environment "(p 40). The participants knew that the observer was the researcher collecting data about their response to the STEM study. The researcher was fully aware of the potential for bias on his part from preconceived notions about STEM education and from being the sole observer with a singular perspective on each observation. Both of these sources of bias may influence what is observed and how it is interpreted. Also, in an environment involving middle school students, it is certain that many events will occur that may attract the attention of the observer, but are not directly related to the study at hand. Consequently, an attempt was made to document only observations that related to the study and to always weigh how much the perspective of the researcher has affected the meaning of the observation.

Focus Groups

The focus groups were conducted at the four school premises, during the lunch period. The teachers that had served as Table helpers provided the meeting space and were present during the focus groups to act as moderators if needed. Since the focus group was held during the lunch period, a snack and drink were made available to each participant. As an incentive to attend the Focus Group one of the various STEM gifts was also supplied to each participant. The Focus Group time was divided into three sections: an introduction, a question and answer session, and the conclusion. During the introduction, participants were thanked again for partaking in the after-school STEM study, and participants were allowed to choose their snack items. This was generally the first 2-4 minutes. Then came the question and answer section, which lasted 23-26 minutes. During the conclusion, the participants were again thanked for their contributions to the study and were allowed to choose a parting STEM gift.

Data Collection for Research Question #1: Hypothesis Testing, $H1_o$

The method of data collection chosen to test RQ1 is discussed below, both the instrumentation used and the interventions that both the treatment and control groups used.

Instrumentation

The pre- post-testing instrument, used in this study to test the first null hypothesis:

> Null Hypothesis 1, H1o. The use of mobile device-assisted maker activities does not affect the knowledge base of African Americans in STEM activities.

The multiple-choice portion of the questionnaire consisted of 9 5-item multiple-choice questions, questionnaire numbers 18 through 26 that were based on knowledge presented during the study, and was used to test the $H1_o$ (see Appendix E-9). The same questionnaire was used before the interventions and after the interventions to determine whether the knowledge base of the participants changed. Also, the same questionnaire was given to both the treatment and control groups to see if the effect was different for each group.

Data Collection for Research Question #2: Hypothesis Testing, H2o, and Qualitative Data

The second research question involved collecting both quantitative and qualitative data. The quantitative data were collected using the Likert portion of the pre- post-questionnaire, questions 1-17 (see Appendix E-9), which measured Attitude using three scales: Interest, Difficulty, and Importance. As with the multiple-choice portion, the pre- and post- Likert portions of the questionnaire were administered both before and after the interventions to both the treatment and control groups.

The qualitative data consisted of direct observation and focus group responses of both treatment and control groups. Observations were made before, during, and immediately following each group session. Periodically, the researcher would leave the test group and spend time with the control group. Notes were taken as discretely as circumstances allowed. Since in a learning situation many youthful learners are accustomed to asking any adult in the class for assistance, the observer did at times interact with the participants, but an attempt was made to answer only non-study related questions and to relay any study-related questions to a Table worker, Green Tower representative, or the instructor.

Pre- Post- Likert Scales

The second section of the pre- post- questionnaire consisted of a 17 question, 5-item Likert session, to measure the Attitude. Three dimensions of Attitude were measured by the scales, Interest, Difficulty, and Importance. The Interest scale was measured using questions 1,2,5,7,14,15, and 16. The Difficulty scale was measured using questions 3 and 17. The Importance scale was measured using questions 4, 6, 8, 9, 10, 11, 12, 13. The Likert questions were scored with values of 0 to 4, with Strongly Disagree = 0, and Strongly Agree = 4. Of the 17 questions 2, 3, 7, 10, 13, and 14 were negatively scored, and the values reversed.

Direct Observation Data

Observation notes were taken concerning the following: the environment and setting of the session, the demographics of each group at each session, what activities were presented during each session, what were both the individual and group responses to the activities and other situations within groups, the interactions between the participants and the instructor and other adult leaders present, and the behavior of the participants when attempting the maker activities. The emotional and mental effects were judged by the observer, taking into effect, body posture, alertness, facial expressions, and spoken phrases. The behaviors were assessed considering the actions, both individual and group, with the response to the class tasks at hand. Notes were made of; (1) how the study influenced the perceived emotions and moods of the participants (Affects), both as individuals and as groups and, (2) how the participants interacted with the instructors, other participants, and the interventions (Attitudes). Table 28 found on page 91 is a list of the codes used for observing the participants. An attempt was made by the instructor to make certain that the Monday group and the Tuesday group followed similar lesson plan chronologies, and apart from the second Monday session, all sessions were held in the same classroom setup. The second Monday session had to be moved to another classroom due to the center's need for a large classroom space.

The instructor and several adult leaders offered their observations in both a structured and unstructured format, and these are noted at the end of each session observation summary, but not included in the analysis of the study.

Focus Groups Data

There were 30-minute focus group sessions held at each of the four schools. Generally, the introduction phase was quite lively and loud, until the teacher settled the group down. Then when the question and answer period started, immediately there was an atmosphere of general seriousness that came over the group. The conclusion was a little hectic since the participants had to both select a parting gift and make it to their next class. It should be mentioned that some who attended the Focus Group did not complete both pre and post questionnaires but participated in the focus group, with some giving responses based on their limited experience.

Data Analysis Procedures

Demographic data

The demographic data were analyzed to determine the characteristics of the study participants, such as school, gender, race, grade, etc. This data was collected using the pre-questionnaire and was analyzed to determine how these characteristics affect the outcomes. This was done by performing descriptive statistics to identify outliers, normality of data from each or combined characteristics; collection and interpretation of frequencies, and relative percent tables.

Quantitative Data Analysis

The analytical tests were run on SPSS v. 26, and are listed in Appendix B (see Table 4). The results are presented in Chapter IV.

Qualitative Observation and Focus Group Data Analysis

The observation data was initially coded by the researcher, and then iteratively according to the themes, topics, and concepts that develop from the evaluation of the data (Srivastava, & Hopwood, 2009). The observational data were analyzed for key terms, convergent data, and dominant concepts. Thematic content analysis was performed on the student focus group data. The findings of the data, both quantitative, qualitative, and mixed, are presented in Chapter IV.

Validity and Reliability

Creswell (2017, p. 160) categorizes validity in three ways;

> ...content validity (do the items measure the content they were intended to measure?), (b) predictive or concurrent validity (do scores predict a criterion measure? Do results correlate with other results?), and (c) construct validity (do items measure hypothetical constructs or concepts?).

Furthermore, threats to the validity of the data are grouped by Creswell into those that affect experimental procedures or participant experiences (internal validity threats), and those that result from the researcher's incorrect generalizations about the data (external validity threats). Some of the internal threats to this research that were identified dealt with the selection and persistence of participants and the instrumentation selection. The participants came from blending critical case sampling with criterion sampling of existing classroom groups, so a quasi-experimental procedure is assumed. Therefore, the lack of randomness was accounted for in the research design. The instrumental design of both the survey and the maker activities considered existing trends in the chosen STEM study, such as; student and teacher attrition, pedagogy in use, and existing student efficacy. The participants in the survey component were contacted using a multi-part process outlined in chapter eight of Creswell (2017). The pre- and post- questionnaire t were the same, eliminating threats to instrument error from that aspect.

The characteristics of the participants were indeed narrow. They were designed to be limited by age (lower secondary school ages), race (African American), region (urban), and financial status (low income). There is a strong correlation between learning and the socioeconomic status of students (Shaheen, & Gul, 2014). They are further limited in that they have already selected a STEM activity, the Green Tower program. But external characteristics exist relative to the sample population, school setting, and community setting, that prevent the findings of this research from being generalizable to all secondary school African Americans. The socio-economic status of the school district, as well as the student, the national standing of the school as well as the particular school's student population, the persistence rates of the students in the chosen schools, the stress components contributed within the school setting as well as from external community and home life settings, the student's self-efficacy and the expectations and support systems of the administrators, teachers, and parents of the students, all affect the generalization of this report to other populations. Attempts were made to control or mitigate the threats to external validity, such as setting up a pre- post-questionnaire. the control group design for the study and the maker activities (the control group will complete the activities without mobile devices and utilizing a traditional format). Also, studies within the literature have attempted to mitigate these external characteristics and a review of their success was formulated.

The criteria for ensuring the viability and reliability of the qualitative portion of this study include the following:

A. Triangulation of the questionnaire, observation, and focus group themes

B. Reflecting upon the researcher's biases will affect the outcomes of the study (Pannucci, & Wilkins, 2010).

C. Examination of the discrepancies and outliers found within the data

Ethics and Human Relations and Threats

The researcher of this study was an African American male, with a STEM career background. He was also a member of the UMSL campus and a doctoral candidate in the College of Education's STEM Cohort. The researcher has had extensive experience in devising STEM activities and is an amateur maker himself. He has had experience teaching STEM classes to African Americans at a St. Louis metropolitan school system. All of these experiences, although helpful for designing the research, possess the potential for subjective bias introduction into multiple phases of the study, but especially during the data analysis stage. An attempt was made to minimized threats by considering the opinions of other professionals who either are not prejudicial to these elements of the study or have had extensive experience in detecting and preventing their bias.

Since this study involved human experimentation the potential threat for participant confidentiality being breached existed. During the observation and interview stages, potential threats existed whereby bias from becoming too friendly with the participants might have occurred. Typically, the compliant practice of participants doing what they believed was expected of them while under observation, the Hawthorne Effect, was a potential factor, and could only be kept to a minimum by keeping the observer as imperceptible as possible (Mostafazadeh-Bora, 2020).

During the coding stage, the potential bias for or against a participant was kept to a minimum since only the demographic data was available to the coder. Safeguards against these types of threats were minimized by removal of all non-study-related interactions between the observers and the participants, and by enacting a double-blind numeric code to the collected data. The data was transcribed into an Excel file and then coded and thematically analyzed.

The researcher took as much effort as reasonable to prevent these biases and threats by frequent referral to the Institutional Research Board Approval (IRB) requirements throughout the study. A copy of the IRB approval letter is included in Appendix D (Figure 19). The required IRB training and approval and NIH human subject testing were completed before the onset of the study and made available for review upon request by all stakeholders. All data, both written and electronic was held within locked metal file cabinets. When the data was used on computers it was secured so that it was accessible only to the researcher and those of members of the dissertation team as deemed necessary. The data will be destroyed after the study, after a sensible period. The data analysis was performed by the researcher using IBM SPSS Statistic 26 software, and Office 2019 Excel supplied by the University of Missouri, St. Louis, MO, and the interpretations of the results were based on standard practices.

Summary of the Chapter

A comparative, quasi-experimental, exploratory mixed method design was implemented for this research. Quantitative data was based on a pre- post- questionnaire, analyzed for t-tests, ANOVA, ANCOVA, Pearson' Correlation, and regression analysis. The qualitative data were coded and themes developed from observation data and four focus group interviews. The following chapter will include the findings in greater detail.

Chapter IV: Data Analysis and Results

Introduction

This chapter presents the results, statistics, and graphics of the study. The purpose of this study was to investigate how mobile device-based maker education activities can be used to answer two research questions:

RQ1: To what extent do mobile device-assisted maker activities affect the STEM knowledge base of African American students at the secondary education level?

RQ2: To what extent do mobile device-assisted maker activities affect the STEM attitude of African American students at the secondary education level?

Research question RQ1 was answered by testing the null hypothesis, $H1_o$;

Null Hypothesis 1, H1o. The use of mobile device-assisted maker activities has no effect on the STEM knowledge base of African Americans at the secondary education level.

Research question RQ2 was answered by testing the null hypothesis, $H2_o$;

Null Hypothesis 2, H2o. The use of mobile device-assisted maker activities has no effect on the STEM attitude of African Americans at the secondary education level.

and by qualitatively investigating the themes developed from the direct observation codes, and those developed from the focus group responses. An attempt to triangulate the data sources was also made.

Summary of Research Design

A mixed-method study was selected, incorporating a quantitative component based on a pre-and post-questionnaire with Likert scales and a multiple-choice measure, and a qualitative component based on direct observations and focus group responses. A 3-session intervention consisting of short lectures, group participation, and two mobile device-assisted maker activities was performed over three days of three weeks. The setting of the study was an after-school program at a local boys and girls club, that had a former association with the participating schools. Methodological triangulation (Mathison, 1988) of the total results is presented at the end of this chapter. A summary of the raw data collected is presented in Appendix A (see Figure 20a-b, Table 5a-e, and Table 6).

All raw data were documented and then cleaned to remove non-related, or unusable data in an Office 2019 Excel database from which the quantitative data were statistically analyzed using IBM SPSS ver. 26. The results of analyzing the cleaned data for descriptive testing, t-test, Cronbach's alpha, ANOVA, ANCOVA, correlation analysis, and multiple regression analysis are presented here. The qualitative data from the direct observation transcripts and the four focus group interviews were iteratively coded and interpreted to support the quantitative findings.

Study Results

The results of the quantitative analysis and quantitative analysis are provided below. They are presented in their relation to the 2 research questions, and the two related null hypotheses of this study. Demographic statistics for the participants of concern are presented first, then the quantitative data as related to H1o and H2o, then the qualitative results of thematic analysis of observation information and focus group responses.

Quantitative Results

The quantitative results of the study were determined by testing the null hypothesis consisted of the demographics, the hypothesis testing of H1o, and the hypothesis testing related to both the treatment and control groups. The two groups were unequal in numbers, so the between group's statistics is scant. Table 3 above (see Chapter III) presents the demographics used in the study, based on 29 African American participants, independent variables of school, session day, age, and gender is documented.

Demographic Information

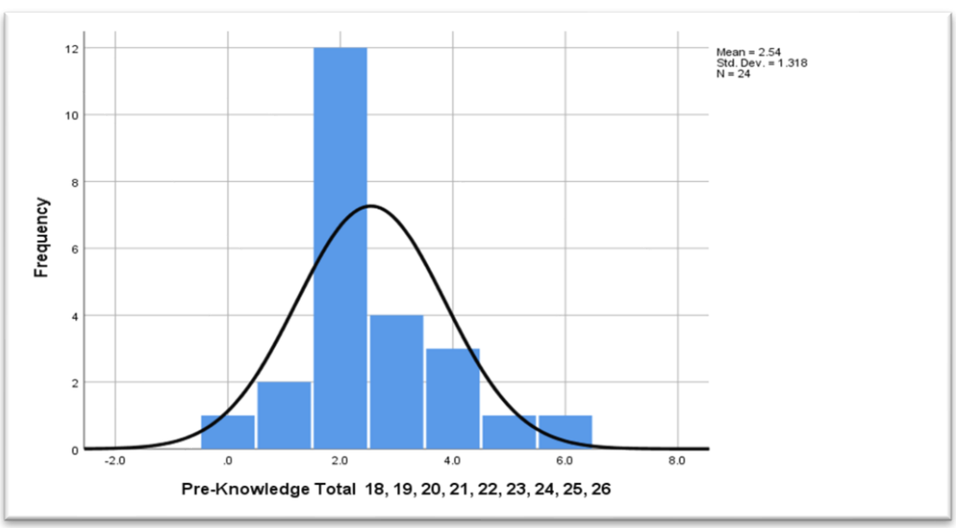
The participants were all middle school students. Three were public schools with a majority African American student population, and one was a private school with a sizable African American student population. The demographic measures collected from the participants were race, gender, school, age, group, and grade. Of these, gender, school, grade, and the group were of most concern. Factors of the research sites and settings that might have affected the outcomes of this study are also listed. Tables 2 (see Chapter III) shows the basic demographics of the schools involved in this study. Table 3 above (see Chapter III) lists the categorical independent variables that affected the stratification of the data. Table 2 above compares the demographics of the four participating schools with each other, and with the district. The information illustrated that the participants all come from a similar population. School 3 can be seen to be slightly different, in that the school was private, parochial, and offered significantly more after-school STEM programs. Also, the teaching profile at School 3 had significantly more advanced university degrees (90% of the faculty had advanced degrees, compared to 45% for the district average, and a 26% for the other schools in the study). Finally, School 3 was the only participating school with a student population that was not majority African American (24%). Despite these anomalies, it was decided that School 3 was needed to provide an atmosphere similar to that of the average classroom.

School 2 did not list their teacher profile, but the previous conversation with the teachers from that school placed it at about one out of four. School 2 was also the only one of the majority African American participating schools that had any after-school STEM program offered (coding).

The graph of the means of the pre-knowledge total scores is shown in Figure 4 below is of the 24 participants in the treatment group for the study. Out of a possible top score of nine, the average score of M= 2.54, SD=1.32. As can be seen, the data is slightly kurtotic and right-skewed but still normally distributed, especially considering the small sample size, N=24 (Ghasemi, & Zahediasl, 2012).

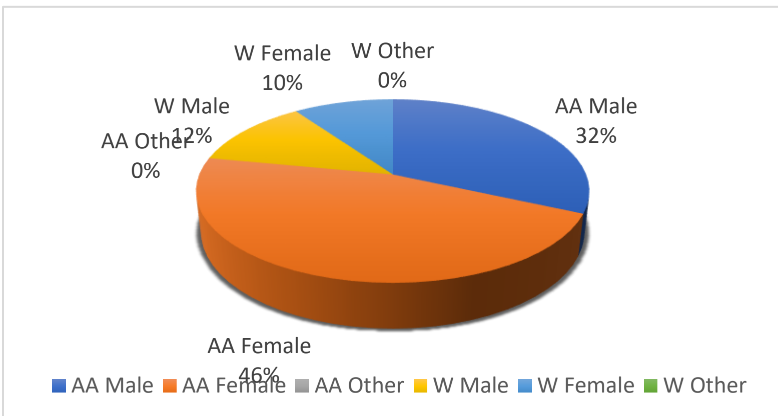
Figure 4

Graph of Normality for Pre-Knowledge of AA-T



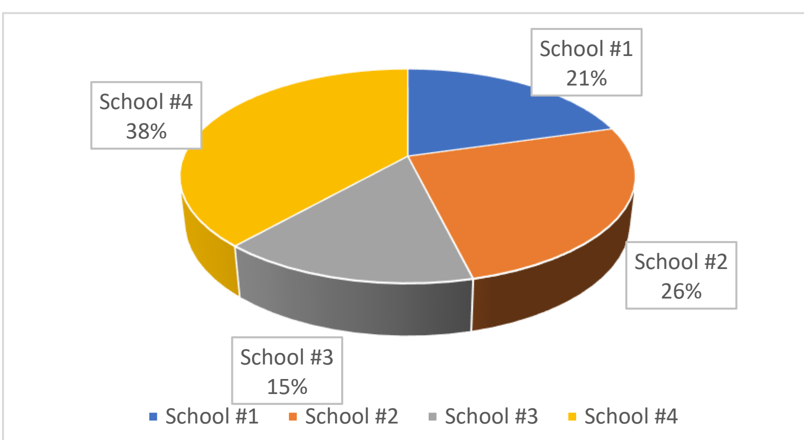
Gender. Table 3 above (see Chapter III) presents the demographics for the African American participants in the study. The largest gender group was female, and African American females made up nearly half of the participants (see also Figure 5 below).

Figure 5
Demographics of All Study Participants by Gender



School. The participating schools contributed generally from 15% to 38% of the study's participants, compared to an ideal 25%, as demonstrated in the graphic in

Figure 6
Demographics of All Study Participants by School



Grade. The distribution of the participants by the school is shown in Table 7 below. Participants' grade levels ranged from 5th to 9th. No academic standing demographic data was collected from the participants. The measure of central tendency of grade-level used was the mode, which shows that the majority of participants are in the 6th-grade level.

Table 7

Grade Distribution of All Participants by School

Building	5th Grade	6th Grade	7th Grade	8th Grade	>8 Grade	Mode
School 1	3	8		5		6th Grade
School 2		6	8			7th Grade
School 3		6				6th Grade
School 4		10	7	7	2	6th Grade
All Schools	3	30	15	12	2	6th Grade

Quantitative Data Analysis, $H1_o$

The relative statistical testing of H1o of the post- Knowledge Total scores of the treatment and control groups was to determine if there was a significant change in the knowledge base of the participants. The research question was:

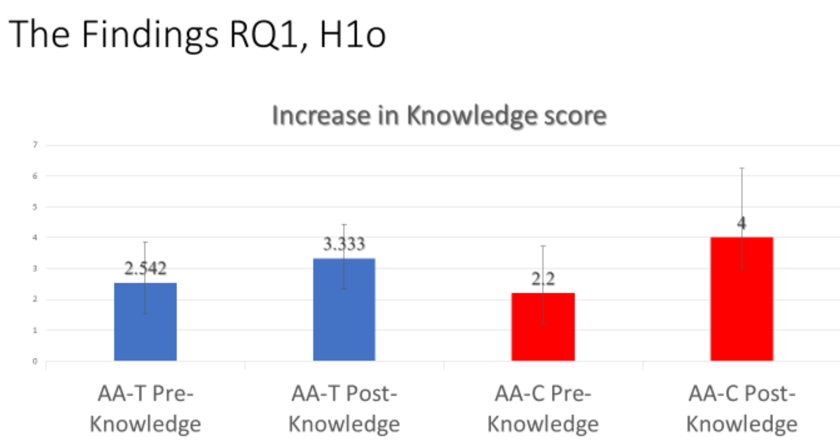
RQ1: To what extent do mobile device-assisted maker activities affect the STEM knowledge base of African American students at the secondary education level?

An independent t-test was conducted to compare the post- knowledge total score of the treatment and control groups. The critical value for 27 degrees of freedom and a two-sided test was C.V.= 2.052 ("PS Student's t", n.d.). The test statistic was t(27)=-.823 was less than the C.V., therefore there was no significant difference between the treatment and control group post- knowledge score means (see Table 22). SPSS p values (see Table

23) confirm this in that there was no significant difference in the scores of the treatment group (M=3.33, SD=1.52) and the control group (M=4.00, SD=1.52). This suggests that the interventions yielded no significant difference between the post- Knowledge of the two groups, and therefore the test failed to reject H1o (see Figure 7).

Figure 7

Means for Treatment and Control Groups for Pre- and Post- Knowledge Scores



Quantitative Data Analysis, H2o

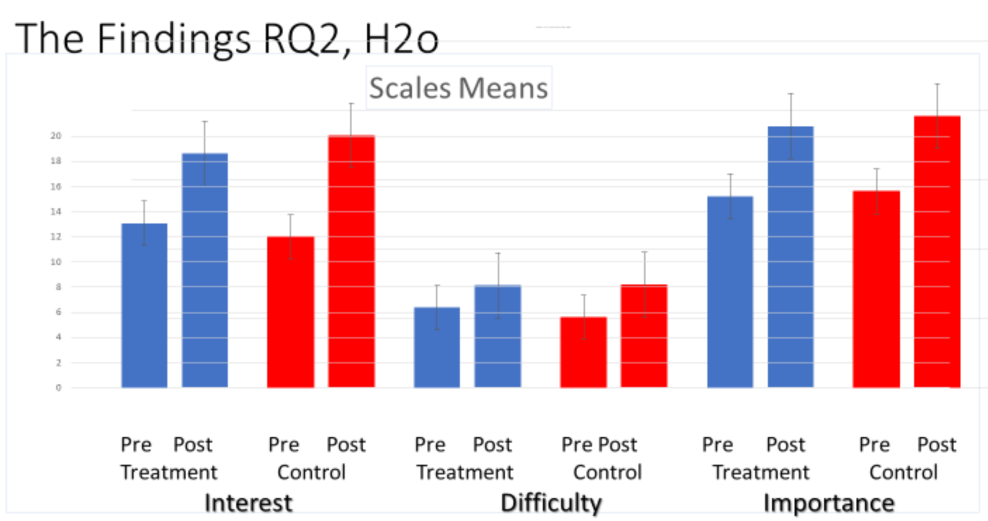
The second question raised, was:

> "To what extent do mobile device-assisted maker activities affect the STEM attitude of African American students at the secondary education level?"

The statistical analysis of the null hypothesis related to this question was tested using SPSS. An independent t-test was conducted on the Likert data set to compare the post-Attitude Scales of Interest, Difficulty, and Importance means, of the treatment and control groups. First, the test statistics were compared to the Critical Value (C.V.) from the Student's t distribution table ("PS Student's t", n.d.). The critical value for 27 degrees of freedom and a two-sided test was C.V.= 2.052. The test statistics for all three scales means (see Table 23) were less than the critical value (t (27)= -.541, -.025, and -.323, for Interest, Difficulty, and Importance, respectively, assuming equal variances). Therefore, there was no significant difference between the treatment and control group post-knowledge scores (see Table 22). SPSS p values confirm this in that there was no significant difference in the three scales of the treatment and control groups: Interest (M=-16.88, SD=5.31), (M=18.20, SD=2.28), t(27)=.541, p=.593; Difficulty (M=7.38, SD=1.88), (M=7.40, SD=2.61), t(27)= -.025, p=.980; and Importance (M=18.88, SD=4.75), (M=19.60, SD=3.36), t(27)= -.323, p= .749, and fail to reject H2o (Figure 8).

Figure 8

Means for Treatment / Control Groups for Pre- and Post- Likert Attitude Scales



Pre-Questionnaire

The first portion of the pre- post- questionnaire collected data related to the attitude of the participants towards STEM, in particular, STEM-related to the study. The paper and pencil questionnaire was based on the Biology Attitude Questionnaire (Prokop et al., 2007). Only questionnaires where the participant completed both pre-and post- sets were included in the study. When a data point was left blank in a questionnaire, it was left blank for SPSS to handle it accordingly. The questionnaire can be found in Appendix E (Figure E9a).

Questionnaire Dimensionality Scales

The pre- post-questionnaire was the source of the quantitative findings of this study. It can be found in Appendix E. This 29-item paper and pencil questionnaire was a modified form of the Biology Attitude Questionnaire (Prokop et al., 2007). The results were based on the cleaned data of N=29 African American participants who successfully took both the pre-and the post-form of the questionnaire. The findings from the questionnaire are presented as quantitative data from the 17 5-point Likert questions, divided into three scales related to student attitudes toward STEM; Interest, Difficulty, and Importance. In this chapter, the quantitative findings are presented; as the statistics of the 17 5-point Likert pre-questionnaire and the three Likert scales, the data from the nine knowledge-based multiple-choice questions, and the comparative results of the pre-and post-questionnaire and the treatment group versus the control group.

Reliability

The questionnaire consisted of two portions: a 17-item 5-point Likert scale, and a nine multiple-choice portion to measure knowledge of the study materials. The 17 questions were further divided into three constructs; six questions formed an Interest construct, two questions formed a Difficulty construct, and eight questions formed an Importance construct, as shown in Table 13 below. The internal reliability was calculated on the Likert scales of the questionnaire and showed an overall alpha value ranging from

.77 to .83. The reliability of the 17-item Likert portion of the questionnaire was shown to be highly reliable (α= .834), as shown below in the SPSS Scale Reliability Analysis summary.

Table 13

Cronbach's Alpha Scale Reliability Analysis Summary

	Dimension	Cronbach's Alpha	No. of items
1.	Overall	.834	17
2.	Interest	.759	7
3.	Difficulty	.772	2
4.	Importance	.828	8

Validity of Scales

Critical Value for Pearson's r = .404 at .05 two-tailed significance of 15 degrees of freedom of Total (*N*=40) were obtained (see Table 14) from a webpage (Jaadi, 2021). This showed that the validity was a low positive correlation. A one-way between-subjects ANOVA showed that there was no difference between the pre- post-knowledge due to the school that the participant attended. The case of School= 3 only has one participant, so it was not included in the analysis. The increase in means shows that participants from Schools 2 and 4, showed increases in their mean knowledge base after the interventions.

Table 14

Table of Critical Values for R

Size of Correlation	Interpretation
.90 to 1.00 or -.90 to -1.00	Very high positive or negative correlation
.70 to .90 or -.70 to -.90	High positive or negative correlation
.50 to .70 or -.50 to -.70	Moderate positive or negative correlation
.30 to .50 or -.30 to -.50	Low positive or negative correlation
.00 to .30 or -.00 to -.30	negligible positive or negative correlation

School=1 did not show an increase and instead decreased from a mean of 3.571 down to a mean of 3.143. All of the schools together showed an increase in knowledge base There was not a significant difference between the independent variable, school, on the dependent variables, pre-knowledge and post-knowledge at the $p<.05$ level for the conditions, [$F(3,20)=2.434$, $p=0.95$] and [$F(3,20)=1.679$, $p=.203$], respectively. Therefore, the results suggest that there was not a significant difference in how the participants changed their knowledge-base as a function of the school that they attended.

Interest Scale. The 17 items Attitude Likert questionnaire measured three-component scales, the first of which was Interest. Interest was measured by asking the participant what he liked (positively scored items) and disliked (negatively scored items). The questionnaire items 1, 2, 5, 7, 14, 15, and 16 comprised the Interest scale, and 2, 7, and 14 were formulated as negative items and were scored in a reversed order. The order was changed for statistical analysis. The items were totaled and averaged and the response. The scores were analyzed across the schools to evaluate and compare schools using one-way ANOVA. They were also evaluated using the same test across the grade level.

Table 15 below shows the mean (*M*), standard deviation (*SD*), and standard error *(SE)* of the participants in the treatment group. The large *SD* of schools 1, 2, and 4 show that the means, although similar, represent a spread-out distribution of the participants from that school. The Post hoc comparisons using the Tukey *HSD* test indicated that none of the pre-Interest mean scores and their *SD* for any of the schools were significantly different. Also, the post-Interest mean scores and their *SD* were not significantly different from the pre-Interest mean scores. There was not a significant difference between the independent variable, school, on the dependent variables, pre-Interest, and post-Interest at the $p<.05$ level for the conditions, [$F(3,20)=0.461$, $p= .712$] and [$F(3,20)=2.993$, $p=.055$], respectively.

Table 15

Pre- Post- Interest Mean and Standard Deviation by School

	Pre-Interest 1,2,5, 7, 14, 15, 16				Post -Interest 1,2,5, 7, 14, 15, 16		
	N	Mean	Std. Deviation	Std. Error	Mean	Std. Deviation	Std. Error
School 1	7	16.714	5.4685	2.0669	19.571	4.9618	1.9
School 2	9	16.667	3.0414	1.0138	16.556	3.8115	1.3
School 3	1	21	.	.	25	.	.
School 4	7	15.429	5.2236	1.9743	13.429	5.5334	2.1
Total	24	16.5	4.4036	0.8989	16.875	5.3105	1.1

Although the paired t-test shows a slightly higher mean Interest at the end of the study than before, it is not significant $t(23)= -.347$, $p=.732$). The Paired Sample Correlation test is shown in Table 16 measures the bivariate Pearson Correlation Coefficient with a two-tailed significance for each pre- post- Interest scale average for each participant, and it showed a significant positive correlation ($r=.419$, $p=.041$) between the two variables of pre-and post- Interest, which demonstrated a mild positive relationship. Although this test showed significance, it was inconsistent with the rest of the analysis of Interest. A bivariate correlation was run on the pre- post- data set and a scatterplot was printed.

Table 16

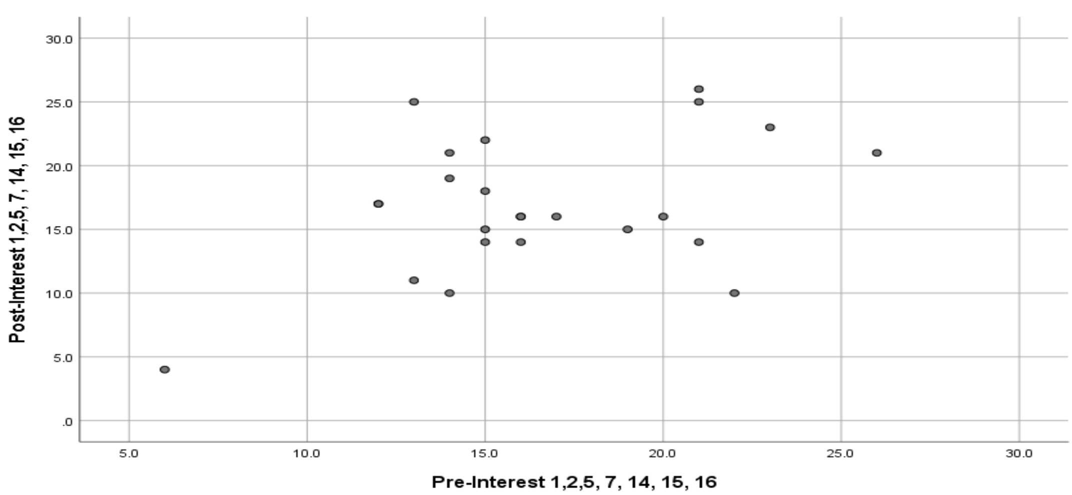
Pre-Interest Pearson Correlation and Alpha

Correlations		Pre-Interest 1,2,5, 7, 14, 15, 16	Post-Interest 1,2,5, 7, 14, 15, 16
Pre-Interest 1,2,5, 7, 14, 15, 16	Pearson Correlation	1	.419*
	Sig. (2-tailed)		.041
	N	24	24
Post-Interest 1,2,5, 7, 14, 15, 16	Pearson Correlation	.419*	1
	Sig. (2-tailed)	.041	
	N	24	24

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

Figure 9

Correlation of Pre- Post- Interest Totals



The results suggest that there is a mild positive correlation between pre- and post-Interest, but there was not a significant difference in the interest of the participants as a function of the school that they attended, nor as a function of the interventions.

Difficulty Scale. The perceived difficulty with STEM-related topics can be found in the literature. The difficulty for this study was defined as the personal construct that demonstrates how STEM subjects are hard to understand or to deal with. Two questionnaire items were a measure of this scale, 3 and 17, with 3 being formulated as a negative item which was scored in a reversed order. The order was changed for statistical analysis. The items were totaled and averaged and the response. Once again, the scores were analyzed by one-way ANOVA for schools, and by paired t-test on the pre-Difficulty and post-Difficulty means. The means of each school for the Difficulty scale shows a significant difference between the participants of different schools, [$F(3,20)=3.251$, $p=.043$] and [$F(3,20)=7.527$, $p<.001$] in the participant's feelings towards how hard they perceive STEM to be after the study. There was not a significant difference between the independent variable, school, on the dependent variables, pre-Interest and post-Interest at the $p<.05$ level for the conditions, [$F(3,20)=0.461$, $p=.712$] and [$F(3,20)=2.993$, $p=.055$], respectively. There was a significant difference between the independent variable, school, on the dependent variables, pre-Difficulty and post-Difficulty at the $p<.05$ level for the conditions, [$F(3,20)=0.461$, $p= .712$] and [$F(3,20)=2.993$, $p=.055$], respectively.

The Difficulty scores were compared before and after the interventions. The means of the pre-Difficulty scale were slightly lower ($M=4.542$, $SD=1.79$) before the intervention than the post-Difficulty scale after ($M=4.625$, $SD=1.56$). The increase in the Difficulty scale, 0.08, is not statistically significant, $t(23)= -.358$, $p= .723$. The Paired

Sample Correlation test measures the bivariate Pearson Correlation Coefficient with a two-tailed significance for each pre- post- Difficulty scale average for each participant, and it shows a significant positive correlation (r=.778, p<.001) between pre- and post-data (see Table 17). The simple scatter plot graph shows a moderate positive correlation. The results suggest that there was not a significant difference in the Interest of the participants as a function of the school that they attended.

Table 17

Mean, SD of Pre- Post Difficulty by Schools

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% C. I. for Mean Lower Bound	95% C. I. for Mean Upper Bound	Minimum	Maximum
Pre-Difficulty 3, 17	School 1	7	6.000	2.0817	.7868	4.075	7.925	3.0	8.0
	School 2	9	4.333	.7071	.2357	3.790	4.877	3.0	5.0
	School 3	1	4.000	.	.	.	.	4.0	4.0
	School 4	7	3.429	1.8127	.6851	1.752	5.105	.0	6.0
	Total	24	4.542	1.7932	.3660	3.784	5.299	.0	8.0
Post-Difficulty 3, 17	School 1	7	6.143	1.4639	.5533	4.789	7.497	4.0	8.0
	School 2	9	4.222	.8333	.2778	3.582	4.863	3.0	5.0
	School 3	1	6.000	.	.	.	.	6.0	6.0
	School 4	7	3.429	1.1339	.4286	2.380	4.477	1.0	4.0
	Total	24	3.208	.9882	.2017	2.791	3.626	1.0	4.0

Importance Scale. How valuable a student may consider STEM education, to both their intellectual development and to career pursuits is, for this study a measure of the level of importance STEM is to the student. The questionnaire items 4, 6, 8, 9, 10, 11, 12, and 13 comprised the Importance scale, and items 10, and 13 were formulated as negative items and scored in a reversed order. One-way ANOVAs were run to compare the effect of the independent variable School on both pre-Importance and post-Importance, and a paired t-test on the pre-Importance and post-Importance means was also run. There was no significant effect of the school attended on either pre-Importance or post-Importance of STEM education amongst the participants of the study, at the $p < .05$ level for the conditions, [$F(3,20)=.528$, $p= .668$] and [$F(3,20)=.253$, $p=.858$], respectively (see Table 18). The pre- and post- Importance scales were analyzed by the paired t-test shows a slightly lower mean value for the participants of the treatment group after the STEM sessions than before, and this difference is not significant $t(23)= .385$, $p=.704$. The paired sample correlation test measures the bivariate Pearson Correlation Coefficient with a two-tailed significance for each pre- post- Importance scale average for each participant (see Table 19), and it shows a significant positive correlation ($r=.489$, $p=.015$). The results suggest that there was not a significant difference in the Importance scale data of the participants as a function of the school that they attended. The scatter plot of pre-Importance vs post-Importance shows a mild positively significant correlation between the two.

Table 18

Mean, SD of Pre- Post- Importance by Schools

Descriptives					
Pre-Scale Item Bldg		N	Mean	Std. Deviation	Std. Error
Pre-Importance 4, 6, 8, 9, 10, 11,12, 13	School 1	7	20.143	7.6470	2.8903
	School 2	9	22.778	3.8006	1.2669
	School 3	1	26.000	.	.
	School 4	7	22.143	4.2984	1.6246
	Total	24	21.958	5.2043	1.0623
Post-Importance 4, 6, 8, 9, 10, 11,12, 13	School 1	7	22.857	7.4482	2.8152
	School 2	9	20.444	4.1866	1.3955
	School 3	1	21.000		
	School 4	7	21.714	4.9232	1.8608
	Total	24	21.542	5.2831	1.0784

Table 19

Pre- Post Importance Paired Mean, SD

Paired Samples Statistics					
		Mean	*N*	Std. Deviation	Std. Error Mean
Pair 1	Pre-Importance 4, 6, 8, 9, 10, 12, 13	21.958	24	5.2043	1.0623
	Post-Importance 4, 6, 8, 9, 10, 12, 13	21.542	24	5.2831	1.0784

Knowledge Total Score. This study takes a very basic view of the term knowledge base. For our purposes, a knowledge base is the existing data, information, or understanding, of the participant about the relevant STEM subject matter at hand. Nascent knowledge is data, information, or understanding that is caused to be added to the participant's knowledge base due to the study interventions. The questionnaire items 18, 19, 20, 21, 22, 23, 24, 25, and 26 comprised the Knowledge scale. A statistical test for a significant change in knowledge of the treatment group was examined using a paired samples t-test (see Table 20). An increase in the mean of the knowledge base was realized (M=2.54, SD=1.32, for the pre-Knowledge and M=3.33, SD=1.52, for the post-Knowledge), But the paired samples correlations showed a very low Pearson's product-moment correlation coefficient between the two variables, which showed no correlations (r=.058, N=24, p=.798). The pre- and post- Knowledge scales paired samples test showed no statistical significance to the observed difference $t(23)$= 1.983, p=.059.

An ANOVA test was conducted on the Knowledge scales and the results are given below. The tables below show the means, *SD*, and SE for each school, both pre-Knowledge and post-Knowledge of the participants in the treatment group. The large *SD* of schools 1, 2, and 4 show that the means, although similar, represent a spread-out distribution of the participants from that school. The Post hoc comparisons using the Tukey H*SD* test indicated that none of the pre-Interest mean scores and their *SD* for any of the schools were significantly different. Also, the post-Interest mean scores and their *SD* were not significantly different from the pre-Interest mean scores. There was no significant effect of the school attended on either pre-Importance or post-Importance of STEM education amongst the participants of the study, at the $p < .05$ level for the between-groups pre- and post- Knowledge, [$F(3,20)=2.434$, $p= .095$] and [$F(3,20)= 1.679$, $p=.203$], respectively.

Table 20

Mean, SD of Pre- Post-Knowledge by Schools

Descriptives					
BldgS		N	Mean	Std. Deviation	Std. Error
Pre-Knowledge Total 18, 19, 20, 21, 22, 23, 24, 25, 26	School 1	7	3.571	1.6183	.6117
	School 2	9	2.222	.6667	.2222
	School 3	1	2.000	.	.
	School 4	7	2.000	1.2910	.4880
	Total	24	2.542	1.3181	.2691
Post-Knowledge Total 18, 19, 20, 21, 22, 23, 24, 25, 26	School 1	7	3.143	1.2150	.4592
	School 2	9	3.111	1.6915	.5638
	School 3	1	1.000		
	School 4	7	4.143	1.3452	.5084
	Total	24	3.333	1.5228	.3108

Comparative Results. Independent t-tests to compare the pre-study scores for both treatment and control participants revealed that both groups came from the same population, with exception for the pre-Difficulty scale, treatment M= 6.375, control M=5.600; conditions; t(23)=.935, p=.003. The paired t-test was used to compare the pre-post- questionnaire means for the control group, and showed that there was no even though there was an increase in the mean post knowledge scale, from pre- *M* = 2.200 to post- *M* = 4.00 it was not statistically significant *t(4)*=1.500, *p*=.208). The Paired Samples Correlations which test measures the bivariate Pearson Correlation Coefficient with a two-tailed significance for each pre- post-knowledge scale average for each participant, showed no significant correlation (*r*=-.204, *p*=.742) between the two variables of pre- and post- Knowledge, for the control group. The same was true for paired t-test of pre- post-questionnaire means of Interest, Difficulty, and Importance for the control group participants *t(*4)=.-2.388, *p*=.075; *t*=.-.919, *p*=.410; *t(*4)=-2.202, *p*=.092, respectively.

The data below (see Table 21) examines the dependent variable pre-Knowledge total, which gives the total score of the knowledge portion of the pre- test questionnaire (items 18 through 26) by gender, male and female. The positive skewness and kurtosis for both groups indicate right-skewed, leptokurtic distributions for both. The mean and standard error for females (*M*=2.400, *SD*=1.18), while the mean and standard error for males is greater (2.778, *SD*=1.56), (Kim, 2013). The calculated skewness and kurtosis z-values (female, *Z*=0.47,1.14; male, *Z*=1.71, 0.71) suggest that both distributions are normal. The Shapiro-Wilk test agrees that the female distribution is normal but does not agree that the male distribution is normal (see Table 9). This may be due to the small sample used, and for this study, both distributions are assumed normal.

Univariate analysis of variance (ANOVA) of the independent variable gender for the dependent variable, delta-Knowledge, which expresses the change in the Knowledge score after the intervention, showed that females (*N*=18, *M*=1.17) had a larger mean difference than males (*N*=11, *M*=.64). Levene's Test for Equality of Error Variances

Table 8

Mean, Standard Deviation and Shapiro-Wilk by Gender

Gender (F, M)	*N*	Pre- K Mean	*SD*	Shapiro-Wilk statistic	df	sig.
F	15	2.40	1.18	.912	15	.146
M	9	2.78	1.56	.813	9	.029

showed that the variances between the female mean and male mean were not significant (F=0.392, p=.536). The Tests of Between-Subjects Effects (F=0.435, p=.515), which was not significant, and therefore gender could not account for the variability difference between the means (η2=0.016).

The univariate analysis of variance (ANOVA) of the independent variable group for delta-Knowledge, shows that the treatment group's mean difference was less than the control (N=24, M=.79, and N=5, M=1.80, respectively). Levene's test showed that this difference was not significant (F=1.493, p=.232). The Tests of Between-Subjects Effects (F=0 .973, p=.333,) was not significant, and therefore group could not account for the variability difference between the means (η2=0.035).

The univariate analysis of variance (ANOVA) of the independent variable Day of Session for delta-Knowledge, shows that the Monday group's mean difference was less than The Tuesday group mean (N=17, M=.29, and N=12, M=1.92, respectively). Levene's test showed that this difference was not significant (F=2.512, p=.125). The Tests of Between-Subjects Effects (F=4.881, p=.036,) was significant, and therefore Day of Session accounts for 15% of the variability difference between the means (η2=.153).

Table 9 examines the dependent variable pre-Knowledge Totals, which gives the total score of the knowledge portion of the pre- test questionnaire (items 18 through 26) by Day of the session, Monday and Tuesday.

Table 9

Mean, Standard Deviation and Shapiro-Wilk by Day of Session

Day(M, T)	N	Pre- K Mean	*SD*	Shapiro-Wilk statistic	df	sig.
M	16	2.81	.3319	.840	16	.010
T	8	2.00	.4226	.932	8	.534

Using Principal Components Analysis, a new variable was computed named Delta2Attitude on components Delta2Interest, Delta2Difficulty, and Delta2Importance. The correlation Matrix yielded fair correlations between Delta2Intrest and Delta2Difficulty, Delta2Interest and Delta2Importance, and Delta2Difficulty and Delta2Importance (r=.476, r=.328, and r=.425, respectively). The component loadings for Delta2Attitude are all very strong, ranging from .73 to .83. A test of the assumption of the homogeny of covariance of the treatment group and control group yielded unstandardized beta weights of B= -.502, p=.256 for the Treatment group and a B=-.825, p=.489 for the Control group, which again verifies that there is no significant difference between the two groups. A confirmation of this is when you run univariant ANOVA using and look at homogeneity of regression assumption on Group*Delta2Attitude which yielded F=2.222, p=.149, and an η^2=.010. The ANCOVA did not reveal that the Delta2Attitude could account for by the difference in Treatment and Control Delta2Knowledge results.

Table 21

Mean, SD of Pre- Post- Knowledge by Gender

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Pre-Knowledge Total 18, 19, 20, 21, 22, 23, 24, 25, 26	Female	15	2.400	1.1832	.3055
	Male	9	2.778	1.5635	.5212

Table 22

Independent Samples t-Test

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Post-Knowledge Total 18, 19, 20, 21, 22, 23, 24, 25, 26	Test	24	3.333	1.5228	.3108
	Control	5	4.000	2.2361	1.0000
Post-Interest 1,2,5, 7, 14,15,16	Test	24	16.875	5.3105	1.0840
	Control	5	18.200	2.2804	1.0198
Post-Difficulty 3, 17	Test	24	7.375	1.8839	.3845
	Control	5	7.400	2.6077	1.1662
Post-Importance 4, 6, 8, 9, 10, 11, 12, 13	Test	24	18.875	4.7486	.9693
	Control	5	19.600	3.3615	1.5033

Table 23

t-test for Equality of Means

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Post-Knowledge Total 18 - 26	Equal variances assumed	.445	.511	-.823	27	.418	-.6667	.8102	-2.3290	.9957
Post-Knowledge Total 18 – 26	Equal variances not assumed			-.637	4.80	.553	-.6667	1.0472	-3.3922	2.0589
Post-Interest 1,2,57,14-16	Equal variances assumed	2.184	.151	-.541	27	.593	-1.3250	2.4478	-6.3475	3.6975
Post-Interest 1,2,5,7,14-16	Equal variances not assumed			-.890	14.9	.388	-1.3250	1.4883	-4.5001	1.8501
Post-Difficulty 3, 17	Equal variances assumed	.240	.628	-.025	27	.980	-.0250	.9869	-2.0500	2.0000
Post-Difficulty 3, 17	Equal variances not assumed			-.020	4.91	.985	-.0250	1.2280	-3.1996	3.1496
Post-Importance 4, 6, 8, 9, 10-13	Equal variances assumed	1.066	.311	-.323	27	.749	-.7250	2.2465	-5.3344	3.8844
Post-Importance 4, 6, 8, 9, 10-13	Equal variances not assumed			-.405	7.78	.696	-.7250	1.7887	-4.8699	3.4199

Effect Size. The Hedges' g calculation was used to determine the effect size of the interventions. Hedges' g was used instead of Cohen's d because of the small sample sizes of the groups (N=24, treatment and N=5, control) to determine a somewhat corrected effect size. (Daniel & Kostic, 2019). A comparison was made between the treatment and control groups' quantitative data, both before the interventions, after the interventions, and the change in values (the delta), after the interventions, to give another measure of the difference of means of the two groups. The Excel software provided by Daniel and Kostic (2019) was used to calculate the effect sizes listed in this study. The results are listed in Table 24 below. All other related Tables are given in the Appendix. All of the Hedges' g values are below +/- .8, signifying that the differences cannot be discerned by the naked eye.

We assumed that, for this study, *g*= 0.3 is a small to medium effect between the means, then the pre- scales of Interest, Difficulty, Knowledge, and the Likert scales taken as a whole, are all small to medium effect or difference between the means of the Treatment and Control groups (*g*= .381, .447, .258, and .257, respectively) whereas the scale for Importance yielded a very small effect between the treatment and control groups (*g*=-.147). Appendix A reveals that after the interventions, the post- scale of Interest and the Knowledge score both yielded a small to medium effect between the treatment and control groups (*g*=.381, -.393 respectively), and the Difficulty, Importance, and the Likert scales taken as a whole all did not yield any effect due to the interventions (*g*=-.012, -.216, and -221, respectively). When we examine the change in each scale or score we find that Interest, Difficulty, Knowledge and the Likert scales taken as a whole yielded a small to medium effect between the treatment and control groups (*g*= -.415, -.291, -.471, and -.330 respectively) while the Importance scale has a small effect due to the intervention (*g*=-.074).

Table 24

Effect Size of Treatment Control Means

Statistics	Group	N	Mean	*SD*	Hedges' g	r2
Pre-Interest Scale Total	Treatment	24	13.083	2.5007	.381	.005
	Control	5	12.000	3.9370		
Pre-Difficulty Scale Total	Treatment	24	6.375	1.1726	.447	.007
	Control	5	5.600	3.3615		
Pre-Importance Scale Total	Treatment	24	15.208	2.6862	-.147	.001
	Control	5	15.600	1.9494		
Pre-Knowledge Total	Treatment	24	2.542	1.3181	.258	.002
	Control	5	2.200	1.0954		
Pre-Likert Scales Total	Treatment	24	34.6667	4.86037	.257	.0082
	Control	5	33.2000	8.46759		

Qualitative Results

The qualitative data were analyzed in consideration of the study's qualitative portion of the research hypothesis, RQ2:

To what extent does the introduction of mobile devices as STEM tools of inquiry during maker activities have on the attitude of African American students toward STEM activities at the lower secondary education level?

The qualitative results of the study were interpreted from two subsets of data: the observation notes made during the six sessions of the study and the four transcripts of the focus group responses. The observations for each session are divided into two parts, one for the treatment group and one for the control group. Each focus group consisted of seven main prompt questions.

Observations

Observations were made using the method known as "direct observation" as a "partially participating observer", as discussed in the Observation method, (Ciesielska et al., 2018). Direct observation occurs in real-time when the object of observation is happening. Ciesielska et al. define a partially participating observer as one who "takes part in the interactions, but not in the type of activity that is specific to the studied environment (2018, p 40). The participants knew that the observer was the researcher collecting data about their response to the STEM study. The researcher made his observations fully aware of the potential for bias on his part from preconceived notions about STEM education and from being the sole observer with a singular perspective on each observation. Both of these sources of bias may influence what is observed and how it is interpreted. Also, in an environment involving middle school students, it is certain that many events will occur that may attract the attention of the observer, but are not directly related to the study at hand. Consequently, an attempt was made to document only observations that related to the study and to always weigh how much the perspective of the researcher has affected the meaning of the observation.

Observations were made before, during, and immediately following each group session. Periodically, the researcher would leave the test group and spend time with the control group. Notes were taken as discretely as circumstances would allow. Since in a learning situation many youthful learners are accustomed to asking any adult in the class for assistance, the observer did at times interact with the participants, but an attempt was made to answer only non-study related questions and to relay any study-related questions to a Table worker, Green Tower representative, or the instructor.

The following was observed: the environment and setting of the session, the demographics of each group at each session, what activity was presented during each session, what was both the individual and group responses to the activities, the interactions within groups, the interactions between the participants and the instructor and other adult leaders present, and the behavior of the participants when attempting the maker activities. The emotional and mental effects were judged by the observer, taking into effect, body posture, alertness, facial expressions, and spoken phrases. The behaviors were assessed considering the actions, both individual and group, with the response to the class tasks at hand. Observations were made of; (1) how the Study influenced the perceived emotions and moods of the participants (Affects), both as individuals and as groups and, (2) how the participants interacted with the instructors, other participants, and the interventions of the Study (Behaviors). The following Table 28 is a list of the codes used for observing the participants. An attempt was made by the instructor to make certain that the Monday group and the Tuesday group followed similar lesson plan chronologies, and apart from the second Monday session, all sessions were held in the same classroom setup. The second Monday session had to be moved to another classroom due to the center's need for large classroom space. The instructor and several adult leaders offered their observations in both a structured and unstructured format, and these are noted at the end of each session observation summary.

Table 28

Observation Codes Used in Direct Observations

Obs Code	OBSERVED AFFECTS	# of Times observed for each session: Mon/Tues						
		Treatment Mon Sessions			Treatment Tue Sessions			total
		1	2	3	1	2	3	
E	Engaged and attentive; appears interested; focused	5	4	7	4	4	5	29
C	Confused about what is being presented; willing but uncertain	3	2		3	1	1	10
B	Bored; uninterested and not willing to engage				1			1
F	Frustrated; Have tried unsuccessfully to comprehend		1	1	2		1	5
D	Delighted; Elated at a successful understanding of the material at hand	4	2	2	5	5	3	21
?A	All other perceived affects or multiple affects		3	3		1		7
	Total	12	12	13	15	11	13	76
	OBSERVED BEHAVIORS							
OT	On task; In sync with the task at hand, and with others	2	2	2	3	2	4	15
OTC	On task with the conversation, verbal interaction with others	5	3	4	3	3	2	20
_XT	Off task; using phone, head on Table; interrupting		2	1	4	3		10
$	Gaming the System; comedic; false involvement; own agenda	1	1	1				3
?B	Other actions by a participant not described above	1	2	2	5	3		13
	Total	9	10	10	15	11	6	61

First Session. During the first day of both sessions, there was an overall feeling of expectation, and a feeling of gladness to be here. Most students seemed curious about the STEM packets and were ready to start. On Monday one African American male participant said:

Can we take this package home? I want to take mine home.

Another Tuesday African American male participant shouted out after he finished his meal:

Hey, what's up! Can we start already?

These statements were a fair demonstration of the feeling of glee that was felt by most of the participants in both sessions. There was also a feeling of unsettledness and confusion by some of the participants on the first session of the study. When the Monday Control group was separated from the Treatment Group, the Control group demonstrated confusion when an African American male said:

What's going on? Why do we have to leave? What are we gonna do?

and a little later, the same male nervously responded:

We NEVER used microscopes!

The same confusion was demonstrated by another African American male when the control group was separated in the Tuesday session:

What are they doing over there? Well, why did we have to leave the group?

There was also some confusion about the taking of photographs that was expressed by some participants on the 1st day of the Tuesday Session until it was explained that it was not connected to the Study but to the Boys and Girls institution.

Second Session. During the second session of both days the participants seemed happy to be at the study right off the buses, and the feeling during the pizza meal was more relaxed, and the participants were slightly more talkative, and it was observed that more pizza slices were consumed although it was delivered about 20 minutes late during the Monday session. There was a slight drop in the number of participants in both sessions who were confused, bored, or frustrated from eight to four.

The observational codes, ?A and ?B, also seems to suggest a more relaxed atmosphere, since on this day the participants were introduced to the Arduino intervention, and one Tuesday session participant stated:

Can't I take this [Arduino and bread board] too? Why not?

While another Tuesday session African American male when he finished his Foldscope, shouted:

I got it, I got it!

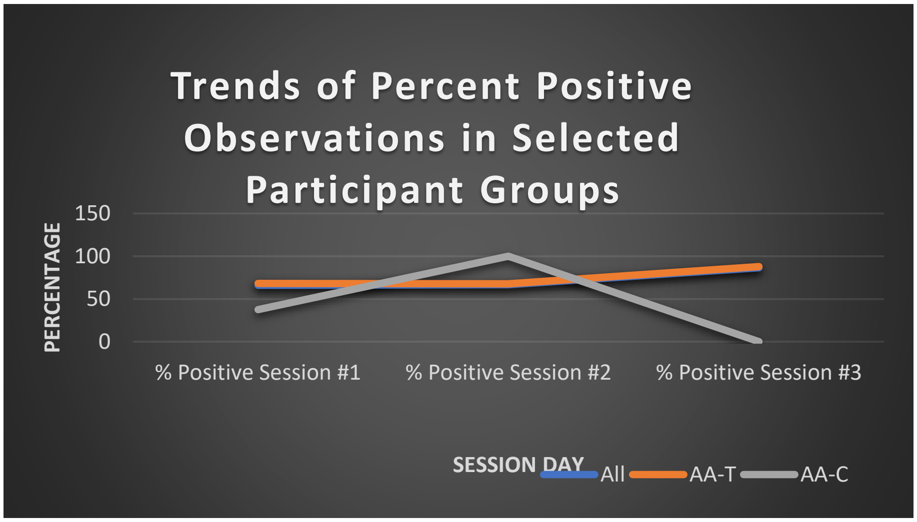
During the Monday second session, three African American females were repeatedly told to stop talking on their phones, although one claimed:

Wait! I was just, um, trying to look this up on YouTube [laugh].

Third Session. Both sessions were surprised and disappointed that the study was ending on that day. On both days some participants personally thanked the instructor and the researcher for the study, expressing frustration that the study was ending too soon, just when things were getting good, and should have been extended. The post questionnaire seemed to go faster than the pre-questionnaire, with many finishing early.

Total Study Trends. Figure 10 shows the trends in positive observations for the selected groups of All Treatment Group Participants (All), African American Participants in the Treatment Group (AA-T), and African American Participants in the Control Group (AA-C). For both the All and AA-T Group sessions 1 & 2 showed about the same amount of positivity in their observed actions with a noticeable increase of 20 percentage points for session #3.

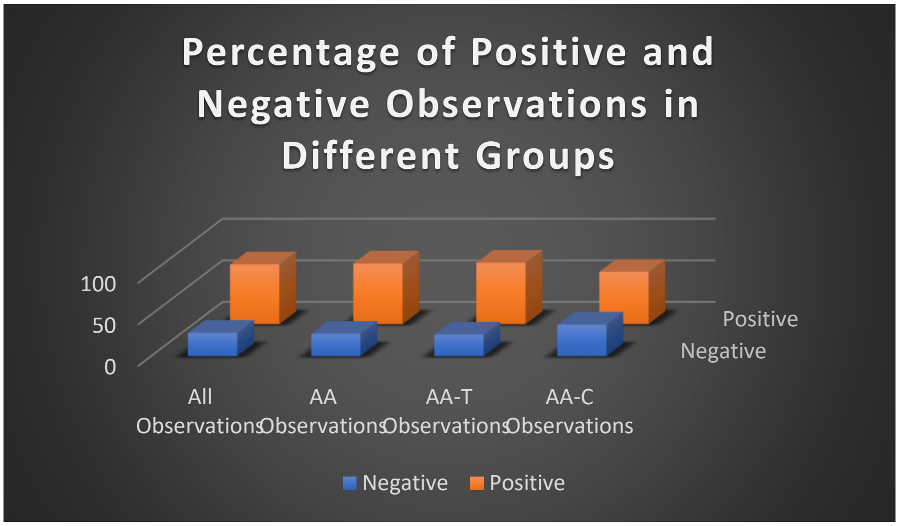
Figure 10
Trends of Observations in Study



The AA-C Group showed an initial increase of 62 percentage points, and then a drop of nearly 100 percentage points of positive observations on session #3. Figure 11 illustrates the comparative percentages of positive and negative observations for the total study for the selective groups of All Participants (All), African American Participants (AA), African American Participants in the Treatment Group (AA-T), and African American Participants in the Control Group (AA-C). A comparison of the AA-T and AA-C groups shows that the treatment group was observed demonstrating positive actions and comments at a higher proportion (74%) than the AA-C group (63%).

Figure 11

Overall Positive vs Negative Observations for the Study



Focus Groups

The focus groups were conducted at the four school premises, during the lunch period. The teachers that had served as Table helpers provided the meeting space and were present during the focus groups to act as moderators if needed. Since the focus group was held during the lunch period, a snack and drink were made available to each participant. Also, as an incentive to attend the Focus Group one of the various STEM gifts was supplied to each participant. The Focus Group time was divided into three sections: the introduction, the question and answer section, and the conclusion. In the introduction, participants were thanked again for partaking in the after-school STEM study, and where participants were allowed to choose their snack items. This was generally the first 2-4 minutes; the question and answer section, which lasted 23-26 minutes; and the conclusion, where the participants were again thanked for their contributions to the study and were allowed to choose a parting STEM gift.

The dates for the collection of each subset of data and their objectives are shown in Table 25. There were 36 codes developed from the four focus groups answers to the 7-prompt questions, which were manually clustered into seven codes keys, and then grouped into four major themes; Classroom Elements (CE), Program Elements (PE), Participant Self-Efficacy (PS), and a theme called Summer Camp (SC), to indicate who would be willing to attend an extended STEM class during the summer.

Table 25

Objectives of Each Session and Focus Group Participants

Objective	Date	Schools Present	Treatment group material covered	Control group material covered
1st Week of Study	1-27, Mon	A & B	Intro, Pre-Questionnaire	Intro, Pre-Questionnaire
	1-28, Tues	C & D	Intro, Pre-Questionnaire	Intro, Pre-Questionnaire
2nd Week of Study	2-03, Mon	A & B	Foldscope with a cellphone, and Green Towers	Microscope with Green Towers
	2-04, Tues	C & D	Foldscope with a cellphone, and Green Towers	Foldscope with Green Towers
3rd Week of Study	2-10, Mon*	A & B	Arduino spectrometer, Post-Questionnaire	Chlorophyll Color Extraction, Post-Questionnaire
	2-11, Tues	C & D	Arduino spectrometer, Post-Questionnaire	Chlorophyll Color Extraction, Post-Questionnaire
1st Focus Group	2-25, Tues	A	9-Participant Focus Group based on 7-prompt questions	
2nd Focus Group	2-26, Wed	B	13-Participant Focus Group based on 7-prompt questions	
3rd Focus Group	2-28, Fri	C	5-Participant Focus Group based on 7-prompt questions	
4th Focus Group	3-2, Mon	D	9-Participant Focus Group based on 7-prompt questions	

Table 26 shows the relational structure of the Focus Group Themes. Table 27 shows the major themes concerning the treatment and control groups. The. major themes of the African American treatment group (AA-T) for all of the schools were remarks concerning the Participant Self-efficacy; how their personal experience was relative to the study, and how they felt about STEM. The second was Classroom Elements; style of pedagogy, the setting and environment, and how to improve the interactions and intra-actions between the participating schools. Third, was Program Elements; such as expressing an interest in the technology used and the excitement about participating in the mobile device assisted maker activities. The final theme was that of Summer Camp; whether the participant would like to attend a longer version of this study, or whether they were inspired to attend a STEM summer event somewhere else. The control group data differed in that PE and CE switched in their order. This may be due to the interactions between the control group and the treatment group outside of the study and sharing experiences with or without the technologies of the study.

Table 26

Focus Group Codes and Themes

Codebook	Code Key	Themes
Environment	**A**	**Classroom Elements**
Liked Environmental Conditions; Setting	ES+	Pedagogy
Impartial to Environmental Conditions; Setti	ES0	Enviroment
Disliked Environmental Conditions; Setting	ES-	
Environmental Conditions; Transportation	ET	**Program Elements**
Liked Environmental Conditions; Food	**EF+**	Technology
Impartial Environmental Conditions; Food	**EF0**	Maker
Disliked Environmental Conditions; Food	**EF-**	
		Participant Self-Efficacy
STEM Knowledge	**S**	STEM Interest
Low Knowledge in STEM	S-	Experience
Moderate Knowledge in STEM	S0	
High Knowledge in STEM	S+	**Summer Camp**
Pedagogy	**P**	
Liked Pedagogy	P+	
Improve Pedagogy	IP	
Group Learning	G	
Maker	**M**	
Liked Hands On	H+	
Impartial Hands On	H0	
Disliked Hands On	H-	
Technology	**T**	
Liked Cell Phone Usage	C+	
Impartial Cell Phone Usage	C0	
Disliked Cell Phone Usage	C-	
liked Arduino/Foldscope Usage	A/F+	
Impartial Arduino/Foldscope Usage	A/F0	
Disliked ArduinoFoldscope Usage	A/F-	
Experience	**E**	
Positive Experience	E+	
Neutral Experience	E0	
Negative Experience	E-	
Time too short	ET+	
Summer Camp	**C**	
Would Like to Attend A Summer Camp	Yes+	
Would Like to Attend, but cannot	CN+	
Would Not Like to Attend a Summer Camp	No-	

Table 27

Summary of Themes Expressed by School in Focus Groups

Theme	School 1		School 2		School 3		School 4		All Schools	
	AA-T	AA-C	AA-T	AA-C	AA-T	AA-C	AA-T	AA-C	AA-T	AA-C
CE	16	1	9	2	0	1	8	0	33	4
PE	8	3	10	2	0	2	7	2	25	9
PS	10	0	19	3	0	5	6	4	35	12
C	5	2	3	0	0	1	7	1	15	4
Total	39	6	41	7	0	9	28	7	108	29

Generally, the introduction phase was quite lively and loud, until the teacher settled the group down. Then when the question and answer period started, immediately there was an atmosphere of general seriousness that filled the group. The conclusion was a little hectic since the participants had to both select a gift and make it to their next class. It should be mentioned that some who attended the Focus Group did not complete both pre and post questionnaires but were allowed to participate in the group, with some giving responses based on their limited experience. The number of responses, 168, to the prompt questions, given in Table 29, started light, increased to question #3, and then tapered off to question #7, the lowest of all the responses. This amounts to an average of 42 questions for an average of 25 minutes of Focus Group answer time. Also, question #3 dominated the responses with an average of 42% of the total time spent on this question. Some questions were coded more than once, resulting in 51 extra response codes for a total of 219 response meaning units. These units can be broken down by schools: School #1 - 48, School #2 - 56, School #3 - 49, and School #4 - 66. The make-up of the focus groups was fairly similar to the make-up of the study participant group, although it did not reflect the participation by schools; (compare Figure 12 and Figure 5). Although School #4 had the largest percentage of participants who completed the study (38%), they contributed less than their share to the Focus Groups Session (26%). The opposite was observed for School #2, who represented 26% of the Study participants (26%) that contributed much more to the Focus Group Session than they should have (35%). The Focus Groups for School #1 and School #3 had the greatest male participation at 78% and 60% respectively, compared with the total male participation for all focus groups of 36%. School #2 had greater female participation at 85%, whereas the total female participation for all focus groups was 55%. School #4 had the greatest other participation proportion at 22% compared to a proportion of only 9% for all focus group participants.

Figure 12

Demographics of Participation in Focus Groups by School

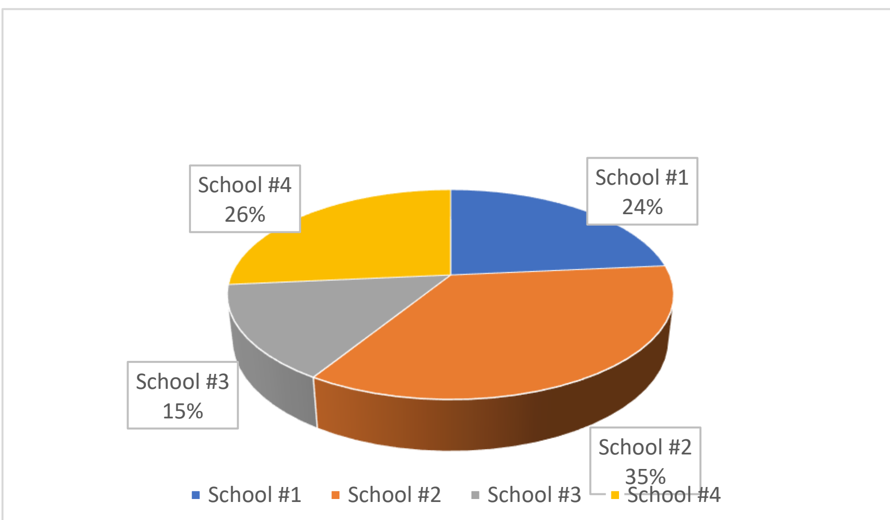
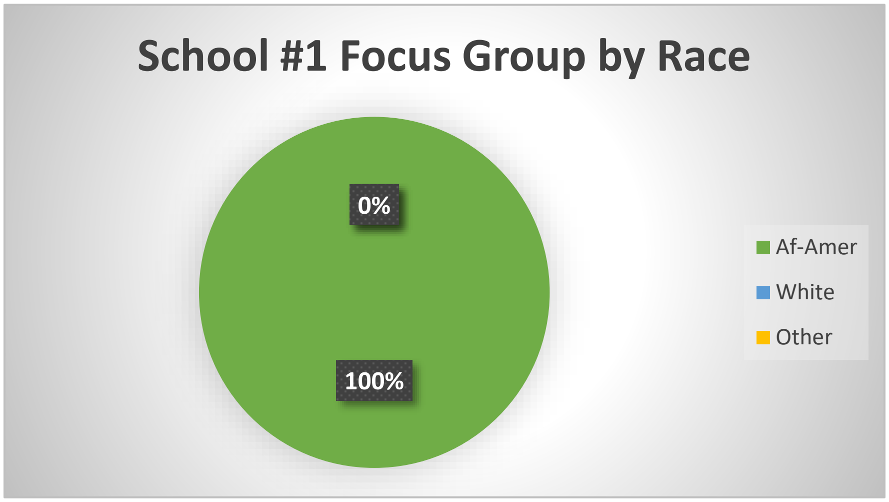


Figure 13a

Focus Group for School #1 by Race



Figures 13a-13d illustrate the racial make-up of the focus groups ranges from a high of 100% African American for School #1 to a low of 20 % for School #3, as compared to 78% for all four school participants.

Figure 13b

Focus Group for School #2 by Race

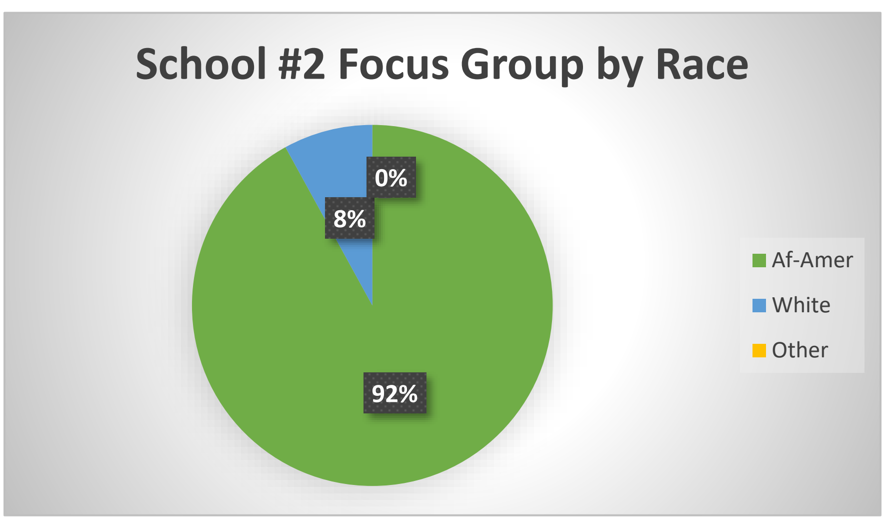


Figure 13c

Focus Group for School #3 by Race

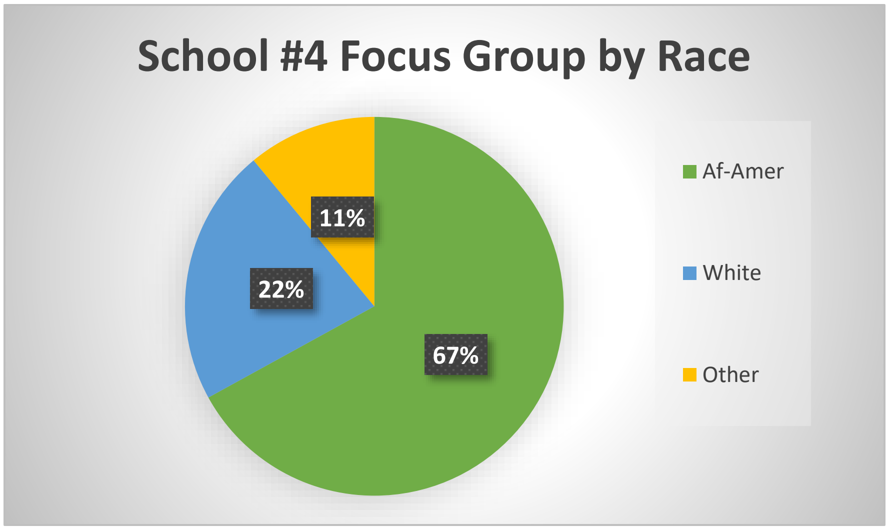
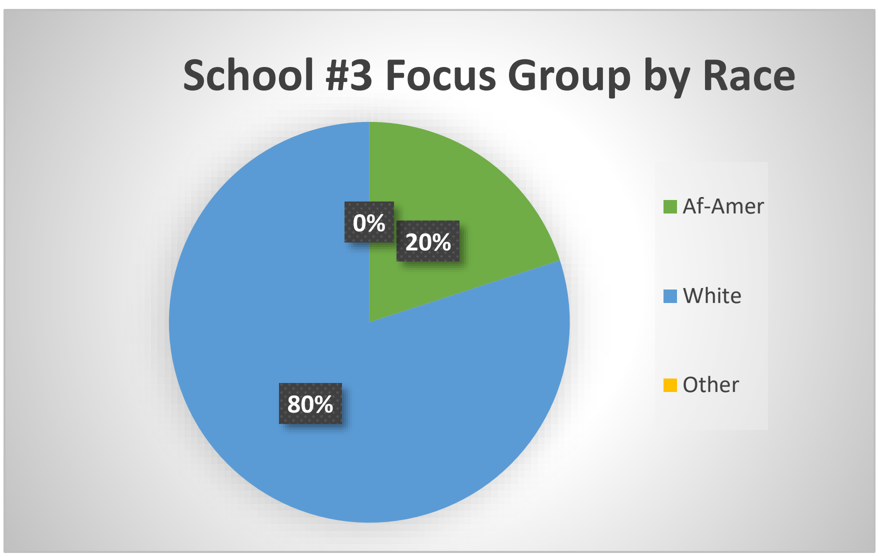


Figure 13d

Focus Group for School #4 by Race



Figures 14a-14d show the responses of each school to the seven-question prompts used during each focus group session. By far prompt question #3 generated the greatest response in each of the focus group sessions.

Figure 14a

Number of Responses from School #1

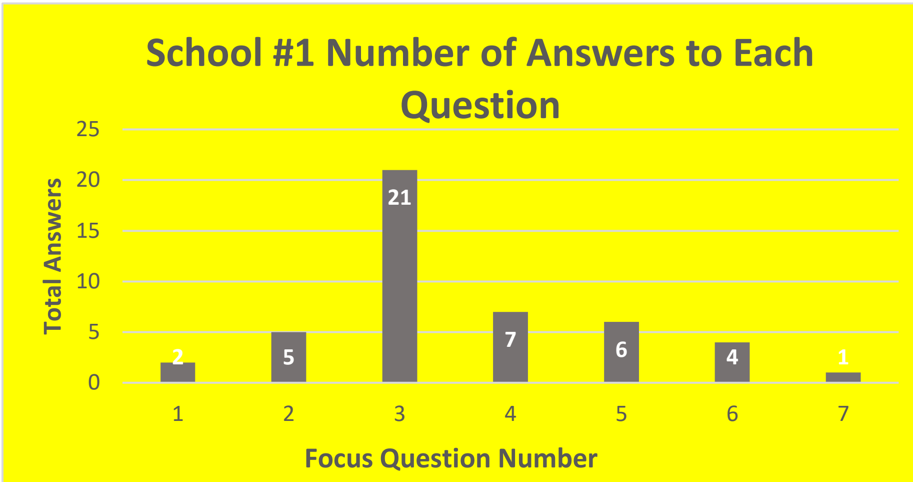
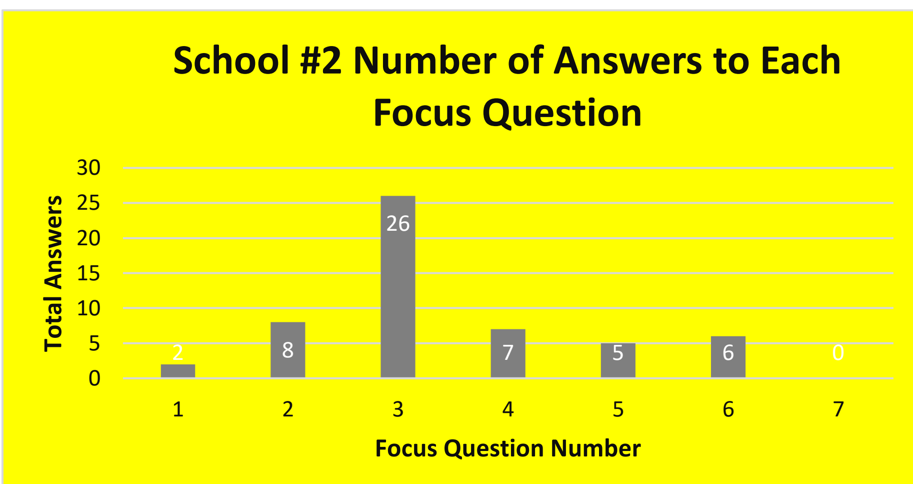


Figure 14b

Number of Responses from School #2



School #4 gave the greatest number of responses to question #1, question #2, question #4, question #5, and question #7. School #2 gave the greatest number of responses to question #3, and question #6.

Figure 14c

Number of Responses from School #3

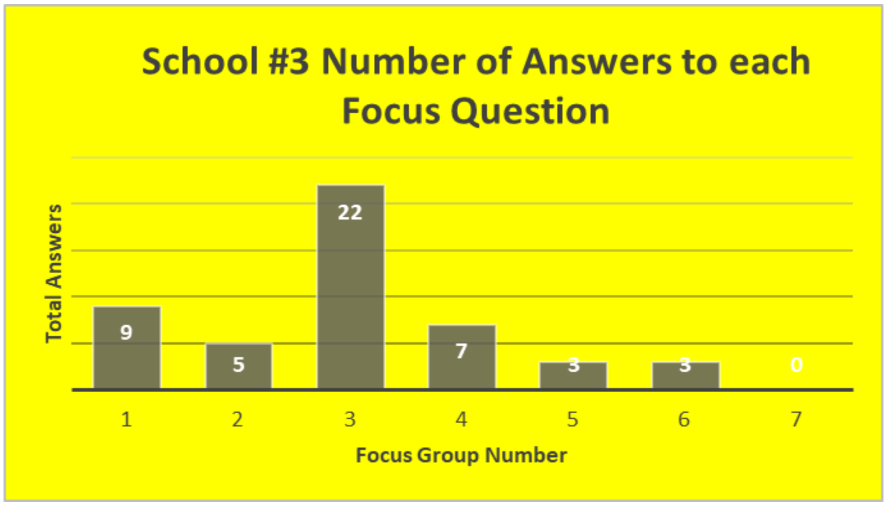
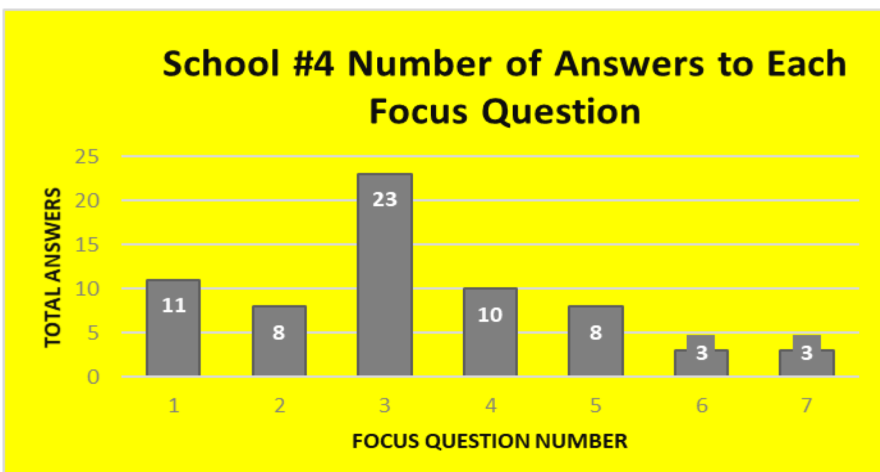


Figure 14d

Number of Responses from School #4



Figures 15a-15d considers the make-up of the respondents in each focus group, and how many times each individual responded. School #2 had the greatest number of participants who responded less than two times, with an average of four responses per participant. School #3 had the greatest response from anyone participant, 15, with an average of 10 responses per participant. School #4 had the greatest number of responses with a total of 66 responses with an average of seven responses per participant.

Figure 15a

Responses per Focus Group Participant from School #1

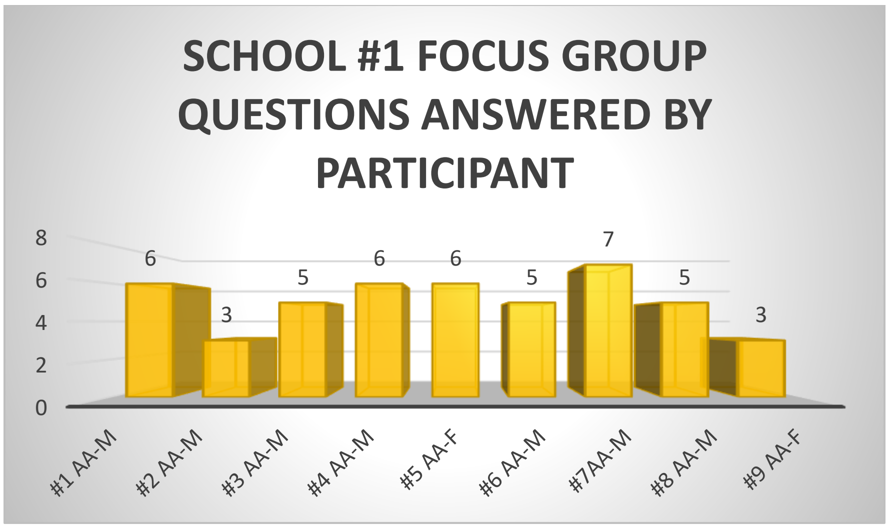


Figure 15b
Responses per Focus Group Participant for School #2

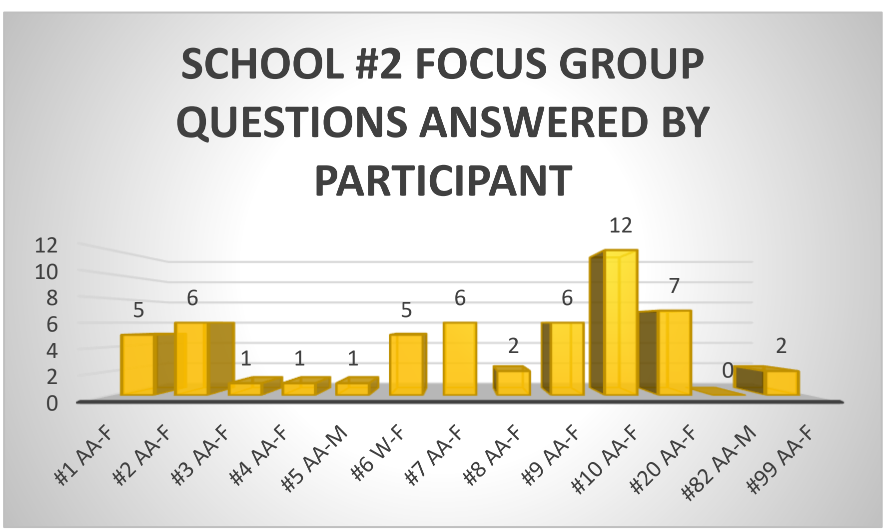


Figure 15c

Responses per Focus Group Participant from School #3

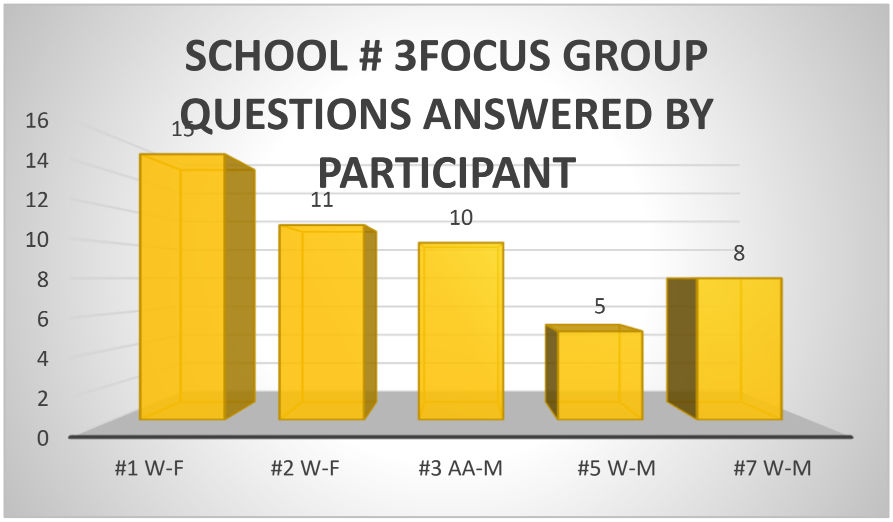
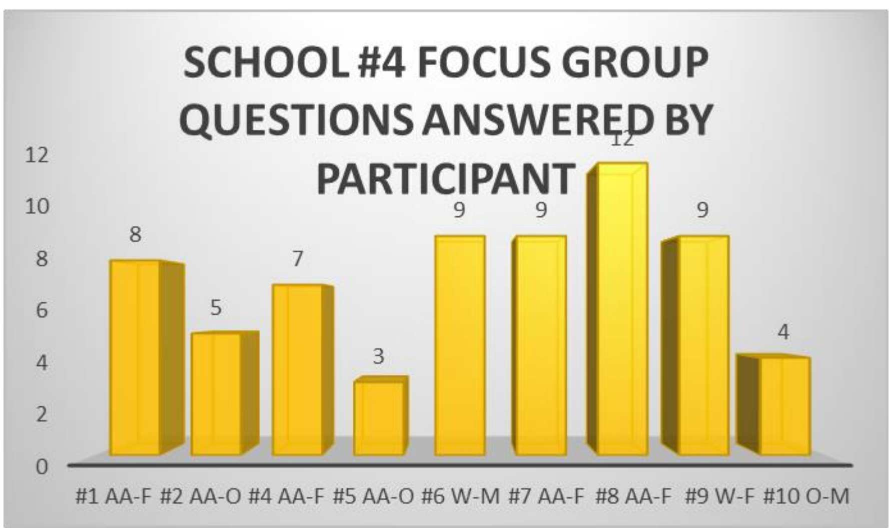


Figure 15d

Responses per Focus Group Participant from School #4



Figures 16a-18d show the relationship of each theme to the AA-T and AA-C participants. It is noticeable that School #1 had the greatest response to the CE theme, which is due to the teaching pedagogy and the study environment, such as food served, transportation, building location. The other three schools were more focused on PS-related themes, such as technology, and maker-related topics. School #3 only had African-American participants in the control portion of the study.

Figure 16a

Control vs Treatment Responses of School #1

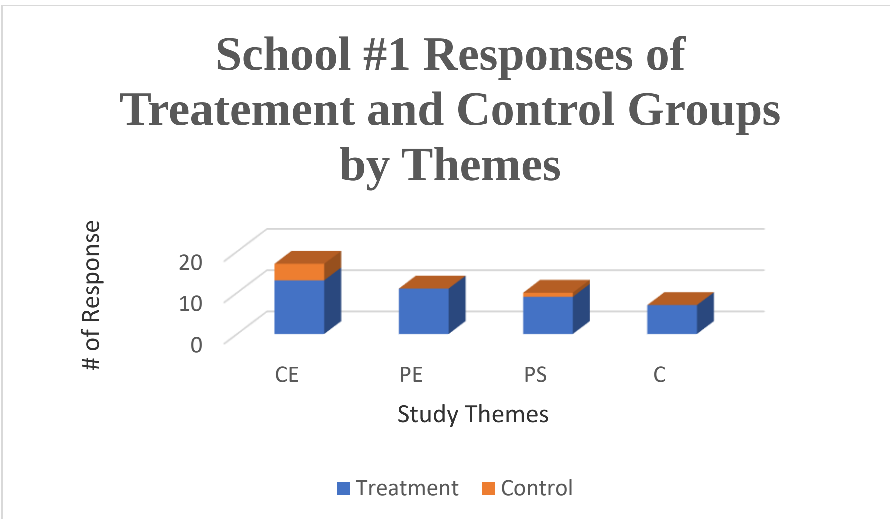


Figure 16b

Control vs Treatment Responses of School #2

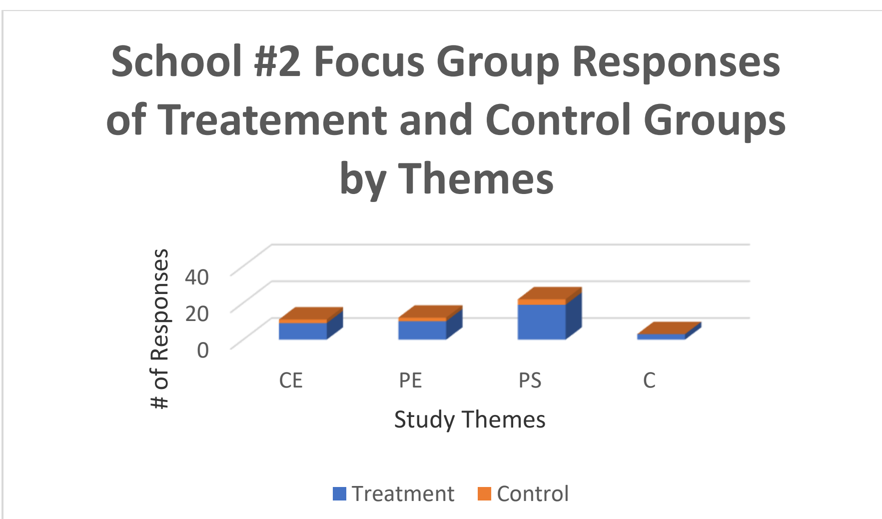


Figure 16c

Control vs Treatment Responses of School #3

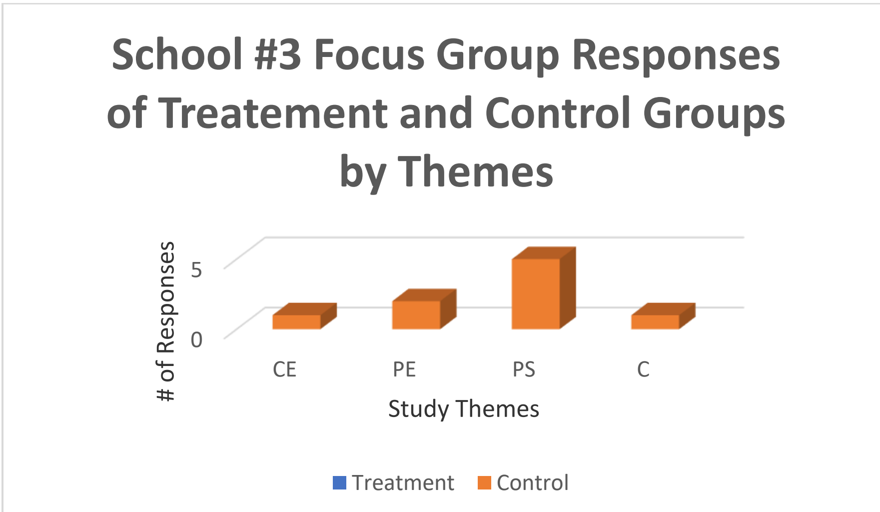


Figure 16d

Control vs Treatment Responses of School #4

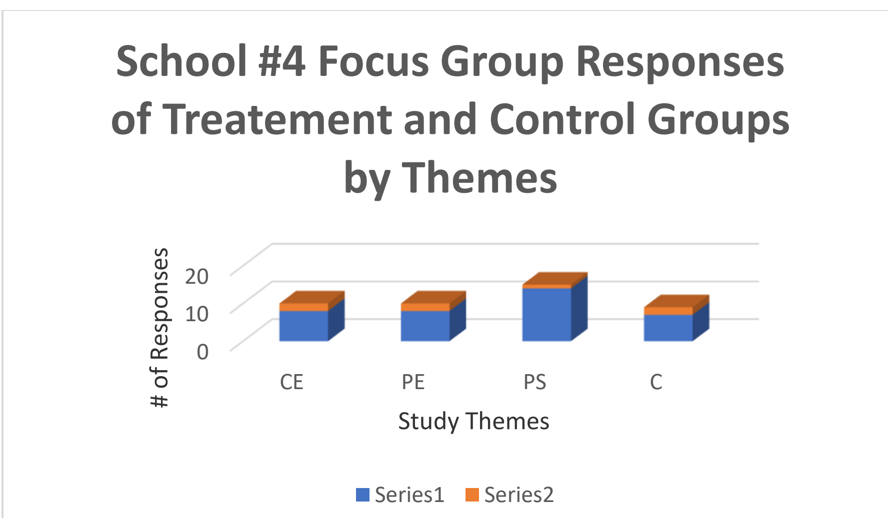


Table 29

Focus Group Prompt Questions

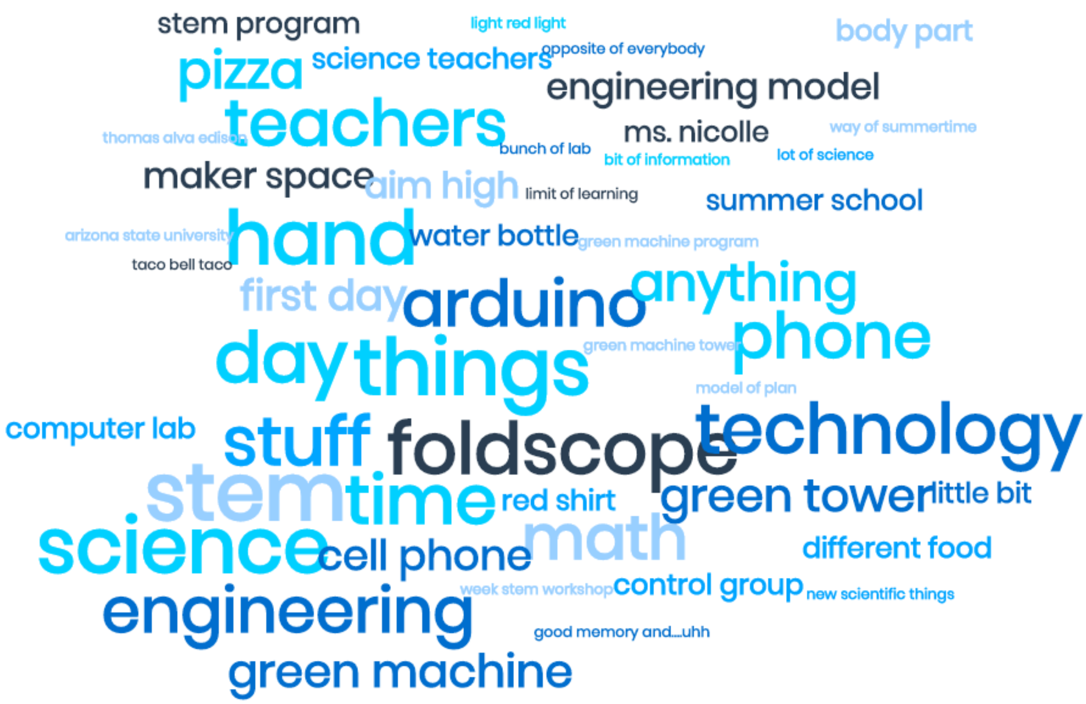
Question order asked	Focus Group Prompt Questions	Number of responses to each prompt question
#1	What does STEM mean to you and your education at your school?	15
#2	How is STEM used in your classroom at (your school) ?	24
#3	What did you Like, dislike, or would change about the Green Tower STEM STUDY	71
#4	Would you like to attend a STEM Summer Program and if so why, or why not?	26
#5	Did you like working with your hands and your phone to make things?	16
#6	Did it help you learn better?	14
#7	Is there anything else that you would like to mention?	2

Word Cloud

Word Clouds are visual algorithms that use words, font color, and font size to signify the relative importance of the word or phrase in the text, or a data array. They began as a kind of spare-time toy but have found great promise as a visual presentation of big data (Viegas, Wattenberg, & Feinberg, 2009). Below is the Word Cloud for all of the focus group responses from all of the schools. The Word Clouds representing the responses from each school can be found in the Appendix E. They provide a rudimentary organization of what is prominent within the content of responses. Presenting a visual snapshot of the content of what was said in the narratives, and is helpful in first impressions of analyzing data.

Figure 17a

All Four School Focus Groups Word Cloud



As to be expected, the majority of the prominent words in the group Word Cloud found in Figure 17a deal with the major focuses of the study; technology, foldscope, green tower, Arduino, etc. This relates to the themes of Engaged (E), Delight (D), and On Task (OT), All of which are positive, and demonstrate a high Attitude towards STEM. A closer look at the lesser words and we find a significant focus based around food; pizza, different food, taco bell. Although these are not necessarily primarily related to this related, they do reflect that setting and environment are important considerations in studies such as this one. The remainder of the Word Clouds generated by the individual schools is found in Appendix E (Figures 17b-17e). Figure 17b represents the Word Cloud for school #1. The most prominent focuses in this cloud are Food-related, vacationrelated, and instructor-related, once again revealing that environment and pedagogy are important secondary considerations in the research design. There is little direct reference to technology, smartphones, or the two interventions. The School #2 Word Cloud (Figure 17c) reflects topics that are related to the study; technology, Arduino, foldscope, cell phone, STEM, Green Machine, teachers. The secondary topics are also related to the study, with little reference to extraneous subjects such as food, which reflect what was observed in general during the direct observation component of this study. School #3 (Figure 17d) is very similar to School #2 in that its Word Cloud's primary and secondary references are to technology and the emphasis of the study. The word cloud for School #4 (Figure 17e) reflects the themes of the study, referencing Foldscope, science, cell phone, Arduino, and teachers as significant references.

Summary

In summary, the results have been presented in this chapter and their relationship to the two research questions. The 29 middle school African American participants in this study were separated into either treatment (24) or control (5) groups; with mobile devices. Then both were observed and pre-and post-tested doing STEM activities, before and after the activities, and then interviewed during the focus groups held within the four schools. The six Affect codes and the five Behavior codes resulting in the five themes demonstrate the attitudes of the participants.

Chapter V: Discussion of Findings and Recommendations

Introduction

The literature confirms a limited success of increasing the number of African Americans in STEM careers. African Americans seem to have less interest in STEM as a career choice which may lead to lower academic achievement in STEM education. The literature also shows that smart devices have permeated societies worldwide, and have potentially made access to virtual knowledge and virtual education ubiquitous. And even though there is research to support both sides of the argument to include personal mobile devices in the classroom, it is the belief of the majority of researchers that mobile devices can provide a viable platform from which STEM may be taught. Likewise, many believe that people learn better by hands-on making and tinkering than by repetitive, rote, memorization. The notion of increasing the achievement and interest of African Americans in STEM utilizing mobile devices, and maker education is scarce in the literature. Accordingly, the following questions were explored:

1: To what extent do mobile device-assisted maker activities affect the STEM knowledge base of African American students at the secondary education level?

2: To what extent do mobile device-assisted maker activities affect the STEM attitude of African American students at the secondary education level?

Chapter V discusses the findings regarding these two questions as determined by the research design. A summary of the conclusions and limitations, along with future research designs to continue the research are presented. The attitude of African Americans towards STEM and what sustains them in STEM Education is comprised of a multitude of factors, the most central are: (a) interest in STEM concepts and activities, (b) the belief that STEM is Difficult to understand and to success in, (c) the judgment of how important STEM is to their worldview and their future careers and (d) the accessibility to the knowledge base of STEM subjects. The investigation of these factors were the measures used to investigate the effect of a mobile device and maker activities on the attitude and knowledge progression of African American middle schoolers in STEM, in a non-academic setting.

Discussions of the Findings

Originally, the research was designed with the expectation of about 75-80 participants, in a single urban, majority-black, upper secondary school setting, utilizing the same teacher. Circumstances were such that the design was changed, and 29 African Americans from four urban, majority-black lower secondary schools comprised the sample population and the setting was changed to an afterschool format. It was originally designed to have a minimum of 50 participants in the treatment group, and 25 participants in the control group. The actual make-up of the two groups was 24 participants in the treatment group and five in the control group. Consequently, the lower N values may have muted the statistical significance of much of the variables analyzed, making their means and trends of the means are less robust. None the less a wealth of knowledge was gained from the qualitative portion of the research, which helps support the affective domain in question 2, and supports the trends recognized, albeit mostly statistically non-significant, in the quantitative analysis of the raw data.

Research Question 1

Research question 1 dealt with how to increase the knowledge base of African Americans in STEM;

> RQ1: To what extent do mobile device-assisted maker activities affect the STEM knowledge base of African American students at the secondary education level?

This was investigated by statistical testing of the first null hypothesis, $H1_o$:

> The use of mobile device-assisted maker activities has no effect on the STEM knowledge base of African Americans at the secondary education level.

RQ1 is a quantitative inquiry, and the answer required quantitative analysis. The statistical analysis of the cleaned data collected from the pre- post- questionnaire used in this study yielded inconclusive results, Therefore $H1_o$ could not be rejected, which suggests that mobile-device assisted maker activities do not affect STEM learning. Although there was an increase in the pre- knowledge and post- knowledge means (M=2.542, 3.333, respectively) this correlation was not significant (p=.059).

Research Question 2

This research question also dealt with how to stimulate the attitude of African American middle schoolers in STEM;

> "To what extent do mobile device-assisted maker activities affect the STEM attitude of African American students at the secondary education level?"

This question was answered using both quantitative and qualitative methods. The quantitative portion was investigated by statistical testing of the second null hypothesis, $H2_o$: The use of mobile device-assisted maker activities has no effect on the STEM attitude of African Americans at the secondary education level.

The pre- and post- correlations of the three scales, Interest, Difficulty, and Importance, were also positive, with post- results always being slightly higher than pre- results. There was no statistically defensible claim that the resulting scores were correlatedly related to any measured independent variable, such as gender, school, or grade (there were other measured independent variables such as ethnicity, but they were split from the data and were not within the scope of this study). Therefore, $H2_o$ could not be rejected.

The study was designed to examine the differences between two groups, one receiving a mobile device-assisted maker activity to investigate an inquiry, and one investigating the inquiry with traditional instruments. The results were to be statistically insignificant, and most likely due to the small size of both treatment and control groups (N=24, N=5, respectively), and the large standard deviations associated with the data points. There does appear to be a significant correlation of the Difficulty scale with regards to schools on the independent variable, school, with regards to the initial pre-questionnaire, but this significance disappeared in the post- questionnaire results. It is believed that this is due to the participants' unfamiliarity with survey-type instruments, and the lackadaisical way in which some approached the questionnaire.

In some cases, the items of the same scale were answered in seemingly haphazard ways, even though all the scales Cronbach's α were 0.7 and higher, and therefore showed good internal consistency. Also, it was noted from comments from the control group, that they had little experience with equipment such as the student microscopes used in the control portion, thereby presenting confounding variables that may have influenced the correlations of the independent and the dependent variables of the control group. Because of this, some post-questionnaire scale means were lesser than their pre- values, such as for School 4 (pre- M=15.429, post- M=13.43, respectively). The Hedges' d effect size comparisons of the pre- scales Interest, Difficulty, and Knowledge showed a small to medium effect size between the means of the treatment and control groups, and only a very small effect size for the scale of Importance. Likewise, the post- scales of Interest and Knowledge showed a small to medium effect size between the means of the treatment and control groups and a small to very small effect size for the scales Difficulty and Importance. This suggests that half of the instrument, the Interest and Knowledge pre-scales could be significant for determining a difference between the means of the treatment group.

The qualitative data that was collected using direct observation and focus group interviews also investigated RQ2. There were confounding variables that may have influenced the outcomes of this study that could or could not have been foreseen in the design methodology. First of all, the study consisted of four schools, and no stipulation was placed on how the participants formed their groups at each table. The desire to use the session time as a time to fellowship with friends and acquaintances may have presented an unforeseen, confounding variable, influencing how the questionnaire was completed. This is illustrated by the trends of the conversations overheard during direct observation. The treatment group showed more positivity in the African American treatment group (74%) than the African American control group because the treatment group was seated in groups that roughly correlated to the school they attended, while the control group was comprised of students from different schools interacting with each other. The codes found in Table 28 for observed affects and behaviors were arranged in such a way that codes E and D were counted as positive observed affects and C, B, and F were negative. Code ?A measured affects that were not easy to categorize because they were convoluted or puzzling in their meaning. This type of affect code in many cases was due to the observer only witnessing a portion of the content of the action or in some way was not privileged to the whole of the conversation or action. The observed behaviors were also grouped into positive and negative behaviors, with codes OT, and OTC being positive behaviors and _XT and $ being negative behaviors. Once again, ?B were behaviors that could not be described as solely positive or negative but were convoluted or puzzling for some actions. The overall theme for the direct observation portion of both Monday and Tuesday sessions combined was that the treatment group had increasingly positive observations throughout the study, while the control group started with an overall negative affect and behavior, which improved during the second session (when the microscopes were being used) and then became extremely negative during the last day. This great drop in positivity during the third session day was observed to be due to a disappointment that the study was ending, and that they (the control) did not get to participate in the same intervention as the treatment group. This is supported by the control group answers given during the focus groups. With this in mind, I believe that the direct observation method of the study revealed that both groups were positive about the study. The attitude of STEM activities was judged more positive for the treatment group as compared to the control group, and this was judged as being due to the mobile-device-based maker interventions of that group.

The AA-T group responded in large part to Program Element and Participant Self-Efficacy themes, which shows how much they both increased their interest in STEM, technology (mobile devices), and hands-on activities like the maker interventions of the study. The responses of both treatment and control groups demonstrated that community, setting, and group interactions are all important when designing STEM educational programs. It may be significant to point out that the order for the control group, which switches their frequencies of PE and CE themes, may be due to the interactions between the control group and the treatment group outside of the study, and sharing experiences with or without the technology intervention. The Word Clouds for the total responses by schools all reflect the general positive attitude in STEM, the same as demonstrated by the observation notes, and the focus group responses. Overall the qualitative measures all agreed that there was an increase in attitude in STEM, with the treatment group having a greater, more sustained increase.

Recommendation for the Future

The analysis of the quantitative and qualitative data sets, along with the literature review was used to formulate the following recommendations for future studies and inquiries into mobile-device equipped maker activities for African American student attitudes and achievement in lower secondary education level classrooms. Overall, the two research questions explored can be more completely answered by future studies that:

1. utilize a much larger sample size, to reduce the high variances
2. separate the settings for the treatment group and the control group so that curiosity about, and interactions with the other group's actions are not a variable
3. extend both the study time frame from 3-days over 3-weeks to 10-days over 10-weeks to allow for the groups to accommodate the teaching-learning style of the study, and eliminate that confounding variable, and

4. increasing and diversifying the number and types of observers and data transcribers, to reduce bias and increase interpretation of data.

Recommendations for Mobile Devices in the Classroom

The findings did not make a clear distinction of the value of the use of mobile devices in the classroom. The bulk of information on the use of such devices was gathered during the focus group sessions, where there were minor responses both for and against. A small number of the participants in the focus group were against the use of mobile devices in the classroom. It was observed that some used them for social media purposes. Some participants indicated that smartphone usage was distracting from learning, as Campbell found in his study of personal smartphones in the classroom (2006). At School 3 it was noted that not only did the school not allow personal devices in the classroom, but the home environment also did not allow smartphones until the student was older than middle school. But the direct observations in this study showed that, in general, the use of smartphones can be an engaging tool of learning in the classroom. Further research needs to be designed to quantify the use of smartphones as a tool of learning, and as a means to increase a positive attitude towards STEM. It was perceived that most participants accepted that mobile phones are useful as a repository of knowledge, but were not sure how to use them as a problem-solving tool. Further study should be designed where smartphones are used solely as a problem-solving tool when compared to a control group using conventional methods. It was observed that some participants allowed someone in their group to complete the smartphone tech portions of the interventions, which limited their exposure to its use. Future research should place a greater emphasis on each participant utilizing the mobile device personally as a problem-solving tool.

Recommendations for Maker Activities in the Classroom

Again, the qualitative data from observations and focus group interviews provided the source of much of the recommendations for improvement of this research design. The pre- and post- questionnaire provided little significance of maker activities to either attitude or achievement. It is proposed that the positive trends noted in Figure 10 for the treatment group would continue to increase, given enough time for the study. Increasing the number of sessions would allow for a less rushed format, and for the participants to become more acclimated to the structure of the study design. It is recommended that studies similar to this study be designed with more sessions to allow students a greater opportunity at exploring the self-directed inquiry of maker education and to have a fuller, more involved use of mobile devices. Constructionism was chosen as the theory of learning and blended with conceptual elements of maker education and technology. Further research is recommended in exploring this viewpoint from a more defined perspective, such as indicated in Hira & Hynes, publication, People, Means, and Activities: A Conceptual Framework for Realizing the Educational Potential of Makerspaces (2018), in which more quantifiable scoring scales can be defined. And although little attention was given to the gender aspect of this study, there is a need for further investigation into why African American middle school girls completed this study at a 2:1 ratio to their male counterparts.

Conclusion

This work is part of the rapidly growing studies on how to increase positive attitudes and STEM knowledge base among African Americans in the k-12 educational setting. This study investigated the use of the constructionist's theoretical framework blended with mobile devise/maker hands-on interventions as educational tools for African American middle school students. While the data did not show a statistically significant impact of the use of smartphones and maker interventions on student achievement, it is believed that this framework can be used to support more purposeful incorporation of mobile devices along with maker activities into the STEM educational classroom. The qualitative observations and the focus group responses suggest that a positive correlation between mobile device-assisted maker activities increases the interest level of African American middle school students in STEM education. This study sought to address the biggest challenges to STEM in majority African American districts, and that is providing an economically feasible methodology to bringing STEM into the classroom.

The findings implicate the need for future research into the areas of mobile-device and maker education usage in the classroom as a key tool for preparing our African American students for STEM fields, and that this direction of learning should increasingly find its way into our urban, underrepresented schools. In addition, this paper is believed to provide a needed contribution to the gap in understanding learning methodologies that work for African American students, especially those in the middle school setting.

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Appendix A: Raw Data

Figure 20a

Raw Demographic and Pre- Post- Questionnaire Data

	A	B	C	D	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
1	Number	Code	school	Day	Age	assent	consent	Ethnicit	Gender	Grade	Pre-Q1	Pre-Q2	Pre-Q3	Pre-Q4	Pre-Q5	Pre-Q6	Pre-Q7	Pre-Q8	Pre-Q9	Pre-Q10	Pre-Q11	Pre-Q12	Pre-Q13	Pre-Q14	Pre-Q15	Pre-Q16	Pre-Q17	Pre-Q18	Pre-Q19	Pre-Q20
2	130	7Y6pT53S	4	Tuesday	sah	yes	yes	AA	M	6	N	D	N	N	N	A	SA	N	SA	N	N	A	SD	N	A	N	N	A	C	C
3	146	q7b5dDYG	4	Tuesday	11	yes	yes			6																				
4	200	qaUXc3YV	4	Tuesday	11	yes	yes	O		6	A	SD	SD	N	N	N	SD	SA	SA	D	SA	A	SD	SD	SA	N	SA	B	D	B
5	251	M3A69WzU	4	Tuesday	14	yes	yes	W	F	8	A	D	D	N	D	SA	N	A	A	SD	A	A	D	D	A	N	D	C	D	B
6	243	p9YVHT6Y	4	Tuesday	14	yes	Yes	W	M	8	SD	SD	SD	N	SD	D	A	SA	SA		D	N	D	D	D	SD	SA	C	B	B
7	3	axm7LkXF	4	Tuesday	13			AA	M	7	D	N	D	N	SD	N	A	SA	A	D	N	SA	N	N	N	N	N	E	B	A
8	4	pN5c7Lm2	4	Tuesday	16			AA	F	11	N	D	A	A	D	A	N	A	A	SA	SA	SA	D	N	N	SA	SD	C	A	A
9	196	nuqLrz3Z	4	Tuesday	12	yes	yes	AA	F	6	A	SD	N	N	SA	A	D	SA	N	N	SA	SA	SD	SD	N	N	N	D	D	C
10	97	QtoaD7Nq	4	Tuesday	13	yes	yes	AA	M	8	N	N	A	A	N	N	N	A	A	N	N	SD	SD	D	D	SA	N	A	E	B
11	8	7ZdRNCHT	4	Tuesday	13					6																				
12	201	QXJTr7yx	4	Tuesday	11	yes	yes	AA	F	6	D	D	D	N	D	N	D	N	N	D	N	N	N	D	A	A	A	D	B	E
13	159x	X1PC9hRr	4	Tuesday	13					8																				
14	2	9PPajHc8	4	Tuesday	yes			W	M	8	N	D	D	A	N	A	SA	A	A	N	N	A	SD	N	A	N	N	C	D	B
15	159	SRd2ez4k	4	Tuesday	12	no	yes	AA	F	7	N	N	N	A	N	A	N	SA	SA	D	A	SA	SD	SD	SA	SA	N	D	E	D
16	58	PMCz5CXV	4	Tuesday	16	yes	yes	AA	f	10	SA	N	D	A	N	N	SD	N	A		D	A	SD	SD	N	N	A	B	B	E
17	91	nXat8Ef5	4	Tuesday	12	yes	yes	W	M	6	N	D	D	N	N	A	A	A	A	D	A	A	SD	D	D	SA	N	C	D	A
18	156	P6h5ZRCC	4	Tuesday	12	yes	yes			7																				
19	101	MDYuWF6D	4	Tuesday	eran	yes	yes	AA	F	8	SD	A	SA	N	SD	N	SA	N	A	N	A	A	D	SA	N	A	SD	C	E	C
20	245	pNHur2W8	4	Tuesday	12	no	yes	W	F	6	A	D	N	A	A	A	SD	N	SA	SD	A	A	SD	SD	A	A	N	C	A	B
21	159b		4	Tuesday	12					6																				
22	140	8ERfcmpV	4	Tuesday	12	no	yes	AA	F	6	A	SA	N	SA	SA	D	SD	SA	SA	D	SA	SA	SD	SD	A	SA	D	B	E	A
23	188	QY6z8rf5	4	Tuesday	14	yes	yes	AA	F	8	N	N	N	N	D	A	N			D	A	A	D	N	N	N	N	C	D	B
24	172	5H6FBXFA	4	Tuesday	12	no	yes	AA	F	7	A	SA	SA	A	N	A	N	A	SA	D	N	SA	SD	SD	SA	A	D			D
25	132	P46ASq5P	4	Tuesday	12	yes	yes	W	F	7	A		D		N	N	SD	A	SA	SD	A	SA	SD	SD	SA	SA	N	C	D	A
26	94	P5dP68RX	4	Tuesday	13	yes	yes	O	F	7	D	D	D	N	N	N	N	A	A	D	N	A	SD	D	N	N	N	C	D	A
27	214	n5DKG78R	4	Tuesday	lan			W	M	7	N	D	SD	N	N	N	D	N	S	SD	A	A	SD	SD	A	A	A	C	D	A
28	39	C2cPY8z5	2	Monday	13	yes	yes	AA	F	7	D	N		D	N	A	D	N	N	N	A	N	SD	D	N	N	N	C	D	E
29	28	DT7hD37z	2	Monday	12	yes	yes	AA	F	6	A	D	N	A	A	N	D	SA	N	D	SA	SA	SD	SD	N	A	N	C	A	B
30	205	CG6rwH3q	2	Monday	13	yes	yes	AA	M	7	A	A	N	A	A	N	SD	N	A	D	N	N	D	SD	N	N	D	B	A	B
31	105	bNZutCE4	2	Monday	13	yes	yes	O	M	7	SA	SD	SD	SA	SA	SA	SD	SA	SA	D	SA	SA	SD	SD	SA	SA	SA	B	D	A
32	236	DJ6VBDRq	2	Monday	12	yes	yes	AA	NA	6	SA	D	N	A	N	SA	D	A		D	A	A	SD	SD	A	N	N	D	A	A
33	16	AnJ2yDNr	2	Monday	12	yes	yes	AA	F	7	SD	SD	N	N	D	N	SD	A	A	SD	A	SA	SD	N	N	A	N	C	C	D
34	240	D64Su8Ea	2	Monday	11	yes	yes	AA	M	6	N	A	D	A	A	N	N	A	A	N	N	A	SD	SD	N	N	A	A	D	A
35	135	DqTZ3D3X	2	Monday	11	yes	yes	AA	F	6	D	D	D	A	N	N	N	N	N	D	A	N	D	D	N	N	N	B	A	C
36	96	CPvV37DK	2	Monday	ylie			W	F	7	N	D	N	N	A	SA	N	A	SA	A	N	SA	SD	SD	A	N	D	A	C	D
37	1777		2	Monday	13	yes	yes	AA	F	7	D	N	D	N	N	N	A	SA	SA	SD	SA	SA	SD	N	N	N	N	A	D	C
38	137	bNJ4VELq	2	Monday	lira			AA	NA	6	N	N	N	N	N	A	N	A	SA	D	N	A	SD	N	N	A	N	D	D	B
39	64	CTrUdVo8	2	Monday	13	yes	yes	AA	F	7	N	N	D	A	N	N		D	N	N	A	N	N	D	N	N	N	E	C	E
40	85	CNcBJ379	2	Monday	a			AA	F	7	N	A	D	A	SD	SA	N	N	SA	SD	A	A	SD	N	A	A	D	E	D	D
41	129	dq4CGFHS	2	Monday	12	yes	yes	AA	F	6	A	D	D	A	A	N	SD	A	A	SD	N	SA	SD	SD	N	N	N	C	D	D
42	84	4KjpPBU8	1	Monday	11	yes	yes	AA	M	5	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	B	A	D
43	163	38D7TcGR	1	Monday	10	yes	yes	AA	M	6	SD	SD	SD	A	A	A	SD	SD	A	A	SD	SD	D	SD	SD	SA	SD	B	D	A
44	103	7DSnH5nu	1	Monday	14	yes	yes			8																				
45	22	7dCruU8R	1	Monday	13	yes	yes	AA	M	8	A	SD	SD	A	A	SA	N	SA	SA	SD	N	SA	SD	SD	SA	SA	A	C	D	A
46	29	6YKrHo2t	1	Monday	12	yes	yes	AA	F	6	N	A	D	SA	N	A	D	A	A	D	A	A	D	D	A	A	N	C	C	B
47	69	6W8oH3BP	1	Monday	13	yes	yes	AA	M	6	SD	SA	A	A	A	D	D	A	A	D	A	N	SD	SD	SD	N	N	C	D	B
48	204	6UH8F264	1	Monday	11	yes	yes	AA	M	6	SD	SA	SD	A	A	A	D	SA	A	SA	SA	SA	D	SD	A	N	N	C	D	A
49	73	7Mt5Um6u	1	Monday	11	yes	yes	AA	M	6	N	SD	SD	SA	A	SA	SD	A	A	SD	A	SA	SD	SD	A	A	SA	B	A	B
50	139	2rK4Znjy	1	Monday	11	yes	yes	AA	M	6	SD	D	SD	A	N	SD	D	SD	N	N	N	N	N	N	D	A	D	A	D	A
51	44	7TCaj29C	1	Monday	10	yes	yes			5																				
52	149	39zDYqP9	1	Monday	10	yes	yes			5																				
53	126	2x9MHqKB	1	Monday	12	yes	yes	AA	F	6	N	SD	SD	A	SA	A	SD	SA	SA	D	A	SA	SD	SD	SA	SA	SA	B	D	A
54	77	6r3q8zF5	1	Monday	12	yes	yes	AA	M	6	N	SD	SD	N	N	SD	N	D	D	N	D	N	SA	SA	N	D	SA	C	B	E
55	21	7bEDYDAu	1	Monday	14	yes	yes			8																				
56	117	7ChL7ddn	1	Monday	12	yes	yes			8																				
57	124	7FZYxSPL	1	Monday	14	yes	yes			8																				
58	231	f9ZK8FEW	3	Tuesday	11	yes	yes	W	F	6	A	D	N	A	A	A	D	A	A	D	A	A	SD	SD	A	A	N	C	D	B
59	28	DT7hD37z	3	Tuesday	11	yes	yes	AA	F	6	A	D	N	A	A	N	D	SA	N	D	SA	SA	SD	SD	N	A	N	C	A	B
60	41	FDRtz6Zo	3	Tuesday	11	yes	yes	W	F	6	N	D	D	A	A	N	SD	A	SA	SD	SA	SA	SD	SD	A	A	N	C	A	B
61	174	qoQ9fZX3	3	Tuesday	12	yes	yes	W	M	6	A	D	D	N	SA	N	SD	A	SA	D	A	SA	SD	D	A	N	N	C	C	B
62	162	h2H4XJRQ	3	Tuesday	12	yes	yes	W	M	6	A	N	D	N	A	A	SD	N	A	SD	A	SA	SD	SD	A	A	N	C	D	A
63	210	Fd2F5KSb	3	Tuesday	11	yes	yes	AA	M	6	A	D	N		N	D	SD	N	A	A	A	SA	SD	SD	A	N	A	B	D	A
64	60	CMJS5ZBb	3	Monday				AA	O	6	SA	SD	SD	SA	SA		SD	SA	SD	SA	SD	N	SA	N	SA	SA	D	A	B	C
65																														

Figure 20b

Raw Demographic and Pre- Post- Questionnaire Data

		AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM
1	Numbe	Pre-Q20	Pre-Q21	Pre-Q22	Pre-Q23	Pre-Q24	Pre-Q25	Pre-Q26	Group	Post-Q1	Post-Q2	Post-Q3	Post-Q4	Post-Q5	Post-Q6	Post-Q7	Post-Q8	Post-Q9	Post-Q1	Post-Q1	Post-Q1	Post-Q1	Post-Q1	Post-Q1	Post-Q1	Post-Q1	Post-Q1	Post-Q1	Post-Q2	Post-Q2	Post-Q2	Post-Q2	Post-Q2	Post-Q2	Post-Q
2	130								T	one day																									
3	146	B	E	A	B	B	E	B	T	A	D	D	A	N	A	SD	SA	SA	SD	SA	SA	SD	SD	SA	N	A	C	D	A	B	B	B	D	B	C
4	200	B	C	A	B	D	B	C	2	one day																									
5	251	B	E	E	B	D	C	C	T	one day																									
6	243	A	A	A	A	A	A	A	2	D	D	D	D	D	SA	N	D	SA	N		N		D	A	N	A	B	E	C	A	B	E	C	E	B
7	3	A	D	D	B	B	C	B	T	D	D	N	A	N	SA	N	SA	SA	SD	A	SA	SD	SD	SA	SA	D	C	D	C	C	C	B	D	C	B
8	4	C	A	E	C	B	A	D	2	A	SD	D		N	SA	N	N	A	A	N	SA	SA	SD	SD	N	A	C	D	A	B	D	E	D	C	E
9	196	B	C	A	D	E	E	C	T	SA	N	A	SA	N	D	A	SD	D	N	SA	N		SD		D	N	C	D	D	C		A	E	B	D
10	97								T	not goes																									
11	8	E	A	C	D	A	B	E	T	D	D	D	D	D	D	D	A	A	D	SA	A	SD	SD	D	A	D	C	C	D	A	B	B	D	E	A
12	201																																		
13	154	B	B	C	B	D	B	C	T	A	N	N	A	A	N	SA	SA	SA	N	A	A	D	D	A	N	N	C	D	A	B	B	B	D	C	C
14	2	D	D	B	D	C	B	C	T	A	N	N	A	N	A	N	A	N	N	N	N	A	N	N	A	N	B	D	A	B	D	B	B	C	C
15	159	E	C	B	D	D	D	A	T	A	N	D	N	N	N	N	N	A	D	A	A	SD	SD	A	A	N	A	C	B	C	A	B	A	C	B
16	58	A	E	A	B	E	C	B	T	N	D	N	N	N	A	N	A	SA	D	A	A	D	D	N	A	N	C	D	A	C	C	B	D	C	B
17	55								T	no show																									
18	154	C	E	D	D	C	A	C	T	D	A	A	N	SD	N	SA	A	A	D	A	A	D	SA	SD	N	SD	C	D	A	A	B	B	C	C	C
19	101	B	D	E	B	C	E	B	T	A	D	N	A	SA	A	D	A	A	SD	A	A	SD	SD	A	A	N	B	D	A	C	C	B	E	E	B
20	245																																		
21	1546	A	D	C	B	D	A	E	T	D	N	SA	A	D	SA	SA	SA	SA	SD	SA	SA	SD	N	S	N	SA	B	D	A	B	E	C	D	E	B
22	140	B	D	B	C	D	B	E	T	D	N	N	N	D	N		A	N	D	N	N	D	N	D	N	N	C	D	D	C	E	B	A	C	A
23	109	D	D	C	B	E	A	D	2	N	A	A	N	N	A	A	A	A		D	A	SD	D	A	A	D	C	E	A	C	D	B	E	D	B
24	172	A	D	D	B	D	D	C	T	A	D	N	A	SA	A	SD	SA	SA	SD	A	SA	SD	SD	A	SA	SA	C	D	A	B	B	B	D	C	C
25	132	A	D	C	B	E	C	C	T	N	D	D	A	N	A	N	SA	A	D	N	A	SD	N	A	N	A	C	D	A	B	B	B	D	C	C
26	94	A	C	A	B	D	C	C	T	N	D	D	N	N	A	D	A	A	D	A	N	D	D	N	N	A	C	D	A	B	B	B	A	C	C
27	214	E	D	C	B	E	B	B	T	D	N	N	A	A	N	D	N	N	D	A	A	D	SD	A	N	A	C	D	A	E	B	B	E	B	B
28	36	B	E	C	C	E	D	A	T	A	D	N	A	SA	A	SD	SA	SA	D	SA	SA	SD	SD	SA	SA	N	B	D	D	C	A	B	D	C	C
29	28	B	B	C	A	C	D	E	T	N	D	N	N	N	N	N	A	N	D	D	N	A	D	D	N	D	C	D	D	B	C	B	E	C	E
30	205	A	E	C	B	D	C	C	T	SA	SD	SD	SA	SA	SA	SD	SA	SA	SD	SA	SA	SD	SD	SA	SA	SA	C	D	B	B	C	B	A	C	C
31	105	A	C	C	E	A	C	B	T																										
32	234	D	A	E	E	A	C	C	T	N	N	D	SA	A	SA	SA	A	A	A	A	N	N	N	N	N	N	B	D	B	C	A	C	D	C	B
33	56	A	C	C	D	D	C	C	T																										
34	240	C	C	D	E	B	E	C	T	N	N	D	N	N	N	N	N	N	N	N	N	D	D	N	N	N	C	D	B	C	C	C	E	B	B
35	139	D	E	C	B	E	E	B	T																										
36	96	C	C	E	D	E	C	C	1	SD	SD	N	A	N	A	D	N	A	D	N	A	SD	SD	N	N	D	C	C	B	A	C	E	A	C	B
37	1777	B	A	B	C	A	B	B	T																										
38	137	E	B	C	B	D	C	B	1	N	N	N	N	N	N	D	N	N	N	N	N	D	N	N	D	N	C	D	B	A	C	E	A	C	B
39	44	D	C	D	A	C	A	C	T	N	D	N	SA	SD	SA	SD	A	A	A	A	A	A	A	A	A	A	C	C	A	E	B	B	D	D	E
40	85	D	B	A	C	E	C	B	T	N	D	N	N	N	N	N	D	A	N	N	N	D	N		D	N	C	D	B	A	C	E	A	C	B
41	125	D	B	A	C	B	D	E	1	D	A	A	N	A	SD	A	A	D	A	N	D	A	A	SD	A	A	A	C	C	C	D	B	D	E	D
42	14	A	B	D	A	A	A	B	T	N	D	SD	N	N	A	SD	N	N	D	A	N	SD	SD	N	N	D	C	C	C	B	C	E	D	B	A
43	162								T																										
44	103	A	D	C	B	D	B	B	T																										
45	22	B		D	B	D	E	C	T																										
46	24	B	C	D	B	D	B	B	T	N	A	D	A	A	N	D	A	A	N	A	SA	SD	D	N	A	N	B	D	B	D	A	B	D	D	A
47	69	A	D	C	B	D	B	C	T	N	D	D	A	SA	A	N	SA	A	SA	A	SA	SD	SD	A	SA	N	C	B	B	D	C	B	E	E	C
48	264	B	B	A	A	A	B	C	T	N	D	D	A	SA	SA	SD	A	SA	D	SA	SA	SD	SD	A	A	SA	A	B	A	B	D	A	C	D	B
49	73	A	C	C	B	D	A	B	1	SD	SD	SD	SA	A	N	SD	SA	SA	SD	SA	SA	SD	SD	SA	SA	A	B	D	B	B	A	C	E	B	D
50	129								T																										
51	44								T																										
52	149	A	B	E	B	B	E	C	T	D	SD	SD	A	SA	SA	SD	A	SA	SD		SA	SD	SD	SA	SA	SA	C	D	A	B	C	E	A	E	C
53	124	E	C	A	E	D	B	A	T	SA	SA	SD	D	SA	N	A	SD	N	N	SD		SD	SD	SA	SA	A	C	C	D	E	C	B	C	E	A
54	77								2																										
55	21								T																										
56	112								T																										
57	124								T																										
58	231	B	C	C	B	D	C	C	T	A	D	D	A	N	A	D	A	A	SD	A	A	SD	D	A	A	N	C	D	B	C	B	B	E	D	C
59	28	B	E	C	C	E	D	A	T	SA	D	N	A	SA	D	SD	N	SA	D	A	A	SD	SD	A	A	SA	A	C	B	A	C	B	C	B	B
60	40	B	B	A	E	D	E	B	T	A	A	N	A	SA	SA	D	A	SA	D	SA	SA	SA	SA	SD	N	A	C	D	A	B	D	B	B	A	D
61	174	B	E	E	B	A	C	A	T	A	D	D	N	SA	N	SD	A	SA	D	SA	SA	N	SD	A	A	N	C	D	A	B	B	B	D	C	D
62	162	A	E	A	B	D	C	C	T	SA	N	D	A	SA	A	SD	A	A	D	SA	A	SD	SD	A	A	N	A	D	A	D	A	B	D		A
63	280	A	C	D	E	B	D	A	2	N	D	SD	A	A	SN	SD	SA	SA	SD	A	SA	SD	SD	N	A	A	C	D	A	B	B	B	D	C	E
64	58	C	C	B	C	E	B	B	T																										

Appendix A (con't)

Table 5a

First Day Observation Monday Group

Time	**Itinerary Date: 01/27/20**	**Observation:** Affect: E= Engaged, C=Confused, B=Bored, F=Frustration, D=Delight, ?A=Other Behavior: OT=On Task, OTC= On Task with conversation, -XT=Off Task, $=Gaming the System, ?B=Other **Affect Behavior Comments**		
4:15	Packets;meals	ED	OTC	Participants seem interested in packets, speaking openly with joy; enjoying meal
4:30	INST introduction	E	OTC	3AAF: "Why are we here? Is this part of our school Work?"(C)
4:47	pre- test given	E	OT	
5:15	Control dismissed	C	B	CAAF: "What's going on? Why do we have to leave? What are we gonna do?"(C)
5:18	Adt#3 explain task	EC	OT	CAAF: "We never use microscopes." (?A=nervous)
5:20	Adt#3 demonstration	E	S	"I like this is so much better than our science at school. All we do is watch youtube videos, and look at each other."(S)
5:22	INST ppt 1	D	OTC	Participants interacting with other tables and schools
5:28				(?A=restless)
5:30	INST recap	D	OTC	5AAM = "Can we take this package home? I want to take mine home?"(F)
5:35	Researcher	C	OTC	_AAF="What should I do with the part I tore off? I'm confused, this is stupid."
5:45	Waiting for rides	D		_WF = "I think I'm gonna like this, Mr. (Adt#3)

Appendix A (con't)

Table 5b

First Day Observation, Tuseday Group

Time	Itinerary Date: O1/28/20	Observation: Affect: E= Engaged, C=Confused, B=Bored, F=Frustration, D=Delight, ?A=Other Behavior: OT=On Task, OTC= On Task with conversation, -XT=Off Task, $=Gaming the System, ?B=Other **Affect Behavior Comments**		
4:05	First bus arrives	D	OTC	_AAM="Hey, what's up! Can we start already?" (D,$) _AAF= "sat down boy, you already been eating too much. Did you just come for the food?) (D) _AAM="Hell yeah!(looked at me) My bad, I'm sorry, sir!"
4:30	Inst Introduction	E	OT	?A=Nervous, ?A=Attentive
4:35	Brief break in presentation	D	OTC	"Mr._, will we be using the garden towers? I hope so."
4:35	Adt#4 photos	C	?B	?B= Inattentive confused about picture taking from more than one participant
4:42	pre- test Given	E	OT	
4:58		D	?B	?B= looking around, small non task related talking, get up to get pizza and drink
5:-05		C	?B	?B= refused to go to control group at first; until Adt#3 insists
5:07		F	XT	CAAM="What are they doing over there?" "Well why did we have to leave the group?"
5:-05		C	?B	?B= refused to go to control group at first; until Adt#3 insists
5:07		F	XT	CAAM="What are they doing over there?" "Well why did we have to leave the group?"
5:10	Inst ppt	B	XT	Talking with others at Table and adjoining table
5:15	Inst in dialogue	E	OTC	In general participants are engaging and attentive
5:20	Adt#3 demonstration	E	OT	
5:35	Inst recap	D	XT	Some participants did not listen to the Instr and did not know what to do with packet
5:35	Waiting for rides	D	?B	"Do you think that microscope will work? I got to see that!(?B=anxious, curious)

Appendix A (con't)

Table 5c

Second Day Observation, Monday Group

Time	Itinerary Date: 02/03/20	Observation: Affect: E= Engaged, C=Confused, B=Bored, F=Frustration, D=Delight, ?A=Other Behavior: OT=On Task, OTC= On Task with conversation, -XT=Off Task, $=Gaming the System, ?B=Other **Affect Behavior Comments**		
4:10	Ist Bus unloading	D,?A	?B	Participants are happy(?A), and Delightful; Pizza is late and participants are waiting patiently(?B)
4:20	Pizzas arrive	?A	?B	5AAM, 5AAF, 5WM " joking back and forth about types of food they would like to eat: "I want Tacos"
4:35	Instr con't PPT #1	E	OT	Participants at all Table have removed Foldscope components; 2AAM tore one component and asked Instr for replacement
4:40	Control separated	E	OT	Participants Engaged, asking Adl#3 for assistance. Adt#2 gave assistance on Green Tower Plants
4:45	Instr demo of Foldscope Ass'y	E, C	OTC, XT	1AAF= "How come my kit is missing something? Oh, that's alright, it is stuck to the lens"(OTC} 7WF = "I don't know how it happened, but my focus stage got throwed away with my scrap, and it's not in the trash can."(Frustrated) 3AAF = talking on cell phone(XT}. She puts it away when Instr asks
5:00	Control Examining Plants Microscope	D, ?A	OTC	CAAF asking for help with cutting Green Tower plants from Adt#2; after tasting plant, "WOW, It actually taste sweet, not bitter!" (?A= Excited, concentrating)
5:15	Instr demo con't	E, F, C	OTC, XT, $	3AAF again talking on phone with two participants at table. When confronted she said, "Wait! I was just, um, trying to look this up on youtube. laugh"(XT, $) 5WM =has finished Foldscope, put it off to side, and has head down on table. [After the session, instead of putting foldscope in package, he walked away and left it on table. Inspection showed that he had put it together wrong.

Appendix A (con't)

Table 5d

Second Day Observation, Tuesday Group

Time	Itinerary Date: 02/04/20	Observation: Affect: E= Engaged, C=Confused, B=Bored, F=Frustration, D=Delight, ?A=Other Behavior: OT=On Task, OTC= On Task with conversation, -XT=Off Task, $=Gaming the System, ?B=Other		
		Affect	**Behavior**	**Comments**
4:07	Bus #1 arrives	D	?A	?A=participants a lot louder than on previous session, more active and open. _AAM = "You [the researcher] remind me of that Neil Tyson"(?A= adoration)
4:30	Instr PPT #1	E	OTC,XT	Instr informed class that too much talking was taking place. Three(3) AAF apologized. Others did not.
4:40	Control group dismissed	D	OT	Group left with no discussion. Begin intervention where they had left off.
4:45	Control group getting slide to work	D	?B	"I looked at the spinach leaf and, once I got my microscope to focus I was like, Mannnn, I could see where the leaf was brown how it was like a skeleton! I mean all the stuff was gone but the outlines of where the, the cells of the leaf were was still there. This is interesting, Ms. __(Adt #3)
4:50	Instr demo	E, C, D	OTC, XT	Most tables: participants are helping each other, or asking the Instr, Adt#3 questions. Overheard 5AAM say, "who is that dude in the red shirt with the camera (Adult #4)? He's freaking me out!"
5:05	Instr demo of phone / Foldscope attach	E, D	OT	Tables mostly quite. Those who finished Foldscope using Instr phone. Periodically, an acclamation of joy and wonder bursts from tables as participants views foldscope/phone. Some leave their Table to visit other tables. AAM= "I got it I got it!"
5:10	Instr begins PPT#2	E	OTC,XT	Most put the Foldscope away and take out Arduino circuit. At least three tables take out supplies before Instr says to and are told to put them back. 1AAM plugs in battery to breadboard and burns out LED. Instr scolds two tables for connecting circuits without being told to.
5:25	Instr instructions	?A	?B	Most happy to take home Foldscope, some are confused, thinking they can take Arduino home also, Two Arduino packages go missing. "Can't I take this [Arduino] to0? Why not?"

Appendix A (con't)

Table 5e

Third Day Observation Monday Group

Time	Itinerary Date: 02/11/20	Observation: Affect: E= Engaged, C=Confused, B=Bored, F=Frustration, D=Delight, ?A=Other Behavior: OT=On Task, OTC= On Task with conversation, -XT=Off Task, $=Gaming the System, ?B=Other		
		Affect	**Behavior**	**Comments**
4:30	Instr PPT#2	E	OTC	Test Group back in regular large room. Control group back in small room. Test group vocal but not disrespectful. Very comforTable with groups.
4:45		E,XT	OTC,$	3AAF two participants Off Task, when asked why they are not participating one answered "What! I don't want to do this! No, wait, I'm sorry, what am I suppose to do? [laugh]($)
4:50		E. ?A	OTC, ?B	"Excuse me, could you help us."[I was asked. Before I could answer, one of the 1AAF said "what do you need? I got ours working so I can probably help ya'll."(?A=proud, confident; ?B=taking on role of helper)
4:55	Assmby of Spectroscope	E,?A	?B	"We're finished, we can help someone."(?A=confident, sincere; ?B=taking on role of helper)
5:05		E,D	OT	Exclamation of excitement throughout the group when the circuit worked. Obvious Frustration when it did not work with a plea of "can you help please,. You could tell when some group got theirs to work whenever a cheer of excitement was raised.
5:10	Post Test	E	OT	Those who did not finish were disappointed when they had to stop. Many exclamations of 'I like this experiment better than the microscope'
5:30		E,?A,D	OTC	Several students thanked me for the study. Many more were frustrated that the study had come to an end. (?A) One WF said that she had taken her Foldscope home and looked at her three cat's and two dogs fur, and was amazed that "all of them had different shaped fur" She said that she let her mother see.(D)

Appendix A (con't)

Table 5f

Third Day Observation, Tuesday, Group

Time	Itinerary Date: 02/10/20	**Observation:** Affect: E= Engaged, C=Confused, B=Bored, F=Frustration, D=Delight, ?A=Other Behavior: OT=On Task, OTC= On Task with conversation, -XT=Off Task, $=Gaming the System, ?B=Other **Affect Behavior Comments**		
4:15		C, F	OT	Adt#2 informed me that Adt#1 needed big room for meeting; Test group moved to Control area…Control moved to corner. Participants confused. Also pizza late. Participants Frustrated
4:45	Instr PPT2	E,D	OT	When groups got LEDs to Light there was "Cool"…."Look, Loiok, I got it"…."I need help, mine won't work""That's great"
5:00		E	OTC	Participants are very focused. Because of the smaller room they would repeatedly tell the Instr that they could not see the screen if someone blocked their view. Seemed excited about using electronic circuitry.
5:10		E	OT	When told that they had to take the post test, most were sorry that they could not finish the intervention.
5:15		D,F	OT	Once a team got their circuit to work they would get up to help a group having problems
5:32	Dismissal	E,D	OTC	When told that this was the last session, the group as a whole was both surprised and disappointed. Lots of expressions of disappointment was expressed in word and in body language. Some participants came up to Instr and adult leaders and thanked them for the STEM study

Appendix A (con't)

Table 6

Prompt Questions for Focus Groups

Response Number	School	Question No.	Response Meaning Unit
1	#1	1	STEM means, Science Technology, Engineering and Math
2	#1	1	: Uhhh, STEM is….science, technology……. Economics, and, and,,, What is the M for……?? Math!
3	#1	2	It's like Nature, STEM.
4	#1	2	We use STEM in Computer Lab. Under technology, we use code to program Acellus. We learn about our body parts, leaves, and our bones.
5	#1	2	Yes, it's something good to do with the Green Tower.
6	#1	3	I liked how you provided food and beverages
7	#1	3	I liked how we learned more stuff about STEM
8	#1	3	We could have different foods, like……pizza and taco bell tacos
9	#1	3	I liked Ms. Nicolle too….And also you. How you broke down how the Foldscope worked
10	#1	3	I also liked how you did not rush. Well, we did rush a little. To me it did not feel like rushing.
11	#1	3	I liked how you walked around and used examples of how stuff worked.
12	#1	3	I like how we got to communicate with the other schools….the other students.
13	#1	3	I did not like the pizza [Oh, why not? Don't you like pizza} Naw, I like pizza, I like Imo's better

14	#1	3	I liked the…..how we, uhm, made, making the Foldscope
15	#1	3	6 I liked the oranges
16	#1	3	I didn't like them taking all those pictures.
17	#1	3	I could have changed my behavior the first day….I was talking and I shouldn't have been.(very sincere)
18	#1	3	I liked all the examples who [you] showed us…all the stuff you did.
19	#1	3	7 I liked that it was set up for after school.
20	#1	3	How you made the microscope, and we took turns with the STEM
21	#1	3	How you made the microscope, and we took turns with the STEM
22	#1	3	I like how we did the step by steps to make a Foldscope.
23	#1	4	3 No, I'm going to "Aim High" this summer.
24	#1	4	I might be going out of town. My dad might be picking me up and I might be going to Arizona State University to a STEM program.
25	#1	4	Another reason I might not be able to go is that….I may go to….LA or North LA or Florida.
26	#1	4	I'm gonna be in Orlando, Florida
27	#1	4	I will be in Hawaii.
28	#1	4	I'm going out of town.
29	#1	4	We may go to six flags. With my family…..No, I think it's in Missouri, but it's….
30	#1	5	I can teach how to do more things when I use my hand.
31	#1	5	When you used to phone it was faster
32	#1	5	Because I'm Really lazy.Can you explain a little about that.I don't like to do anything, but…when I worked with my hands I liked it

33	#1	5	Because I'm Really lazy.I don't like to do anything, but…when I worked with my hands I liked it
34	#1	5	8 I like working with my phone, you can do more stuff.
35	#1	5	Uhh, I liked making those things with my hands and doing things.
36	#1	6	Yes, you can do more with your hands and it helps you to remember better.
37	#1	6	I like working with my hands better because I can remember more details.
38	#1	6	Yes, Because….when I do stuff with my hands it helps me to learn…. better.
39	#1	6	Yeah, I have a good memory and….uhh…. (pause) Is that all you want to sayYeah, leave it there
40	#1	7	We should have different foods. Some people don't eat pizza.
41	#1	2	#1 When we do our math work….Umm, Humm. When we go to STEM lab, we code.
42	#1	2	I was (in control Group).
43	#1	3	I liked Ms. Nicolle…how she explained everything to us, how she did not rush.
44	#1	3	I like how you set up everything before we got there.
45	#1	3	I like how you formed everything for us, so that we could do our lesson.
46	#1	3	I like thin crust best, not the fat crust
47	#1	3	(yes, yes
48	#1	3	laughter
49	#2	**1**	Science and technology shows up in your daily life. Uhh, every were we go… you need to build stuff, and Figure out stuff.
50	#2	**2**	Stem shows up, like… if we have a hard problem or question or and use STEM to find out answers. And that's every day.

51	#2	**2**	Mr. [teacher] uses the Green Machine Towers to teach STEM.
52	#2	**2**	Walking. Mr. [teacher] taught me that I use proprioception to know where I am walking.
53	#2	**2**	I see that the teachers uses cameras on board as in technology, and the Smartboard and Mac book.
54	#2	**2**	You use a lot of science in the classroom, uhh…..never mind.
55	#2	**3**	<u>1 I like to work together</u> when we was using the magnets….on the Foldscope.
56	#2	**3**	2 I like to work together <u>when we was using the magnets….on the Foldscope.</u>
57	#2	**3**	1 I liked how what she said how we should put together our Foldscope and I caught on quick.
58	#2	**3**	It was hard! (lgh) But…… it was has hard. (lgh)
59	#2	**3**	what I liked was that, even though there was review of what we already knew, we learned something extra 'bout some things.
60	#2	**3**	What I disliked about the, the Green Machine Program was that the if the majority of the students did not get it we had to wait until everybody got it.
61	#2	**3**	What I would like to see improved is more assistance, more instructors to help.
62	#2	**3**	I liked that I stepped out of my comfort-zone and, and learned something new
63	#2	**3**	What I liked was … anything that uses technology, like the Arduino and the Foldscope. It, it was a good invention.
64	#2	**3**	I did not like that it was only three days long. I wish it could have not been longer.
65	#2	**3**	More technology

66	#2	**3**	I like the Green Machine. I like that we got to learn how to make our own Foldscope and to use the Arduino.
67	#2	**3**	I like the Green Machine. I like that we got to learn how to make our own Foldscope and to use the Arduino.
68	#2	**3**	When I had built the Foldscope I didn't understand. I could not understand how….
69	#2	**3**	I liked the food and (lgh) the pre-test and then we took a… yeah, post-test and…y'all.
70	#2	**3**	I liked the food and (lgh) the pre- test and then we took a… yeah, post-test and…y'all.
71	#2	**3**	I liked that you and the other instructor let us ask questions and did not just throw it all up in our face. And this showed respect for us
72	#2	**3**	The program was too short. It should have been longer. There needs to be for more time. (lgh) And another thing, the Arduino should have been bigger [reference here to the breadboard] you know… I would have liked to have had more assistance with the Arduino.
73	#2	**3**	The program was too short. It should have been longer. There needs to be for more time. (lgh) And another thing, the Arduino should have been bigger [reference here to the breadboard] you know… I would have liked to have had more assistance with the Arduino.
74	#2	**3**	The program was too short. It should have been longer. There needs to be for more time. (lgh) And another thing, the Arduino should have been bigger [reference here to the breadboard] you know… I would

			have liked to have had more assistance with the Arduino.
75	#2	**3**	We need more days and…cause we did not get finished.
76	#2	**3**	when we built the circuits to make the light red light-up.
77	#2	**3**	LED
78	#2	**4**	I would not attend because in summertime we have our family trip, and this will get in way of summertime. This is the only time we have for fun.
79	#2	**4**	I would… if I Upward Bound= NOcould….I gotta, to go to UPWARD BOUND.
80	#2	**4**	I think we could (interruption). I would attend it but, that is, summer is when we are free and when my family go on trips, so we are going places. And what if you want to attend something else?
81	#2	**4**	I would not attend but if it was shorter like one or two days a week.
82	#2	**5**	Yes I did because that what you use to create things
83	#2	**5**	I did like working with my phone because I want to be a coder.
84	#2	**5**	Like [# 8] said, we, we need to interact more with other students from other schools.
85	#2	**6**	Yep
86	#2	**6**	Yes
87	#2	**6**	Yeah and no, because we have hands on experience, which is good, but, like #20 said, we can get distracted.
88	#2	**6**	Yeah and no, because we have hands on experience, which is good, but, like #20 said, we can get distracted.
89	#2	**2**	And we use STEM… you know… we use science and engineering when we are working on plants, and we learn about body systems and body parts, and planets.

90	#2	**2**	(lgh) You can use STEM, you can look at plants and when you don't know what the name, you can look it up on google. That s technology.
91	#2	**3**	We should have more days and maybe do it on Fridays. [a lot of grumbling]. I mean Thursdays.
92	#2	**4**	What I think about, I would go but….. y'all got to feed us [group laughter] get breakfast, and lunch, and fruits for snacks. Not vegetables, fruits are healthy.
93	#2	**4**	I believe that Is it. Will y'all take us home?
94	#2	**5**	We should not use our cell phones because they can be a distraction.
95	#2	**5**	I believe that the Arduino was too small, I could barely fit my finger into it
96	#2	**6**	<u>Yes</u>, but no. <u>The cell phone helped but you need (contact clues)</u> [not sure what this is], it also can be…too easy to use your phone for something else. Cause we have our phones on after school and people expect to be on their phones then.
97	#2	**6**	Yes, <u>but no.</u> The cell phone helped but you need (contact clues) [not sure what this is], <u>it also can be…too easy to use your phone for something else. Cause we have our phones on after school and people expect to be on their phones then.</u>
98	#2	**1**	STEM means, Science, Technology, Engineering and Math. And you have to learn science every day in class. We search stuff on google and that's technology. Oh, and we do math in class.
99	#2	**2**	There is an extent that we use the Acellus robot and we code.
100	# 2	**3**	I liked to have y'all come around and helped us fix our mistakes.

101	#2	**3**	6 I did like that we didn't have no transportation home. They could have dropped us off at the corner at least.
102	#2	**4**	6 I do summer school and its in June and also in May
103	#2		
104	#2	**3**	LED
105	#3	1	Science is like when you are talking about electronics and stuff. It is very fun.
106	#3	1	Science is like when you are talking about electronics and stuff. It is very fun.
107	#3	2	Uhh, I like what we are doing in the computer lab. We are doing a scientist project, about our favorite scientist.
108	#3	3	I liked making the circuit with the LEDs. And the Foldscope, I liked building it.
109	#3	3	I liked making the circuit with the LEDs. And the Foldscope, I liked building it.
110	#3	3	I did not like that we did not use the Green Towers as much as I had expected. I wanted to take more time exploring the leaves.
111	#3	3	Definitely more time, and I think that more schools participating
112	#3	3	Definitely more time, and I think that more schools participating
113	#3	4	I will be attending a summer camp so, no.
114	#3	1	I think that the STEM program was a good learning opportunity it helped me understand how the world works, how things works.
115	#3	1	uhh, it means science. And I think it is fun because I like science.
116	#3	1	uhh, it means science. And I think it is fun because I like science.

117	#3	1	Its kind of, of Like…. all science…. technology…. and Its very fun
118	#3	1	Its kind of, of Like…. all science…. technology…. and Its very fun
119	#3	1	I like STEM it is really interesting
120	#3	1	I like STEM it is really interesting
121	#3	2	umm here I can of think of back when our teacher, science teacher was teaching us about geology. Me I like rocks, I collect them, and I make jewelry
122	#3	2	Mine is Galileo Galilei
123	#3	2	I think of the tower garden that Mr. [teacher] has, and I like what every those things are… Foldscopes.
124	#3	2	I think of the tower garden that Mr. [teacher] has, and I like what every those things are… Foldscopes.
125	#3	3	I liked the Foldscope, how we put it together.
126	#3	3	I liked the Foldscope, how we put it together.
127	#3	3	Yes, I liked the Arduino too. I TOOK MY FOLDSCOPE HOME AND, I HAVE TWO CATS AND A DOG, SO I LOOKED AT SOME OF MY CAT'S HAIR IN THE FOLDSCOPE AND IT WAS, WOW, INTERESTING. AND WHEN I LOOKED AT MY DOG'S HAIR, IT LOOKED SO DIFFERENT!
128	#3	3	Make it longer and with more technology
129	#3	3	Make it longer and with more technology
130	#3	3	1 I feel similar to [#5]. I was really looking forward to working more with the plants and tower gardening
131	#3	3	Yes, I liked the Arduino too. I TOOK MY FOLDSCOPE HOME AND, I HAVE TWO CATS AND A DOG, SO I LOOKED AT SOME OF MY CAT'S HAIR IN THE FOLDSCOPE AND IT WAS, WOW, INTERESTING. AND WHEN I LOOKED AT MY DOG'S HAIR, IT LOOKED SO DIFFERENT!

132	#3	3	2 I liked the way the teacher showed us how to work if we were stuck and did not understand.
133	#3	3	<u>And I feel that it should have been longer… three weeks was not long enough,</u> because I really liked it.
134	#3	3	And I feel that it should have been longer… three weeks was not long enough<u>, because I really liked it</u>.
135	#3	3	I think that it should have more plant science and the Foldscope.
136	#3	3	I like anything dealing with technology, and I was interested in the…..what was it called, yes, the Arduino.
137	#3	3	I would relate it more to the Green Tower and plants life. And using the Foldscope more
138	#3	3	<u>I am really into electronics, so I liked the Arduino and, even though I missed a day</u>, I was excited about working with it.
139	#3	3	I am really into electronics, so I liked the Arduino and, even though I missed a day, <u>I was excited about working with it.</u>
140	#3	3	Yea, I feel that we did not have enough time to explore what we had made. We should have had more time.
141	#3	3	More electrical, and programming
142	#3	4	<u>Well, it would be pretty cool…. and I am interested in science…</u>. but my summer is already pretty much packed. Also I am supposed to attend a smaller, one week STEM workshop.
143	#3	4	Well, it would be pretty cool…. and I am interested in science…. <u>but my summer is already pretty much packed. Also I am supposed to attend a smaller, one week STEM workshop</u>.

144	#3	4	Like what [#1] said, I would go back. I would attend. I really think it will be fun. But unfortunately, my summer is already filled up.
145	#3	4	Like what [#1] said, I would go back. I would attend. I really think it will be fun. But unfortunately, my summer is already filled up.
146	#3	4	I would really like to go, because I like STEM and anything dealing with science
147	#3	4	I would like to go to a summer program.
148	#3	5	two things; I really enjoyed working with my hands, putting stuff together. So I liked that part. Also I, I liked including my cell phone in it. I did not have a cell phone and I got one for Christmas and it was really cool, and I like finding out all that I can do with it.
149	#3	5	two things; I really enjoyed working with my hands, putting stuff together. So I liked that part. Also I, I liked including my cell phone in it. I did not have a cell phone and I got one for Christmas and it was really cool, and I like finding out all that I can do with it.
150	#3	5	So, I don't have a phone. But I do like working with my hands and I like to Figure things out things out.
151	#3	6	Yeah it did. There is a difference between watching and doing it and watching someone building a model of plan....I liked putting together myself.
152	#3	6	I understood it more and I like feeling things with my hands. It makes it easier to see how things go together
153	#3	6	Actually, yes. Building things always helps me see how things work better, instead of reading it in book and watching videos.
154	#4	1	To me STEM means to work with, like science, technology, math and, what's that…. [#6 said engineering] yeah, engineering… I was thinking about

			economics. All of those letters that are in the word have a meaning.
155	#4	1	I think STEM that we did was mostly like testing your limits of learning
156	#4	1	I think this means, well at first, I thought STEM was like a plant, you know, stems and leaves and stuff. Now I know it means basically science. Also with STEM education is like basically fun.
157	#4	1	I think this means, well at first, I thought STEM was like a plant, you know, stems and leaves and stuff. Now I know it means basically science. Also with STEM education is like basically fun.
158	#4	2	like the green machine…
159	#4	2	In my engineering Model and Design class we build airplanes and other cool things, like today we built a bunch of Lab pieces [??] and built stuff with it.
160	#4	3	I really liked the hands on part. It was also fun to experience working with a group.
161	#4	3	I really liked the hands on part. It was also fun to experience working with a group.
162	#4	3	I wish we had more projects that were like centers where we could walk around to see the projects as a group.
163	#4	3	I would have liked more time, when we built the Arduino so that we could have finished it.
164	#4	3	I would have liked more time, when we built the Arduino so that we could have finished it.
165	#4	3	I disliked the, the old man who wore the red shirt(Adult #4), taking about, "pull up your pants.", and my pants was already pulled up. He was kind of creepy. The man in the red shirt.

166	#4	3	I though the first two days was very interesting but the last day… it was mostly my teammates doing everything, and I liked it, but I wish I could have had my own electronics [you mean, Arduino] yeah, the Arduino.
167	#4	3	I was confused the first day, but I liked the last two days. I like the Arduino part. I also liked the group work.
168	#4	3	I was confused the first day, but I liked the last two days. I like the Arduino part. I also liked the group work.
169	#4	3	I was confused the first day, but I liked the last two days. I like the Arduino part. I also liked the group work.
170	#4	3	I would change, I liked the teacher, Ms. [the name of the instructor], but, well, we needed more teachers to help. We should have had more time and more instructors.
171	#4	3	The first day, I thought it was so-o-o boring. (laughter) But the second day I was kinda confused UNTIL WE MADE THE CIRCUIT, AND THEN IT WAS LIKE, "HA-LA-LU-JAH, I MADE A LIGHT! AND THAT WAS COOL. We should have had more days so that we could have finished that project.
172	#4	3	The first day, I thought it was so-o-o boring. (laughter) But the second day I was kinda confused UNTIL WE MADE THE CIRCUIT, AND THEN IT WAS LIKE, "HA-LA-LU-JAH, I MADE A LIGHT! AND THAT WAS COOL. We should have had more days so that we could have finished that project.
173	#4	3	The first day, I thought it was so-o-o boring. (laughter) But the second day I was kinda confused UNTIL WE

			MADE THE CIRCUIT, AND THEN IT WAS LIKE, "HA-LA-LU-JAH, I MADE A LIGHT! AND THAT WAS COOL. We should have had more days so that we could have finished that project.
174	#4	3	I disliked the first day. I was just sitting there watching the video and I couldn't really understand about the photosynthesis. I was confused.
175	#4	4	My mother has a baby on the way, so I will most likely be watching the little brat.
176	#4	4	I have nothing planned. I would go.
177	#4	4	I would go, if there is going to be food [they plan to have breakfast, lunch and a snack.]. Bet! Then I'll go.
178	#4	4	I would go, if there is going to be food [they plan to have breakfast, lunch and a snack.]. Bet! Then I'll go.
179	#4	4	I would but we have already booked 2 vacations
180	#4	4	I would like to come but this summer I got dance, swimming, basketball, and I have summer school.
181	#4	5	Yes, I liked working with my hands.
182	#4	5	Yes
183	#4	5	I also say yes, I like working with my hands putting the Foldscope together, and I also liked using the cellphone with the Foldscope.
184	#4	5	I also say yes, I like working with my hands putting the Foldscope together, and I also liked using the cellphone with the Foldscope.
185	#4	5	Yes
186	#4	6	I like to work with hands my hands, because I may not understand the video and you cant stop a video if you don't get it right where as you can always try something a different way.
187	#4	6	Ok, so working with your hands you like, oooh I got this correct! You know, that's how I learn. Like if I

			wanted to learn how to open a water bottle, I can do it better by touching and holding the water bottle in my hands.
188	#4	7	<u>My advice is that we should get Pizza Hut next time.</u> And my advice is also to go every single day of the week for three weeks. I have more time be able to watch the videos, and then we should have group discussions about what the videos are telling us.
189	#4	7	My advice is that we should get Pizza Hut next time<u>.</u> A<u>nd my advice is also to go every single day of the week for three weeks.</u> I have more time be able to watch the videos, and then we should have group discussions about what the videos are telling us.
190	#4	7	My advice is that we should get Pizza Hut next time<u>.</u> And my advice is also to go every single day of the week for three weeks. I have more time be able to watch the videos, and then <u>we should have group discussions about what the videos are telling us.</u>
191	#4	2	10 So what you said [speaking about #6] science, technology, engineering, and math. Oh the classes here are science, math… and I take those. They are required for engineering Model and Design and also Maker Space… [Oh, you have a Maker Space here at Grand Central] yes and it was fun. Uhh, I used to be like, it when I was in engineering Model and Design, because we worked with our hands and we, we made an airplane and stuff.
192	#4	3	<u>So I thought it was good, but it was a little bit boring</u>. I wish we had more time to do the STEM
193	#4	3	So I thought it was good, but it was a little bit boring. <u>I wish we had more time to do the STEM</u>

194	#4	4	10 I would come but my summer is already packed. My family has two trips planned and also camping
195	#4	1	I think it means, like to me, I see it is a new experience. New knowledge and new things and cool stuff.
196	#4	2	4 Last year I was in Maker Space, awww, we went on trips. I am not in it anymore but I feel like that they do a good job here and that show us that other classes can use STEM.
197	#4	2	Now I like the way the teachers teach. I love how Mrs. [the science teacher] teaches descriptively and gives us creative assignments
198	#4	3	I sometimes did not understand the language that was used. I would change the language used, like "photosynthesis".
199	#4	4	I would go but I have tight schedule already for this summer, but if I could fit it in, I'll go. You see, I have family that think I'm supposed to baby sit my brother. Also, I got, like, things to catch up on
200	#4	5	Yes
201	#4	5	I like to work with my hands because when you handle something you get like, well if it don't work I can twist it this way or move it that way. If you are watching a video you cant ask anything or you cant change it.
202	#4	1	uh it means… basically it means that you are smart about science and things. You are not actually smart though. Also it means free pizza… and you do things that ahh, are kind of smart, but I don't really think you are no smarter that the rest of the class. You are somewhat smart though
203	#4	1	uh it means… basically it means that you are smart about science and things. You are not actually smart though. Also it means free pizza… and you do things

			that ahh, are kind of smart, but I don't really think you are no smarter that the rest of the class. You are somewhat smart though
204	#4	1	STEM means helping the earth and saving it.
205	#4	1	STEM is like educational things that help the environment, and it is fun, and it's basically cause fun you learn new scientific things
206	#4	1	STEM is like educational things that help the environment, and it is fun, and it's basically cause fun you learn new scientific things
207	#4	1	STEM is like educational things that help the environment, and it is fun, and it's basically cause fun you learn new scientific things
208	#4	2	uh and so we have classes in science and technology and engineering and math….
209	#4	2	Yeah. we have no engineering though, we have technology though, I used to be in computer class, but now I am in science and math. You have to be in both.
210	#4	2	At this school we talk about STEAM you know with an "A" for Arts, because we believe in dance, visual arts, and music as well as engineering, and the green machine, and science and math.
211	#4	3	I though the first two days was very interesting but the last day… it was mostly my teammates doing everything, and I liked it, but I wish I could have had my own electronics [you mean, Arduino] yeah, the Arduino.
212	#4	3	The Arduino… I did not like that part, but the Foldscope was very interesting.
213	#4	3	The Arduino… I did not like that part, but the Foldscope was very interesting.

214	#4	3	Uhm, we got to do some fun things, I liked we got to explore two different things… the foldscope and the other, electronic thing.
215	#4	3	I wish we had more time
216	#4	4	I will try to go. My summers are the opposite of everybody else's…I don't have anything planned, so I would like to go.
217	#4	4	I would also go, but I would need a ride 'cause I don't have transportation
218	#4	5	Yes
219	#4	6	I am an Interactive learner, so I learn best with hands on learning

Appendix B: Statistical Tests Tables and Figures

Table 4

Statistical Tests, Tables, and Figures

Comparison	Variables	Analysis
Maximum Variance	All	Factor Analysis
Internal Consistency	Questionnaire Scales	Cronbach's alpha
Goodness of Fit	Grade, School, Gender	Chi-square
Study	Grade, Gender, School, Group	ANOVA
Characteristics comparability	Pre-questionnaire, Pre-Total Knowledge, Pre-Interest, Pre-Difficulty, Pre-Knowledge	Independent Samples *t*-test
Age, PQ1-17 mean, PQ 18-27	Strength of Correlation	Pearson's Correlation
Academic Learning by Gender and School	Post-Total Knowledge, Gender, School	ANCOVA
Academic Learning by School	Post-Total Knowledge, Grade, School	ANCOVA
Variable impact on Academic Learning	Post-Total Knowledge, Gender, School, Grade, Group, Post Interest, Post Difficulty, Post Importance,	Regression Analysis

Figure 21a

Histogram of Monday Participants Pre- Knowledge Total Score

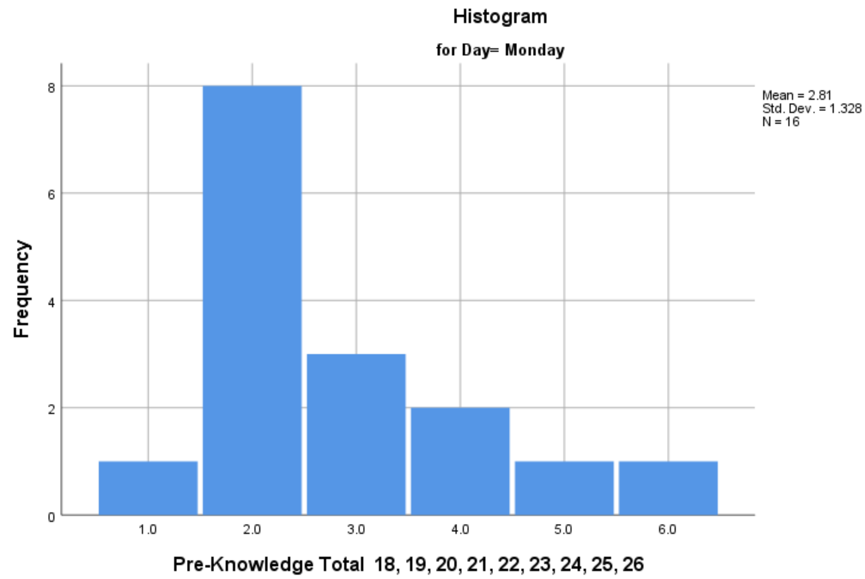


Figure 21b

Histogram of Tuesday Participants Pre- Knowledge Total Score

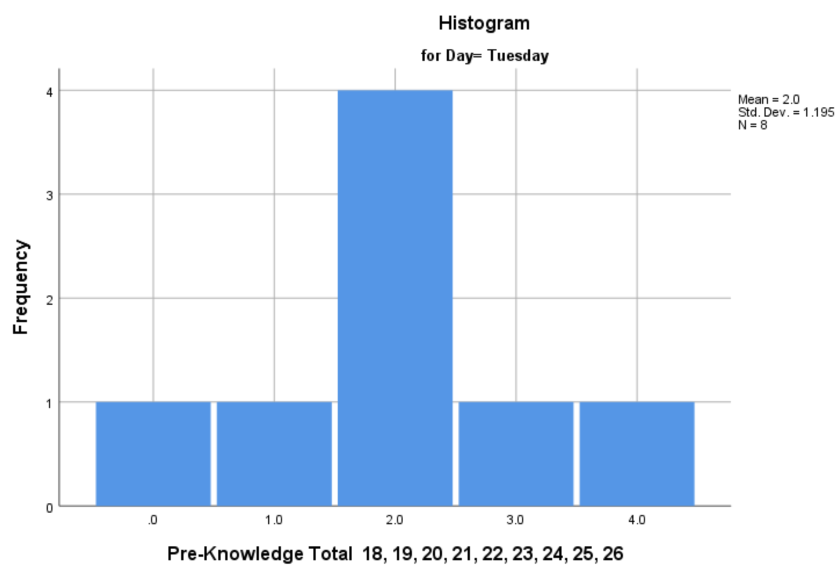


Figure 22a

Normal Q-Q Plot of Monday Participants Pre- Knowledge Total Score

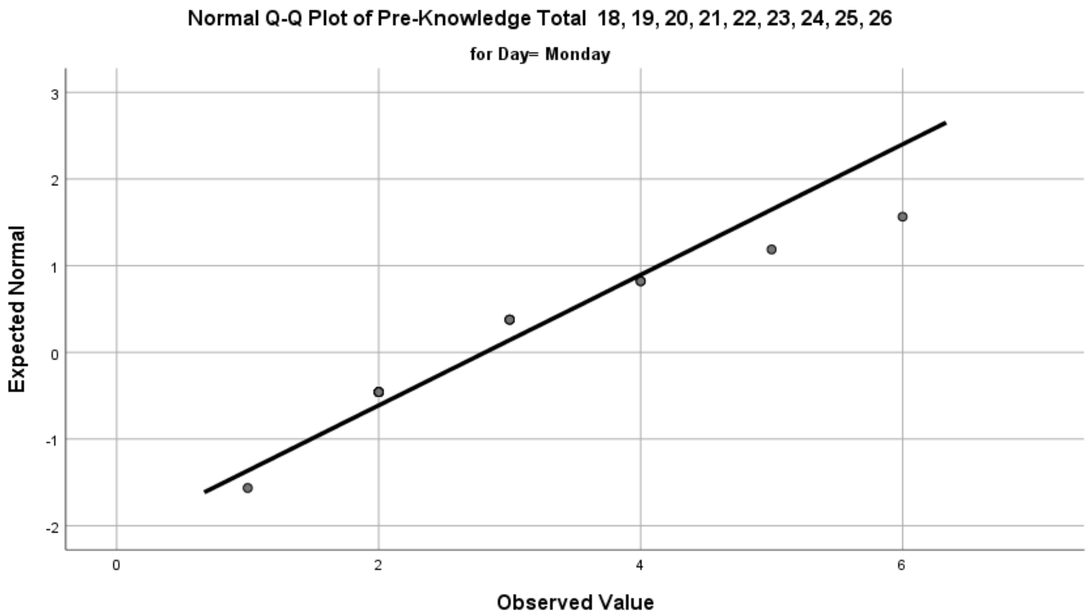
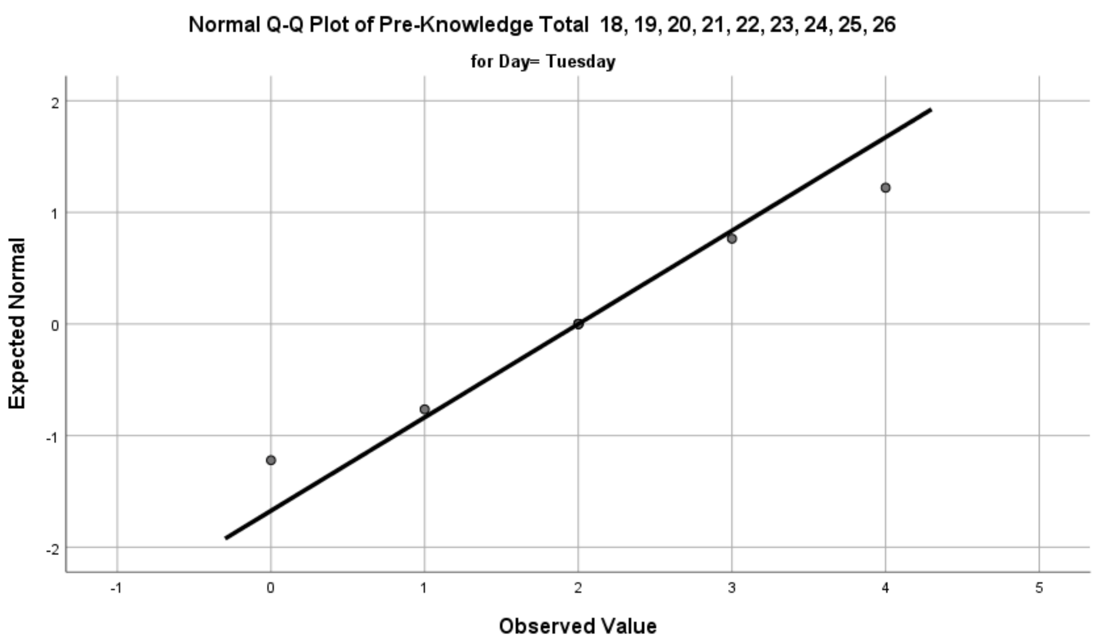


Figure 22b

Normal Q-Q Plot of Tuesday Participants Pre- Knowledge Total Score



Appendix C: Questionnaire Results

Table 10

Pre- Post- Knowledge Questionnaire Results

Multiple Choice Question Number	Pre-Questionnaire (%)		Post-Questionnaire (%)		
	Right	Wrong	Right	Wrong	Delta Change (%)
18	10 (41.7%)	14 (58.3%)	15 (62.5%)	9 (37.5%)	5 (20.8%)
19	9 (37.5%)	15 (62.5%)	17 (70.8%)	7 (29.2%)	8 (33.3%)
20	4 (16.7%)	20 (83.3%)	8 (33.3%)	16 (66.7%)	4 (16.7%)
21	6 (25.0%)	18 (75.0%)	6 (25.0%)	18 (75.0%)	0 (0.0%)
22	3 (12.5%)	21 (87.5%)	5 (20.8%)	19 (79.2%)	2 (8.3%)
23	8 (33.3%)	16 (66.7%)	14 (58.3%)	10 (41.7%)	6 (25.0%)
24	7 (29.2%)	17 (70.8%)	7 (29.2%)	17 (70.8%)	0 (0.0%)
25	4 (16.7%)	20 (83.3%)	3 (12.5%)	21 (87.5%)	-1 (-4.2)
26	10 (41.7%)	14 (58.3%)	5 (20.8%)	19 (79.2%)	-5 (-20.3%)
Total	61 (28.2%)	155 (71.8%)	80 (37.0%)	136 (6296.3%)	19 (8.8%)

Table 11

Pre Mobile Device/Maker Project Attitude of African Americans

Question #	Question	SA (%)	A (%)	N (%)	D (%)	SD (%)
1	I like science more than other subjects	5 (20.8%)	4 (16.7%)	10 (41.7%)	5 (20.8%)	0 (0.0%)
2	Nature and science are strange for me	4 (16.7%)	7 (29.2%)	7 (29.2%)	3 (12.5%)	3 (12.5%)
3	Science lessons are difficult for me	1 (4.2%)	2 (8.3%)	10 (41.7%)	6 (25.0%)	5 (20.8%)
4	Science helps development of my conceptual skills	2 (8.3%)	13 (54.2%)	8 (33.3%)	1 (4.2%)	0 (0.0%)
5	I would like to have science lessons more often	2 (8.3%)	8 (33.3%)	10 (41.7%)	3 (12.5%)	1 (4.2%)
6	Science knowledge is essential for understanding other courses	2 (8.3%)	6 (25.0%)	12 (50.0%)	2 (8.3%)	2 (8.3%)
7	During science lessons, I am bored	2 (8.3%)	1 (4.2%)	8 (33.3%)	7 (29.2%)	6 (25.0%)
8	The progress of science improves the quality of our lives	7 (29.2%)	5 (20.8%)	9 (37.5%)	2 (8.3%)	1 (4.2%)
9	Science is our hope for solving many environmental problems	6 (25.0%)	8 (33.3%)	9 (37.5%)	1 (4.2%)	0 (0.0%)
10	Science is not important in comparison with other courses	1 (4.2%)	0 (0.0%)	8 (33.3%)	10 (41.7%)	5 (20.8%)
11	I make many efforts to understand science	5 (20.8%)	11 (45.8%)	7 (29.2%)	1 (4.2%)	0 (0.0%)
12	Science is an important part of our lives	10 (41.7%)	4 (16.7%)	9 (37.5%)	0 (0.0%)	1 (4.2%)
13	No one needs science knowledge	1 (4.2%)	0 (0.0%)	5 (20.8%)	5 (20.8%)	13 (54.2%)
14	I hate science lessons	2 (8.3%)	0 (0.0%)	7 (29.2%)	5 (20.8%)	10 (41.7%)
15	I find scientific principles interesting	2 (8.3%)	6 (25.0%)	13 (54.2%)	2 (8.3%)	1 (4.2%)
16	The work with living plants in science lessons is very interesting	4 (16.7%)	4 (16.7%)	11 (45.8%)	1 (4.2%)	0 (0.0%)
17	Science is one of the easiest courses for me	3 (12.5%)	1 (4.2%)	15 (62.5%)	4 (16.7%)	1 (4.2%)
Total (%)		59 (14.5%)	80 (19.6%)	158 (38.7%)	58 (14.2%)	49 (12.0%)

Table 12

Post- Mobile Device/ Maker Project on Attitude of African Ameicans

Q#	Question	SA (%)	A (%)	N (%)	D (%)	SD (%)
1	I like science more than other subjects	3 (12.5%)	2 (8.3%)	10 (41.7%)	7 (29.2%)	2 (8.3%)
2	Nature and science are strange for me	2 (8.3%)	3 (12.5%)	8 (33.3%)	9 (37.5%)	2 (8.3%)
3	Science lessons are difficult for me	1 (4.2%)	3 (12.5%)	11 (45.8%)	6 (25.0%)	3 (12.5%)
4	Science helps development of my conceptual skills	4 (16.7%)	10 (41.7%)	8 (33.3%)	2 (8.3%)	0 (0.0%)
5	I would like to have science lessons more often	6 (25.0%)	6 (25.0%)	7 (29.2%)	3 (12.5%)	2 (8.3%)
6	Science knowledge is essential for understanding other courses	5 (20.8%)	5 (20.8%)	10 (41.7%)	3 (12.5%)	1 (4.2%)
7	During science lessons, I am bored	2 (8.3%)	4 (16.7%)	7 (29.2%)	5 (20.8%)	6 (25.0%)
8	The progress of science improves the quality of our lives	4 (16.7%)	12 (50.0%)	5 (20.8%)	1 (4.2%)	2 (8.3%)
9	Science is our hope for solving many environmental problems	7 (29.2%)	8 (33.3%)	7 (29.2%)	2 (8.3%)	0 (0.0%)
10	Science is not important in comparison with other courses	1 (4.2%)	3 (12.5%)	8 (33.3%)	9 (37.5%)	3 (12.5%)
11	I make many efforts to understand science	6 (25.0%)	7 (29.2%)	9 (37.5%)	1 (4.2%)	1 (4.2%)
12	Science is an important part of our lives	7 (29.2%)	7 (29.2%)	9 (37.5%)	1 (4.2%)	0 (0.0%)
13	No one needs science knowledge	0 (0.0%)	4 (16.7%)	2 (8.3%)	6 (25.0%)	12 (50.0%)
14	I hate science lessons	1 (4.2%)	2 (8.3%)	6 (25.0%)	3 (12.5%)	12 (50.0%)
15	I find scientific principles interesting	4 (16.7%)	6 (25.0%)	9 (37.5%)	3 (12.5%)	2 (8.3%)
16	The work with living plants in science lessons is very interesting	6 (25.0%)	7 (29.2%)	8 (33.3%)	3 (12.5%)	0 (0.0%)
17	Science is one of the easiest courses for me	4 (16.7%)	5 (20.8%)	11 (45.8%)	3 (12.5%)	1 (4.2%)
Total (%)		63 (15.4%)	94 (23.0%)	135 (33.1%)	67 (16.4%)	49 (12.0%)

Appendix D: IRB Approval Letter

Figure 19

IRB Approval Letter

Office of Research Administration

One University Boulevard
St. Louis, Missouri 63121-4499
Telephone: 314-516-5899
Fax: 314-516-6759
E-mail: ora@umsl.edu

DATE:	June 19, 2019
TO:	Allen Savage
FROM:	University of Missouri-St. Louis IRB
PROJECT TITLE:	[1433127-2] Utilizing Mobile Devices and Maker Projects in the Academic Achievement, Attitude and Interest, of African Americans in High School Biology
REFERENCE #:	
SUBMISSION TYPE:	Amendment/Modification
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	June 19, 2019
REVIEW CATEGORY:	Exemption categories # *1, 2*

The chairperson of the University of Missouri-St. Louis IRB has APPROVED the above mentioned protocol for research involving human subjects and determined that the project qualifies for exemption from full committee review under Title 45 Code of Federal Regulations Part 46.101b. The time period for this approval expires one year from the date listed above. You must notify the University of Missouri-St. Louis IRB in advance of any proposed major changes in your approved protocol, e.g., addition of research sites or research instruments.

You must file an annual report with the committee. This report must indicate the starting date of the project and the number of subjects to date from start of project, or since last annual report, whichever is more recent.

Any consent or assent forms must be signed in duplicate and a copy provided to the subject. The principal investigator must retain the other copy of the signed consent form for at least three years following the completion of the research activity and they must be available for inspection if there is an official review of the UM-St. Louis human subjects research proceedings by the U.S. Department of Health and Human Services Office for Protection from Research Risks.

This action is officially recorded in the minutes of the committee.

If you have any questions, please contact Carl Bassi at 314-516-6029 or bassi@umsl.edu. Please include your project title and reference number in all correspondence with this committee.

Appendix E: Flyers, Forms, Pre- Post- Questionnaire, and MOU

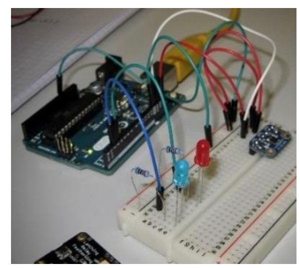
IRB#: 1433127-2

Figure E1

Informational Flyer for Students

Are you a Future Engineer/Astronaut/Scientist/Math Prodigy?

Would you like to build an Aeroponic System and then grow and study your plants?
Would you like to create your science gadgets to study your plants?
Are you curious about **STEM**? (Science, Technology, Engineering and Math, that is.)



Well, Congratulations!!!

Researchers at the University of Missouri, St. Louis are seeking volunteers for a study in STEM involvement using smart-phones and "Do-It-Yourself" projects. The study is designed to be Fun, Fun, and Fun! It will be conducted in early 2020 and is Free, Free, Free! Snacks will also be provided and you will get to keep your Foldscope Microscope to study microbes at home. If this is for you please talk with your parents and contact <Teacher Name> for more info.

Attachment E-2

Figure E2
Informational Flyer for Guardian/Parent

<<Number>> IRB#: 1433127-2

Are you the parent/guardian of a Future Computer Engineer, Astronaut, Scientist, or Math Prodigy? Well, Congratulations!!!

Researchers at the University of Missouri, St. Louis, would like to study ways that will help your child succeed in STEM (Science, Technology, Engineering and Math).

What is the Study about?

- A researcher will pre-test your child on his/her STEM knowledge and interest.
- Your child will then participate in two STEM labs where they will construct STEM devices to systematically investigate indoor aquaponic garden towers.
- During the labs, a researcher will observe the STEM activity to see how they enjoy it.
- After the STEM labs, your child will again be tested and may volunteer to share how the felt about the labs.

Why do this Study?

- This study is part of a doctoral research dissertation to investigate if the use of mobile devices (such as laptops, tablets, and smartphones), in conjunction with Do-It-Yourself STEM devices can improve both knowledge and interest in STEM.

Do participating youth get anything?

- Those who complete the study will take home a Foldscope Microscope.

Are there any dangers, risks, or pressures to my child?

- No, the associated risks are no greater than in any middle school science class.
- Either You or your child may decide to quit the study at any time with no consequence.

How do I register my child to participate?

- On the back of this flyer is a consent form giving your permission for your child to be in this study. Your child will give his or her signed assent participate.
- Return both signed forms to the researcher by way of your child's teacher.

For more information, contact:
Allen Savage, Principal Investigator
Phone: 314-243-7111
Email: asxv2@mail.umsl.edu
[redacted], Study Faculty Advisor
Phone: [redacted] Email:
[redacted].edu

Figure E3

Recruitment Flyer for Students

Mobile Devices and Maker Projectsin STEM *After School Program* IRB#: 1433127-2

Description & Purpose of Research: Researchers at the University of Missouri, St. Louis, College of Education, want to study the use of mobile devices and Do-it-Yourself projects in learning about science, technology engineering, and math (STEM). This research study is for children who attend after school programs. It is a voluntary study and requires both you and your parent/guardian's written approval.

Is this study for me? This study would be a good fit for you if:

- You are in grade 6, 7, or 8
- You can attend, would like to attend, or already a part of an after-school garden tower program.
- You are curious about STEM Education

What can I expect if I took part in the study? If you decide to take part in the research study, you would:

- Attend three (3) 90-minute sessions at an after-school site
- During the first session, you will be introduced to the researchers, the study, and will take a short test
- During the second session, you will construct a Foldscope microscope and study plants leaves
- During the third session, you will construct an Arduino spectroscope and study plant chlorophyll. Also, you will repeat the earlier test.
- Shortly after the study you may take part in a volunteer focus group and share your experiences

Specify Location of Research: This research will take place at the M[redacted]s Club located at [redacted]

Contact Information: To take part in the *Mobile Devices and Maker Projects for Improving Academic Achievement, Attitude, and Interest in STEM* research study or for more information, please contact Dr[redacted] Study Faculty Advisor, University of Missouri, College of Education, 314-[redacted].edu.
PI Name, department & email address: The principal researcher for this study is Allen L. Savage, Sr., UMSLCOE, 314243-7111, asxv2@mail.umsl.edu.

Attachment E-4a

Figure E4

Recruitment Flyer for Guardian/Parent

Green Tower STEM Study

Green Tower STEM (GTS) is a two-week long study involving three instructional sessions designed to investigate the potential of increasing middle-school youth's interest and engagement in STEM through mobile device incorporated into Maker Education projects. The after-school program will be held at the Mathews-Dickey Boys' and Girls' Club, and in cooperation with the Green St. Louis Machine (GSM). The program has been designed as a pilot program in hopes of developing an on-going intervention that can be used by after-school organizations, schools, churches, and other institutions. Even thou[redacted]eriments presented during GTS were chosen for their "WOW and FUN" factors, they were also selected to support the standards-based education offered in public education, and to cultivate a desire within the participant to know more about STEM activities.

GTS was developed by Allen Savage, Sr. as partial requirements for the completion of the STEM Education EdD program at University of Missouri, St. Louis (UMSL). Dr.[redacted] is the study's dissertation committee chair and a veteran administrator of multiple after school programs, such as Girl's Inc., and other organizations.

Population

GTS is seeking partnership with [redacted] Club, both of which have long served GTS's target population, which is:

- Children between the ages of 6-18,
- who show interests in science, technology, engineering and math,
- from all backgrounds, cultures, and classes, but especially those considered at-risk or disadvantaged.

It is the belief that this population would benefit both academically and inspirationally from participation in the GTS program. Since the GTS program is designed to be cohort-based an added benefit is believed to be increased social engagement development.

Program Features

- Prior to the GTS program, all participating organizations, institutions, instructors, investigators, students, and parents will be required to read through the program and give their consent and/or assent to be a part of this study. All STEM instructors and investigators will be required to pass a background check.

The STEM Instructor(s) will meet with the GSM group(s) weekly for a 90-minute period of informal, maker-based activities designed to implement a particular STEM educational concept. Each group will consist of no more than 24 participants divided into approximately 6 cohorts (four

Attachment E-4b

Recruitment Flyer for Guardian/Parent

- members to a cohort). The two interventions selected for this study are designed to be in harmony with the GSM program, with the goal of teaching STEM concepts and stimulating STEM interest.
- Prior to the first intervention the participating students will be given a 26-item questionnaire as a pretest. The items will be used to measure the initial STEM academic acumen and interest. The same questionnaire will be taken again after the completion of the GTS program, so that any changes may be noted.
- Each of the interventions will begin with a brief instructor-led discussion that may include videos, handouts, demonstrations, etc., to help facilitate the hands-on Maker activity. During the activity the instructor will limit his or her interactions to a minimum. At the conclusion of each session, the participants will reflect on their experiences, and share their findings and what they have learned.

- The interventions are as follows:
    - **<u>Intervention 1</u>:** Using the Foldscope to examine and photograph stems, leaves, and seeds of the Green Tower vegetables.
    - **<u>Intervention 2</u>:** Building an Arduino Spectrometer for determining Chlorophyll in plants.
    - **<u>Volunteer Focus Group</u>:** A 20 – 30 min of open-ended questions for the purpose of assessment of STEM interests.

During each of the above interventions an observer will passively observe the participants, noting the interactions, attitudes and body language of the groups.

Outcomes

All of the GTS workshop materials are funded totally and completely by the study, and the participants will receive their activities for free in exchange for [redacted] Club. providing demographics data. The data will be collected, stored, and analyzed in confidence and will be destroyed after acceptance and publication of the dissertation report. There will be no traceability of data to any individual, institution, organization or participant in this study. All data findings will be shared with [redacted] also UMSL for their usage, with proper citation. It is hypothesized that participation in the GTS program will increase the academic achievement of the participant in STEM related courses and will stimulate a greater interest in STEM education.

Attachment E-5

Figure E5

Assent Form for Minor Participant

Department of Education Sciences
and Professional Programs
One University Boulevard
St. Louis, Missouri 63121-4499
Telephone: 314-516-4828
Fax: 314-516-5227
E-mail: asxv2@mail.umsl.edu

Assent to Participate in Research Activities (Minors)

Utilizing Mobile Devices and Maker Projects in the Academic Achievement, Attitude and Interest, of African Americans in High School Biology.

1. My name is Allen L. Savage. I am a graduate student at the University of Missouri, St. Louis, College of Education. I am conducting research in STEM laboratories in high school biology classes.
2. I am asking you to take part in a research study because we are trying to learn more about how to increase the number of African Americans in science and math careers.
3. If you agree to be in this study, you will complete two laboratory experiments in your current science or biology class in which you to use a mobile phone and make some apparatuses. You will then be asked to volunteer to participate in a focus group session. Participation in the study or focus group is at your discretion and you may choose not to participate.
4. Agreeing to participate in this study should not be harmful in any way, and if you agree to participate and later believe that you have been or will be hurt or upset in any way you can quit the study, with no repercussions to yourself. If you are harmed by someone who is a participant in this study, I am bound under law to report it to the proper authorities.
5. This study has been designed to help the participant understand and appreciate STEM activities, so you may gain a greater knowledge and interest in science and math. Also, since this activity replaces your normal activity for your class, you will gain a grade commensurate with your completion of the assignment.
6. Please talk this over with your parents before you decide whether to participate. You will be given a Parental Consent form to take home to your parent/guardian, for written permission for you to take part in this study. Bring the signed copy back to your class. If they decide not to have you participate, or if you do not return the signed consent form prior to the beginning of the study, you cannot participate in the study. Even if your parents say "yes," you still can decide not to do this.
7. If you don't want to be in this study, you don't have to participate. You will complete an equivalent non-study related lab. Remember, being in this study is up to you, and no one will be upset if you don't want to participate or if you change your mind later and want to stop.
8. You can ask any questions that you have about the study. If you have a question later that you didn't think of now, you can call me at (314)243-7111 or ask me next time.
9. Signing your name at the bottom means that you agree to participate in this study. You and your parents will be given a copy of this form after you have signed it.

_______________________________________ __________________________________
Participant's Signature Date Printed Name

_______________ _______________
Participant's Age Grade in School

Attachment E-6

Figure E6

Consent Form for Guardian/Participant

Parent/Guardian Informed Consent for Participation in Research Activities

1. What is this Research Study About?

Your child is being invited through the Green St. Louis Machine program at your school, to participate in a research study by Mr. Allen Savage, Sr., a doctoral candidate graduate student of Dr. Keith Miller, at the College of Education, UMSL. The purpose of this research is to study if urban middle school students' (ie. African-American) interest and ability in STEM careers can be increased by do-it-yourself projects with aeroponic growing systems like the ones at your child's school!

2. What are the dates and times?

- Dates: Monday January 27th, Monday February 3rd and Monday February 10th
- Time: 4 - 5:30 PM at [redacted]
- Note: (Transportation TO [redacted]
- Transportation HOME needs to be provided by parents/guardians *or a carpool arrangement.*

3. What are the things my child will do during the project?

- A light meal will be served including pizza, fruit and vegetables
- They will build their own and assemble testing equipment and use mobile devices to analyze scientific principles or perform engineering tasks.
- They will get to keep what they build!!
- Your child will be observed during these labs, notes taken, and labs graded to assess academic progress.
- A pre and post questionnaire will be given at the beginning and the end of the three-week period.

4. Focus Group Session

Within one week after the last lab, your child will be asked to participate in a voluntary focus group to determine your child's opinions on the experiment and whether their interests and attitudes towards STEM have changed. The 30 minute focus group process will be held in a group format.

5. This opportunity is voluntary.

- Your child's participation is voluntary, contingent upon both your agreement, and their agreement.
- You may withdraw at any time if your child chooses not to participate.
- Your child may choose not to answer any questions that they do not want to answer.

6. Privacy and Confidentiality of Research Data for University Research

- We will do everything possible to assure the protection of your privacy as well as that of your child.
- Any disclosure, presentation or publication of the study data will also protect your and your child's privacy.
- For any additional questions about privacy and confidentiality of this research, see contacts below.

7. Contact information for questions

- Your Child's Teacher
- Allen L. Savage Sr. Principal Investigator (314) 243-7111, asxv2@mail.umsl.edu
- [redacted]
- [redacted]
- [redacted]
- You may also contact the Office of Research Administration at UMSL at (314) 516-5899, ora@umsl.edu, regarding your child's rights as a research participant.

I have read this consent form and have been given the opportunity to ask questions. I hereby consent to participate in the research described above. TEACHER *(a copy will be returned to you during the Study)*

--<<Number>>--

Participant Name ______________________________HSC Approval Number __IRB#: 1433127-2_____________

Parent's or Guardian's Signature ________________________ Date ____________________

PLEASE RETURN SIGNED CONSENT FORM PRIOR TO FRIDAY, 01/24/20 TO YOUR CHILD'S TEACHER

Attachment E-7a

Figure E7a
Consent Form for Teachers

Consent to Participate in Research Activities (Teachers)

Utilizing Mobile Devices and Maker Projects in the Academic Achievement, Attitude and Interest, of African Americans in High School Biology

Dear <Teacher>

My name is Allen L. Savage. I am a doctoral student at the University of Missouri, St. Louis, College of Education. I am conducting research in STEM laboratories in high school biology classes. I am asking you to take part in a research study because we are trying to learn more about how to increase the number of African Americans in science and math careers. I would like to conduct research in your class under the supervision of my advisor from the College of Education, Dr. Keith Miller. The purpose of this research study is to explore the utility of mobile devices and maker projects on academic achievement, attitude, and interest, of African Americans in High School Biology. The study is brief, consisting of two laboratory experiments in which your child with construct a laboratory instrument which utilizes a mobile phone for investigation of scientific principles. We will supply all the supplies needed to construct the devices, and we will also provide you with all ancillary information, directives, and instructions necessary during this study. The anticipated time frame of this study is during the second half of the fall semester of 2019, and your administration has already given permission to conduct this study. Your participation, however, is totally voluntary.

If you agree to participate, I would like to meet with you and explain h the research design, the roles that the student participants will play, your part, and how the data from this study will be analyzed and presented. This should require about 30 minutes of your time and may be conducted during a lunch period or free hour. If you decide that you would prefer not to answer any particular question, decided to discontinue the meeting or decide that you would not like to participate in the research study you can do so with no repercussions to yourself, your school or district, with the University of Missouri, St. Louis.

If you agree to participate, then your class or classes will be used to recruit approximately 125 students from several high school biology majority African American biology classes in the St. Louis Metropolitan area. To assure that your identity will not be disclosed in this study, you will randomly be recorded with an identifier such as "Teacher #___." If you have more than one class, you may have more than one id. Those of your students who choose to participate will be given a blind, randomly selected five character code with which they will be identified throughout the study to keep their anonymity. They will be instructed to keep this code confidential, and to use it as an identifier on any materials turned in for the study. Your class may be chosen to be a part of this treatment group or part of a control group. The participants will complete two science labs in which they will assemble their own testing equipment and use their cell phones to analyze scientific principles or perform engineering tasks. These labs will

Attachment E-7b

Consent Form for Teachers

your choosing. For those who do chose to participate, and who have all consent forms on file with the administrator, a pre- and post-test questionnaire will be given for each lab. These labs will be graded as any typical lab and will become part of the normal assessment process. Within one week after completing the second lab, the participants will be asked to take part in a voluntary focus group to determine student opinion, insights, interests, and attitudes towards the experiments and STEM in general. The focus group process will be held in a group format and will last no longer than 30 minutes. The amount of time required for each class participation will be the length of two regular 90-minute classes, or approximately three hours total, spread out over two regular school days. For those who choose to participate in the focus group process, an additional 20 to 30 minutes will be required.

The purpose of this study is to investigate means by which African American academic achievement and attitude towards STEM education might be increased, something that is of concern to me, and, I believe, to you also. If you choose to participate in this study, please sign below and return the signed form in the enclosed self-addressed envelope. Alternatively, if your institution has its own Documentation of Permission, please send a signed copy on your institution's letterhead, acknowledging your consent and permission for me to conduct this survey/study at your institution. If you have any questions or need further clarification, please contact me at asxv2@mail.umsl.edu (314-243-7111) or the UMSL Faculty Advisor [redacted].edu (314-[redacted]) before signing this form. Thank you for your consideration.

I, the below signed, am authorized to give my consent, and give approval to Allen L. Savage, Sr. to conduct the above-stated research in my class.

Signature of Teacher ______________ Date ______________ Printed Name ______________

cc: Dr. [redacted]r

Attachment E-8a

Figure E8a
MOU

MEMORANDUM of UNDERSTANDING

between

UNIVERSITY OF MISSOURI (UMSL), ST. LOUIS, College of Education

and

[redacted]**), St. Louis, MO**

and

[redacted]**St. Louis, MO**

and

[redacted]**, St. Louis, MO**

and

[redacted]**, St. Louis, MO**

Attachment E-8b

Memorandum of Understanding

I. Primary Goals of this Partnership are: • To provide a mechanism where the passion for STEM Education may be fostered in a non-traditional teaching environment, primarily, but not exclusively, for disadvantaged, low-income African Americans, who are the principal focus of this research study. • Demonstrate that STEM academic learning and interest may take place by utilizing available technology, such as personal mobile devices.

- Demonstrate that STEM academic learning and curiosity may take place by using opensourced projects provided on the internet.
- Provide an informative venue for partnering instructors who may develop a more indepth and complete after school STEM program.
- Investigate the viability of the program from the participating student's perspective.
- Develop and demonstrate a productive working relationship between UMSL and local middle schools in the Greater St. Louis Area.
- Provide documentable, statistical evidence suitable for partial requirements of the UMSL COE doctoral STEM EdD program
- The above parties made and entered into this MOU on the ___th day of the month of January, of the year of 2020, by and between:

UMSL COE Doctoral Candidate, Allen L. Savage, Sr.
1 University Blvd, 201 Education Administration Building (EAB), St. Louis, MO 63121
[redacted] MO 63115
[redacted] MO 63115
[redacted] is, MO 63112
[redacted] MO 63103
[redacted] MO 63108

II. Purpose and Scope

The purpose of this Memorandum of Understanding (MOU) is to clarify the duties and responsibilities of the above participants involved in the Green Tower STEM (GTS), an afterschool study designed to investigate the potential of increasing middle-school youth's interest and engagement in STEM through mobile device incorporated into Maker Education projects. **This document is nonbinding, and obligates no party to the funding of any sort; no party that signs this document are not bound to any action or to provide any fund.** The above individuals and organizations summarily agree that participating in this study might prove to be of significant benefit to increasing the pursuit of a career in a STEM-related field, thereby improving the participants' odds of escaping poverty.

Attachment E-8c

Memorandum of Understanding

III. Duration

The term of the MOU is for the period of the date of signing through February 14th, 2020, and maybe extended upon written mutual consent of all parties involved.

IV. Responsibilities

A. University of Missouri, St. Louis through its agent, doctoral candidate Allen L. Savage, Sr. agrees to:

- Provide the complete Green Tower STEM Study materials, supplies, all printed materials, including pre- and posts tests, recruitment materials, consent forms, assent forms. This does not include the Garden Towers, plants, and required supplies.
- Make available to all institutional parties involved assurance of and compliance with the Federal Regulations 45 CFR 46 and National Research Act PL 93-348 requirements of Human Subjects Research.
- Provide teachers, observers, and focus group leaders, and whatever instruction they may require for completion of the Green Tower STEM Study.
- Assure confidentiality of all participants in the study.
- Provide access to the final report to all participating institutions, as requested.
- Provide for a light meal during each session for all youth involved. [redacted] **agrees to:**
- Recruit and refer qualified MDBGC youth to participate in the Green Tower STEM Study. This includes distribution and collection of recruitment, registration, and pre/post-test materials and submissions of articles of interest to the Primary Investigator, Allen L. Savage, Sr.
- Provide the facilities for conducting the Green Tower STEM Studies for the required timeframes.
- Provide the Garden Towers, plants, and maintenance supplies.
- Provide support as needed for security, maintenance, and management.
- Provide transportation as needed.

C. [redacted] agree to:

- Recruit and refer qualified youth from their school to participate in the Green Tower STEM Study. This includes distribution and collection of recruitment, registration, and pre/post-test materials and submissions of articles of interest to the Primary Investigator, Allen L. Savage, Sr.
- Provide encouragement and support to the students who are interested in registering for the Green Tower STEM Study.

V. Signatures and Date

This MOU, as outlined in its entirety, shall be valid upon the completed signatures of all parties of concern. This MOU may be amended only in writing, executed by all the parties of interest. The parties' duly authorized agents will sign below, which constitutes acceptance for their institution of the MOU, and all of its provisions.

Attachment E-8d

Memorandum of Understanding

Signatures

Print Name Here	Sign Name Here	Date

[*Signing agent for University of Missouri, St. Louis-COE above*]

Print Name Here	Sign Name Here	Date

[*Signing agent for* [redacted] *above*]

Print Name Here	Sign Name Here	Date

[*Signing agent for* [redacted] *above*]

Print Name Here	Sign Name Here	Date

[*Signing agent for St. Roch Catholic School above*]

Print Name Here	Sign Name Here	Date

[*Signing agent for* [redacted] *above*]

Print Name Here	Sign Name Here	Date

[*Signing agent for* [redacted] *above*]

Attachment E-9a

Figure E9a

Pre- Post- Questionnaire

The Aeroponics Science Questionnaire

(modified from http://pdf.truni.sk/download?kb/prokop/Biology-Attitude-Questionnaire.pdf)

Ethnicity:	African-American____	Hispanic____	White____	Other____
Gender:	Male____	Female____	Other____	No Answer____
Grade:	5____ 6____	7____ 8____	Other____	

Part A. Attitude: Interest, Difficulty & Importance	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I like science more than other subjects	SD	D	N	A	SA
2. Nature and science are strange for me	SD	D	N	A	SA
3. Science lessons are difficult for me	SD	D	N	A	SA
4. Science helps development of my conceptual skills	SD	D	N	A	SA
5. I would like to have science lessons more often	SD	D	N	A	SA
6. Science knowledge is essential for understanding other courses	SD	D	N	A	SA
7. During science lessons, I am bored	SD	D	N	A	SA
8. The progress of science improves the quality of our lives	SD	D	N	A	SA
9. Science is our hope for solving many environmental problems	SD	D	N	A	SA
10. Science is not important in comparison with other courses	SD	D	N	A	SA
11. I make many efforts to understand science	SD	D	N	A	SA
12. Science is an important part of our lives	SD	D	N	A	SA
13. No one needs science knowledge	SD	D	N	A	SA
14. I hate science lessons	SD	D	N	A	SA
15. I find scientific principles interesting	SD	D	N	A	SA
16. The work with living plants in science lessons is very interesting	SD	D	N	A	SA
17. Science is one of the easiest courses for me	SD	D	N	A	SA

Part B. FOLDSCOPE and Leaves

18. A plant is sometimes called a "factory" because:
    - A. They both spew out carbon into the atmosphere
    - B. Plants have three shifts, just like any factory
    - C. They produce valuable products from basic energy and raw materials
    - D. It is only by chance that they have the same names
    - E. Farms employ large number of people, just like manufacturing factories

19. A Foldscope is a type of ...
    - A. Stethoscope
    - B. Periscope
    - C. Telescope
    - E. Bathyscope
    - D. Microscope

PLEASE TURN OVER AND COMPLETE

Attachment E-9b

Pre- Post- Questionnaire

20. Leaves serve the vital function(s) of …
A. Using light energy to make sugar from water and carbon dioxide
B. Using light energy to make oxygen from water and carbon dioxide
C. Converting sugar into carbon dioxide and water
D. Providing shade for the lower portions of the plant in extreme heat
E. Helping the plant to bend safely in a strong wind without breaking the stem

21. Antoni van Leeuwenhoek is known as the father of …
A. Zoology
B. Microscopy
C. The Green Garden Tower
D. Biochemistry
E. Botany

22. The Foldscope can be used with a cellphone by utilizing a:
A. USB to Foldscope optical coupler
B. Magnetic coupler
C. Optical Lens to camera coupler
D. Software A/D interface coupler
E. Nothing, cellphones and Foldscopes are incompatible

Part C. Chlorophyll and Arduino

23. The green pigment that captures the sun's energy in photosynthesis is called
A. anthocyanin
B. chlorophyll
C. algae
D. blue-green pigment
E. chloroplast

24 Chlorophyll is found in the chloroplasts of plants. Of the five types of chlorophyll structures, plants contain only …
A. One, chlorophyll a
B. One, chlorophyll b
C. One chlorophyll c
D. Two, chlorophyll a and chlorophyll b
E. Three, chlorophyll a, chlorophyll b and chlorophyll c

25. The absorption of plants is in the 650 -675 nm range, which lies in which the
A. Microwave spectrum
B. Infrared spectrum
C. Ultraviolet spectrum
D. Visible spectrum
E. Radio-wave spectrum

26. What does IDE stand for in the Arduino programing language…
A. Internet Deep Environment
B. Internal Development Element
C. Integrated Development Environment
D. Nothing, it is just to let you know you are working in an Arduino environment
E. Individual Deep Element

Figure 17b

School #1 Focus Groups Word Cloud

Figure 17c

School #3 Focus Groups Word Cloud

Figure 17d
School #3 Focus Groups Word Cloud

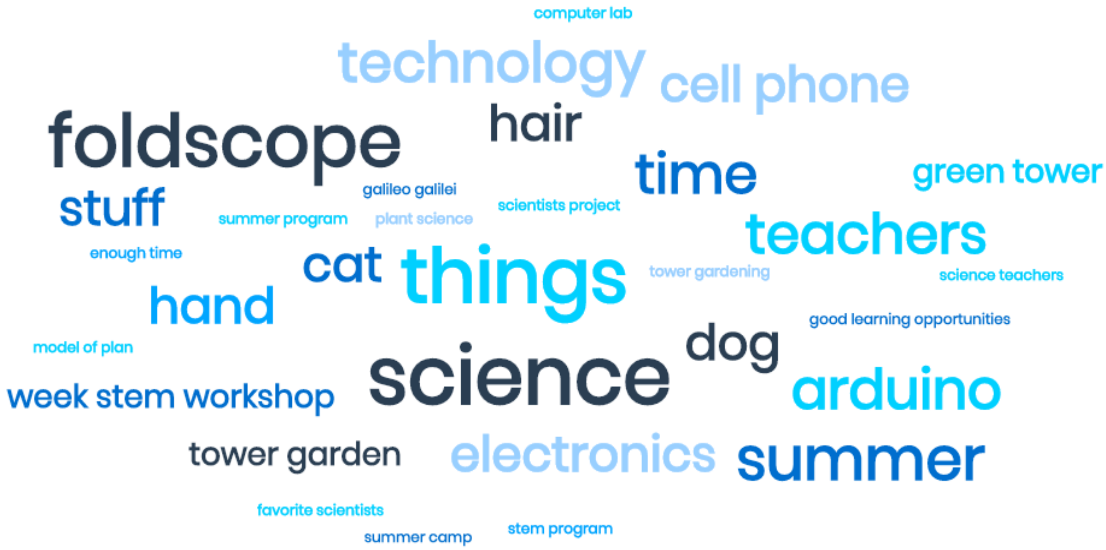


Figure 17e
School #4 Focus Groups Word Cloud

Appendix F Intervention Packet Materials

Figure F1a

Intervention #1 for Treatment Group

COURSE NUMBER: XXXX
SUBJECT AREA: Science
ACTIVITY TIME:90 minutes

SETTING: Classroom/Lab

SKILLS: Making, analyzing communication, observing, categorizing.

VOCABULARY:

BALL LENS:
The spherical, light-refracting optical component that has two focal points.

BIOME:
A major region on Earth defined by its climate and plants; examples are tundra, taiga, deciduous forest, rainforest, savanna, desert, and more

CARBON DIOXIDE: starting material for photosynthesis, present in air as a gas

CHLOROPHYLL: green pigment that captures energy from sunlight

CHLOROPLASTS:
are small organelles inside the cells of plants and algae. They absorb light to make sugar in a process called **photosynthesis.** The sugar can be stored in the form of starch. Chloroplasts contain the molecule **chlorophyll**.

PHOTOSYNTHESIS:
the process of making sugar from carbon dioxide and water powered by sunlight

PIGMENT:
A colored chemical that responds to light

OXYGEN – waste product of photosynthesis that is essential for life on earth;
present in air as a gas

SUGAR – product of photosynthesis; starting material for all forms of food

MATERIALS:

- Foldscope and slides
- Digital Cell Phone
  Tower Garden Plants
-
- Handout, *"Green Tower and the Foldscope"*
- Worksheet, *"Leaves: The inside story about how plants rule the world"*

OBJECTIVES:

1) Understand how plants use bio-chemicals to make energy 2) Learn how to make and use a paper Foldscope
3) Learn vocabulary related to photosynthesis in plants.

VIDEOS:

- **"Stephen Ritz: A teacher growing green in the South Bronx"** , First 6:20 min only
https://youtu.be/RF6qTlgtHU0
- **"How to assemble your Foldscope"**, 11:19 min
https://www.youtube.com/watch?v=cnWxM2FqEm8
- **"How to insert a slide into a Foldscope"**, 2:04 min
https://youtu.be/IQzdc_UB6T8

"Foldscope Viewing: With your phone camera" 3:01 min
https://www.youtube.com/watch?v=hDIBLYLK_kg
- **"How to prepare paper slides for Foldscope"**, 5:40 min
https://youtu.be/GSEc7vHypi0

GREEN TOWER AND THE FOLDSCOPE

PROCEDURE (PART 1):
After the Instructor's presentation, discuss within the group the potential change that Tower Gardens can make in our world. Read over the vocabulary and definitions. View the Youtube video, **"How to assemble your Foldscope"**, https://www.youtube.com/watch?v=cnW xM2FqE m8 (you may also use your cell phone to view it), and assembly your Foldscope. Stop the video as needed. View the Youtube video, •**"How to insert a slide into a Foldscope"**, 2:04 min https://youtu.be/IQzdc_UB6T8
When the Foldscope is completed as per instructions, each student will operate the scope using the prepared slides. Check with the Instructor if you need assistance.

PROCEDURE (PART 2):
Mount coupler by viewing **"Foldscope Viewing: With your phone camera"** https://www.youtube.com/watch?v=hDIB LYLK_kg
Obtain a leaf sample from the instructor. View the video, •**"How to prepare paper slides for Foldscope"**, 5:40 min https://youtu.be/GSEc7vHypi0 .
Put a small portion of the sample on a paper slide, carefully place it on the Foldscope slide, and bring into focus. Allow everyone within the group to search for and observe. Take a photo using the attached cell phone. If you find anything interesting within the scope of the sample, such as organisms or example of plant structure or damage take a photo of it too. Be sure to number the photos record the time taken, the person who found took the photo. As always, the instructor is available for assistance, if needed.

Appendix F-1b

Figure F1b

Intervention #1 for Control Group

What is your ID number__________________

Complete the following:

1. **Watch the Video** https://youtu.be/2zvv8EOXyG4**, and Discuss with the group**

2. **Chose a healthy leaf from the Garden Tower. Using the provided magnifying glass and microscope, record what you see in detail. Do the same with a healthy stem.**

3. **Chose a leaf showing damage or disease. Repeat Step 2 above and record.**

4. **What do you think the advantages of using a microscope to observe your plants? The disadvantages?**

Appendix F2a

Figure F2a

Intervention #2 for Treatment Group

SMARTPHONE (BLUETOOTH) ARDUINO SPECTROPHOTOMETER

COURSE NUMBER: XXXX

SUBJECT : Technology

ACTIVITY TIME:90 minutes

SETTING: Classroom/Lab

SKILLS: Making, analyzing communication, observing, categorizing. Understanding electronic basics

VOCABULARY:

ARDUINO BOARD:
is a single-board micro-controller for building digital devices that can be equipped with sensors and can also control other devices.

BREADBOARD:
A thin plastic board used to temporarily connect electronic components in a circuit. Used to develop prototypes of electronic circuits.

CIRCUIT DIAGRAM:
A simplified conventional graphical representation of an electrical circuit, usually a simplified pictorial diagram using simple images of components.

IDE SOFTWARE:
Integrated Development Environment software that runs on your computer, used to write and upload computer code to the microcontroller.

LED:
Light Emitting Diode. A device that emits light, usually of a specific wavelength, when activated

PIGMENT:
A chemical that plants use to interact with light. Two major pigment types that are pivotal in plant photosynthesis are the chlorophylls, which are green, and the carotenoids, which are yellow, orange and red.

SPECTROMETER:
a device used for measuring absorbance at specific wavelengths of light, generally over a wide range of the electromagnetic spectrum

MATERIALS:
- Arduino Uno
- 10K and 220 ohm resistors
- Breadboard, mini
- LDR
- Cuvette
- Chlorophyll solutions
- Plant materials
- Various connectors
- Cell compartment (parts)

OBJECTIVES:
1) Understand Arduino/Android system
2) Learn how to use Arduino
3)Understand Bluetooth.

VIDEOS:
- UNO Overview 8.14 min https://youtu.be/09zfRaLEasY
- Arduino Lesson 1: Basic Circuit Wiring 7.04 min https://youtu.be/Sm5rglcr0GQ
- LED w/ LDR/Arduino 4.12 min https://youtu.be/4fN1aJMH9mM

PROCEDURE (PART 1):

The instructor will show the video "Arduino Lesson 1: Basic Circuit Wiring", https://youtu.be/Sm5rglcr0GQ At your table, make the LED circuit found in the video. Then watch "UNO Overview" https://youtu.be/09zfRaLEasY and "LED control with LDR/Arduino" https://youtu.be/4fN1aJMH9mM.

After the brief discussion, at your table construct the LED circuit on the back of this page. Once the spectrometer has been properly assembled the group will then ask the Instructor to download the software onto the Arduino board.

PROCEDURE (PART 2):

Follow the directions provided to test the Chlorophyll. Use the standard solutions to calibrate the spectrometer then measure the vegetable solutions of both types of Chlorophyll. Take care not to stain your clothes or skin with the solutions. Empty solutions into provided waste receptors.

Appendix F2b

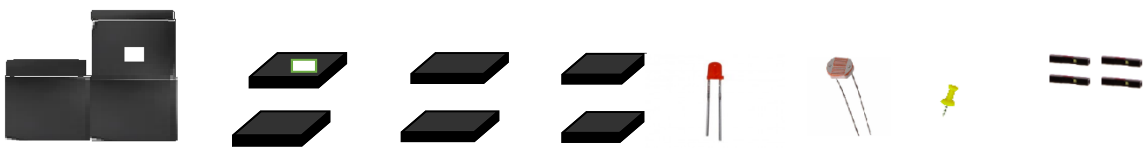
Figure F2b

Intervention #2 for Treatment Group

Materials:

Cell compartment

Folded Box	Top and Bottom 3” x 3”	Side A(2) 3” x 2 ¾ ”	Side B(2) 2 ¾ “ x 2 ¾ “	Red LED 5 mm	LDR Light Sensor	Push Pin	Wire Connectors Female/Female (4)



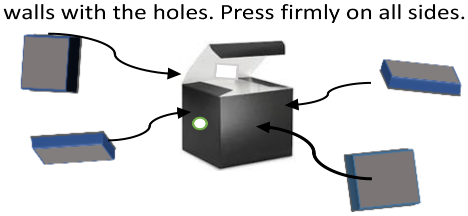
Arduino Circuit

Arduino UNO	Bread Board Mini	Jumper wires various	Resistors 10K(1), 220(2)	Red LED	9Volt Battery

1. Unfold box and lock tabs in bottom into place

2. Using a paper hole cutter, cut a hole 1.7” down in the left and right sides of the box

3. Place inserts in this order: 3” x 3 “ bottom, two (2) 3” x 2 ¾ ” side short length up, two (2) 2 ¾ “ x 2 ¾ “ squares, on the walls with the holes. Press firmly on all sides.
4.



Appendix F-2b

Figure F2b

Intervention #2 for Control Group

What is your ID number___________________

Complete the following:

1. **Watch the Video** https://youtu.be/qH-AJDqsSII **and discuss among the group**

2. **Take three different types of leaves from the Green tower.**
   Make certain that each is about 4 inches by 4 inches. As shown in the video, chop up each in a plastic cup. Pour in 50 mls into each cup. Place one of the provided filters into each cup and allow 10 min for the chlorophyll to be absorb.

3. **Remove the filter paper from the cups and compare to the comparator strips that were supplied. Write down the values for each type of plant.**

Plant#1 type__________ Plant#2 type__________ Plant#3 type__________

#1 concentration______ #2 concentration______ #3 concentration______

4. **Which plant is the darkest green? Which has the most Chlorophyll? Why do you think plants need different levels of Chlorophyll?**