5-13-2022

Computational Thinking and Its Mathematics Origins through Purposeful Music Mixing with African American High School Students

Douglas Edwards

ACCEPTANCE

This dissertation, COMPUTATIONAL THINKING AND ITS MATHEMATICS ORIGINS THROUGH PURPOSEFUL MUSIC MIXING WITH AFRICAN AMERICAN HIGH SCHOOL STUDENTS, by DOUGLAS EDWARDS, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree, Doctor of Philosophy, in the College of Education & Human Development, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chairperson, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship as determined by the faculty.

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COMPUTATIONAL THINKING AND ITS MATHEMATICS ORIGINS THROUGH PURPOSEFUL MUSIC MIXING WITH AFRICAN AMERICAN HIGH SCHOOL STUDENTS

by

DOUGLAS EDWARDS

Under the Direction of Dr. David W. Stinson

ABSTRACT

Computational thinking (CT) is being advocated as core knowledge needed by all students—particularly, students from underrepresented groups—to prepare for the 21st century (Georgia Department of Education, 2017; Smith, 2016, 2017; The White House, 2017; Wing, 2006, 2014). The *K–12 Computer Science Frameworks* (2016), written by a national steering committee, defines CT as "the thought processes involved in expressing solutions as computational steps or algorithms that can be carried out by a computer" (p. 68).

This project investigated current national introductory CT curricula and their related programming platforms used in high schools. In particular, the study documents the development, implementation, and quantitative outcomes of a purposeful introductory CT curriculum framed by an eclectic theoretical perspective (Stinson, 2009) that included culturally relevant pedagogy and critical play through a computational music remixing platform known as EarSketch. This purposeful introductory CT curriculum, designed toward engaging African American high school students, was implemented with a racially diverse set of high school students to quantitatively measure their engagement and CT content knowledge change. The goal of the project was to increase engagement and CT content knowledge of all student participants, acknowledging that what benefits African American students tends to benefit all students (Hilliard, 1992; Ladson-Billings, 2014).

An analysis of the findings suggests that there was a significant increase in student cognitive engagement for racially diverse participants though not for the subset of African American students. Affective and conative engagement did not significantly change for racially diverse participants nor for the African American student subset.

However, both the racially diverse set of students' and their subset of African American students' CT content knowledge significantly increased. As well, there was no significant difference between African American students and non-African American students post-survey engagement and CT content knowledge post-assessment means when adjusted for their pre-survey engagement and pre-assessment knowledge respectively. Hence, showing that purposeful music mixing using EarSketch designed toward African American students benefitted a racially diverse set of students in cognitive engagement and CT content knowledge and the African American subset of students in CT content knowledge. Implications and recommendations for further study are discussed.

INDEX WORDS: African American students, computational thinking, high school mathematics, music

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A Dissertation

Presented in Partial Fulfillment of Requirements for the

Degree of

Doctor of Philosophy

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Teaching and Learning

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Department of Middle and Secondary Education

in

the College of Education and Human Development

Georgia State University

Atlanta, GA
2021

ACKNOWLEDGMENTS

There are many people whose guidance and support have made this research project possible. First, my chairperson, Dr. David Stinson, whose knowledge, patience, guidance, and encouragement stopped me from giving up and belief in me was unwavering. Our journey in education has been an inspiration from teacher certification to now and please know that you have made and continue to make a very deep impact on my life.

Also, in appreciation to my committee members: Dr. Christine Thomas, Dr. Audrey Leroux, and Dr. Christina Gardner-McCune. Thank you Dr. Thomas for your class on grant writing and guidance to “stay in my lane” as part of the foundation to this project being turned into a grant funded by the National Science Foundation. Thank you Dr. Leroux, for your quantitative statistics class and your guidance on ANCOVA analysis that made chapters 4 and 5 readily doable. Thank you Dr. Gardner-McCune, for your insight and papers on computer science education were part of the inspiration on applying mathematics education to computer science education. Moreover, I am grateful to all of my professors at Georgia State University.

Additionally, I would like to thank my work colleagues who joined me in this journey, particularly my supervisor and friend, Dr. Marion Usselman and the CAPACiTY project team, Dr. Meltem Alemdar, Dr. Diley Hernandez, Dr. Mike Helms, Dr. Sunni Newton, Dr. Jessica Gale, and Mr. Mike Ryan. Working with you all to turn the culturally relevant ideas into reality and evaluate them has been one of the most enjoyable and rewarding projects in my career. As well I would like to thank my school colleagues, Dr. Ervin China and Dr. Norman “Storm” Robinson, who kept checking up on me.

Last in appreciation to my family and friends who both pushed me to continue and watched my hair gray through it all. My daughters, Nia and Imani, who believed in their “baba” from the beginning to the end. My fiance, Dea, who joined in mid way through and was ready to and continues to provide the love I need to keep going. My brother, kadamu and mentor, Dr. Mwawaza Sanyika, whose inspiration, information, and consultation for the past thirty years has taken me further than I imagined. My sisters and brother dissertation push guides, Dr. Ajile Rahman, Dr. Esi Willis, and Dr. Nyawi Hollis who continually reminded me that it's step by step. And last but certainly not least to my parents and older brother, Mr. Robert and Mrs. Manola Edwards and Keith Edwards, my first teachers whose love, caring, and motivation have brought me this far and will continue to take me to infinity and beyond.

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CHAPTER 1

INTRODUCTION

We have come over a way that with tears has been watered
We have come, treading our path through the blood of the slaughtered

–"Black National Anthem" by J. Rosamond and James Weldon Johnson

During a professional development for high school introductory computer science teachers, I (the instructor) presented a slide with five images and no other identifying information (see Figure 1).

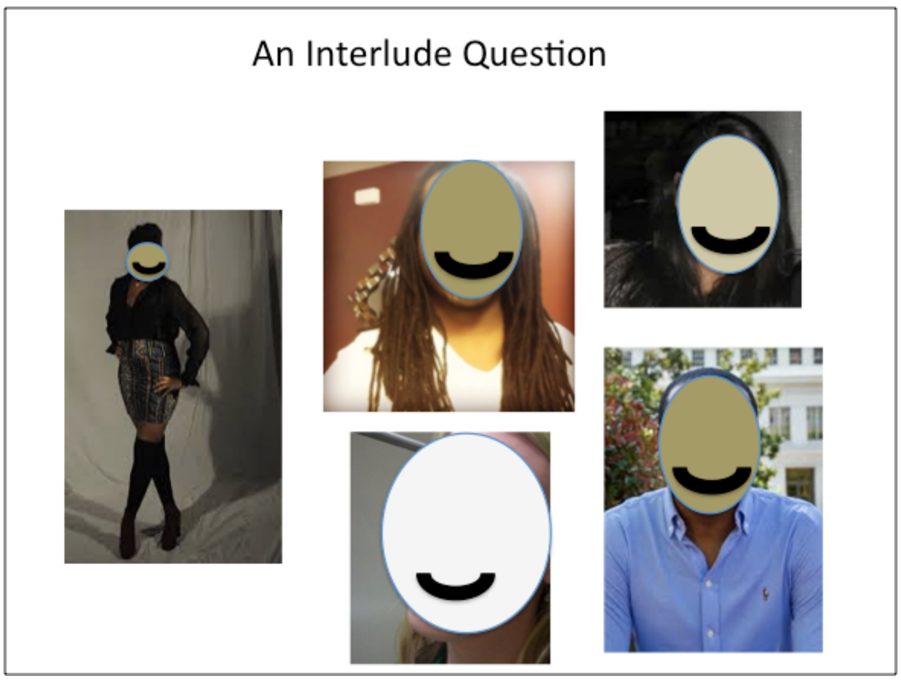

Figure 1. Professional development presentation slide.

From left to right, the five images were a full length shot of a 27-year-old African American woman with her hair pinned up and dressed in a fashionable shirt, skirt, and boots; a headshot of a 30-year-old African American man with shoulder length dreadlocks in a t-shirt; a headshot of a 28-year-old White man with long blond hair wearing glasses; a headshot of a 28-year-old Indian

American woman with shoulder length black hair; and a headshot of a 26-year-old African American man with short hair wearing a button down oxford shirt.

The next presentation slide asked: Who is a coder? Who is an entrepreneur? The three teachers, two African American women and one White woman came to the following consensus: the African American young woman was a model, the African American young man with locks was an artist of some type, the White young man was an entrepreneur though they thought I wanted them to think he was a coder, the Indian American young woman was a Georgia Institute of Technology (i.e., Georgia Tech) student and therefore a coder, and the African American young man with short hair was a coder because he looked "smart" in the button down oxford shirt.

The next day of the professional development a slide with the same five people was shown with a caption. The caption under the 27-year-old African American young woman and 28-year-old White young man read "Went to school in Empress County." The caption under the 30-year-old African American man with locks read "Self-employed." The caption under the 28-year-old Indian American young woman read "Graduated from Georgia Tech," and the caption under the 26-year-old African American young man in the oxford shirt read "Works for Google."

With this additional information, the teachers came to the following consensus: the African American young woman was still a model, the African American young man with locks was evidently an entrepreneur because it read "Self-employed" as a musical artist or some other type of artist, the White young man was still an entrepreneur, the Indian American young woman was definitely a coder given that she graduated from Georgia Tech, and the smart African American young man in the oxford shirt was a coder because he worked for Google.

I had planned to provide the teachers additional information, however, they insisted on knowing who was who given that I had told them from the beginning that I had taught all of the young people in the pictures. I obliged them and shared that the young African American woman, who they thought was a model, is an entrepreneur and coder who also hires coders to promote performing artists in New York. In addition, she majored in dance at New York University and taught herself to code. The young African American man with locks, who they thought was a self-employed artist, is an apparel company entrepreneur. In addition, he was the high school quarterback and majored in business in college. The White young man, who they thought was an entrepreneur, is a biology graduate student. The Indian American young woman, who they thought was a coder, is a Geology Information Systems (GIS) Technician for Southern Company, and the smart African American young man in the oxford shirt, who they thought was a coder, is a recruiter for Google who does not code.

After the vocations of all the former students were revealed, one of the teachers stated, “See, you can’t judge a book by its cover.” This actual scenario is an anecdote on how people tend to view who is a computational thinker. All three teachers said that they wanted to use this same learning activity in their high school classrooms that consist mostly of African American and Latinx students to prompt discussion on what it means to be a coder, and that your race and culture do not determine whether you are a computational thinker. Then, what does determine who is a computational thinker, and what is computational thinking?

What is Computational Thinking?

“The Matrix is older than you know,” are the words of the architect to Neo in the movie *The Matrix Reloaded* (Silver & The Wachowski Brothers, 2003). The Matrix is a “simulated reality created by sentient machines in order to pacify and subdue the human population although their bodies' heat and electrical activity are used as an energy source." The architect is the creator of the Matrix and Neo is a computer programmer/hacker who, at this point in the movie, learns that he is the sixth anomaly in the Matrix, which the architect describes as a "harmony of mathematical precision" (Genius, n.d.).

Why talk about a movie where the main character is a computer programmer? Why talk about a movie that is about a system of control whose architect calls it a harmony of mathematical precision and is older than was known?

The *K–12 Computer Science Framework* (CS Framework) document was released in September 2016, and defines computational thinking as—

> the thought processes involved in expressing solutions as computational steps or algorithms that can be carried out by a computer (Cuny, Snyder, & Wing, 2010; Aho, 2011; Lee, 2016). This definition draws on the idea of formulating problems and solutions in a form that can be carried out by an information-processing agent (Cuny, Snyder, & Wing, 2010) and the idea that the solutions should take the specific form of computational steps and algorithms to be executed by a computer (Aho, 2011; Lee, 2016). (CS Framework, 2016, p. 68)

The members of the "community effort" (p. ii) steering committee who authored the document were from the following organizations:

- Association for Computing Machinery – a professional organization for computer science and computer science education;
- Code.org – a non-profit organization that develops curriculum and does teacher professional development in K–12 computer science education;
- Computer Science Teachers Association (CSTA) – a professional organization for K–12 computer science teachers;
- Cyber Innovation Center – a non-profit organization that does workforce development for adults related to computing; and

- National Math and Science Initiative – a non-profit organization that seeks to improve K–12 students' performance in STEM.[1]

One of the computer scientists heavily cited by the committee, Jeanette Wing, formerly a professor at Carnegie Mellon University and currently a vice president of Microsoft Research is considered the impetus for the K–12 push for computational thinking courses in schools nationwide. She states, CT is "shorthand for thinking like a computer scientist" (Wing, 2014, p. 1). The CS Framework elaborates with four practices of computational thinking:

1. Recognizing and Defining Computational Problems – a computational problem is one whose solution capitalizes on the power of computers that begins before a single line of code is written. It defines memory, speed, and accuracy of execution as the power of computers.
2. Developing and Using Abstractions – abstractions are generalizations formed by identifying patterns and extracting common features from specific examples. Generalizations can be used and reused to simplify development and manage complexity.
3. Creating Computational Artifacts – examples of computational artifacts include programs, simulations, visualizations, digital animations, robotic systems, and apps.
4. Testing and Refining Computational Artifacts – the deliberate and iterative process of improving a computational artifact by comparing actual outcomes to intended outcomes to respond to the changing needs and expectations of end users and

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[1] STEM – science, technology, engineering, and mathematics
STEAM – science, technology, arts, engineering, and mathematics

improve the performance, reliability, usability, and accessibility of artifacts (CS Framework, 2016).

The College Board in its new Advanced Placement (AP) course, AP Computer Science Principles, does not define computational thinking, but instead lists six computational thinking practices:

1. Connecting Computing – identify impacts of computing and describe connections between computer concepts and between people and computing.
2. Creating Computational Artifacts – create computational artifacts with practical, personal, or societal intent using appropriate techniques and appropriate algorithms and information management principles.
3. Abstracting – explain how data, information, or knowledge is represented for computation and modeling.
4. Analyzing Problems and Artifacts – justify and evaluate a proposed solution to or artifact for a problem and locate and correct errors of the solution or artifact.
5. Communicating – summarize the purpose and explain the meaning of a computational artifact.
6. Collaborating – work equitably with others to solve a computational problem or produce a computational artifact (The College Board, 2016).

In 2009, the National Science Foundation (NSF) funded a project titled Leveraging Thought Leadership for Computational Thinking in PK–12 (Barr & Stephenson, 2011). This project convened a diverse group of educators with an interest in CT from higher education, PK–12, and industry to help define a common language surrounding computational thinking. The group, led by two of the largest K–12 teacher organizations related to computing—the

International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (CSTA)—came to consensus on an operational definition of CT:

> Formulating problems in a way that enables us to use a computer and other tools to help solve them • Logically organizing and analyzing data • Representing data through abstractions, such as models and simulations • Automating solutions through algorithmic thinking (a series of ordered steps) • Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources • Generalizing and transferring this problem-solving process to a wide variety of problems. (ISTE & CSTA, 2011)

Consistent across all these influential national organizations are the following four dimensions defining CT:

- Problem Formulation – decomposing problems so that they can be solved using an information processing agent (i.e., computer);
- Creating Computational Artifacts – designing, prototyping, testing, and refining an artifact that requires the use of the algorithmic and/or abstraction dimensions;
- Algorithms – a series of ordered steps; and
- Abstraction – induction from specific examples to generalizable patterns that can be used to simplify and manage complexity.

Previously, when I began to define CT, I quoted the architect in the movie *The Matrix Reloaded* (Silver & The Wachowski Brothers, 2003): “The matrix is older than you know.” I have learned that CT is older than I knew. It does not begin with Wing’s (2006) call to action to make “Computational thinking [is] a fundamental skill for everyone, not just for computer scientists. To reading, writing, and arithmetic, we should add computational thinking to every child’s analytical ability” (p. 33). CT was originally phrased and defined by a mathematician.

Purpose of Study

The purpose of this study was to investigate introductory CT content knowledge and its mathematics education origins in relationship to African American high school student engagement and purposeful computational music mixing. Purposeful in this case means designing music to "consider critical perspectives on policies and practices that may have direct impact on [students] lives and communities" (Ladson-Billings, 2014, p. 78).

Computational music mixing in this study was done using the web-based platform EarSketch. EarSketch is an integrated curriculum, programming, and Digital Audio Workstation (DAW) platform where students learn either the Python or JavaScript computer science language by writing computer code to mix music sound samples. EarSketch has a selection of over 4,000 music sound samples from two award winning artists. Young Guru, Grammy nominated audio engineer and tour DJ for multi-platinum hip-hop artist Jay Z; and Richard Devine, Remix Technology Award winner, developed the music sound samples in EarSketch. The only way to mix the music samples in EarSketch is through coding; hence, the four computational thinking dimensions stated earlier are learned through mini performance tasks, project challenges, and curricular activities (see Table 1).

Table 1
Computational Thinking Dimensions Applied in EarSketch

Computational Thinking Dimension	Related EarSketch curriculum
Problem Formulation	Create for Me, Fix the Errors, Most Repetitious Song Ever, More Cowbell, Tempo Changer, and Make a Drum Set Mini-Performance Tasks
Creating Computational Artifacts	Musical Introduction, Ringtone, and Jukebox Project Challenges
Algorithms	Looping, Console Input and Conditionals, Debugging Logic, Randomness
Abstraction	Musical Form and Custom Functions, String Operations, Data Structures

EarSketch was used in an NSF award titled EarSketch: An Authentic, Studio-Based STEAM Approach to High School Computing Education (NSF, n.d.). The EarSketch curriculum is integrated into the EarSketch programming platform and is aligned to the AP Computer Science Principles (AP CSP) course first offered by The College Board in 2016, and the Georgia Computer Science Principles (GA CSP) course first offered in 2013. The computer science principles courses are second-year high school courses to learn computational thinking.

The EarSketch curriculum musical design performance task end products are a 15-second musical introduction for a client of the student's choice with teacher approval, a 60-second musical ringtone for personal expression, and a jukebox that gives the user three song choices to play or has the computer randomly choose one of the songs to play. The three song choices are computationally mixed as a personal expression (Freeman et al., 2015).

The EarSketch NSF study team, in which I was a co-PI for curriculum development, has assessed student pre- and post-computational thinking content knowledge and engagement for the AP CSP and GA CSP aligned EarSketch curriculum using the EarSketch programming platform. The first set of assessments were given at six high schools. The schools were diverse in race[2] except for one, Destwood, which is 99% African American. At a project team meeting, the results of the assessment were shared and Destwood was the only school whose scores did not show a significant improvement. Not only did their scores not show a significant improvement but also their score percentage was the exact same.

I and one other researcher of the six researchers at the meeting suggested that something must be wrong with the data for Destwood. When the data was revisited by the evaluation team on the project, it was found that the data had been entered incorrectly. Destwood improved from

[2] Diverse in race meaning that no one race/ethnicity constituted more than 75% of the school

10% to 22% correct. The Destwood students start the CSP second-year high school course answering 10% of the questions correctly when more than 50% of these students have taken a first-year introductory high school course to develop CT. I was not satisfied that these students only answered 10% correctly considering that over half of them had taken a first-year introductory high school CT course (McKlin, 2016). I wanted a better outcome in African American student content knowledge from this introductory high school CS course.

This first-year course is often taught with a NSF promoted CT curriculum, Exploring Computer Science (ECS) that uses a programming platform called Scratch (Goode & Margolis, 2011). Performance tasks in this course include computationally making a dialogue between characters, implementing a set of games like rock-paper-scissors, and developing a culmination project where the student can either design a different game or make a dialogue between characters about "one positive thing that you want to highlight and one thing you want to improve about your community" (Chapman & Goode, 2013, p. 187).

African American high school students in the second-year high school CSP computer science course have shown significantly increased content knowledge and student engagement when the curriculum uses computational music mixing within the EarSketch programming platform (Magerko, Freeman, McKlin, McCoid, Jenkins, & Livingston, 2013). There are no studies where students have used computational music mixing in the first-year Georgia course.

The research questions for this study are:

1. What is the change from pre-instruction to post-instruction in the student engagement survey means of racially diverse high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform?

2. What is the difference in engagement post-instruction between African American and non-African American high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform, when adjusted for their engagement previous to instruction?
3. What is the change from pre-instruction to post-instruction in introductory computational thinking (CT) content knowledge of racially diverse high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform?
4. What is the difference in introductory CT knowledge post instruction between the African American and non-African American high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform, when adjusted for their CT knowledge previous to instruction?

Corresponding to the research questions above, the null hypotheses tested in this study are:

1. H_0: There is no change from pre-instruction to post-instruction in the student engagement means of racially diverse high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform.
2. H_0: There is no difference difference in engagement post-instruction between African American and non-African American high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform, when adjusted for their engagement previous to instruction.

3. H_0: There is no change from pre-instruction to post-instruction in introductory computational thinking (CT) content knowledge of racially diverse high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform.
4. H_0: There is no difference in introductory CT knowledge post instruction between the African American and non-African American high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform, when adjusted for their CT knowledge previous to instruction.

Rationale for Study

In January 2016, President Barack Obama advocated during his State of the Union address, "In the coming years, we should build on that progress, by … offering every student the hands-on computer science and math classes that make them job-ready on day one" (Smith, 2016). The Computer Science for All website explains the need for every student to have access to CS courses in their school because—

> Last year, there were more than 600,000 high-paying tech jobs across the United States that were unfilled, and by 2018, 51 percent of all STEM jobs are projected to be in computer science-related fields. Computer science and data science are not only important for the tech sector, but for so many industries, including transportation, healthcare, education, and financial services. (Smith, 2016)

On February 1, 2017, the 115th Congress stated in its priorities press release that it would reauthorize NSF programs because "Science, Technology, Engineering and Math (STEM) education initiatives are a priority for the committee along with initiatives including computer science" (Smith, 2017). By the end of the month on February 28th, President Donald Trump signed into law House Resolution Bills 255 and 321, which, as he stated, "promote women entering and leading the STEM fields—science, technology, engineering, and math" (The White House, 2017). These house resolution bills were introduced on January 4th and 5th, 2017, respectively.

There was house resolution bill 2709 introduced on May 25, 2017, to "increase the participation of women and underrepresented minorities[3] in the fields of science, technology, engineering, and mathematics (STEM)" (Smith, 2017). It remains to be seen if this bill, which includes "underrepresented minorities" and not only women, will pass congress and be signed into law. The bill has been read twice by the senate and referred to the Committee on Health, Education, Labor, and Pensions (Women and Minorities in STEM Booster Act, 2017) and its last action has been referral to the Subcommittee on Research and Technology on May 22, 2018. Another form of this bill has been reintroduced January 5, 2021, as house resolution bill 204 known as the STEM Opportunities Act. Its purpose is to "identify, disseminate, and implement best practices at Federal science agencies, including Federal laboratories, and at institutions of higher education to remove or reduce cultural and institutional barriers limiting the recruitment, retention, and success of women, minorities, and other groups historically underrepresented in academic and Government STEM research careers" (STEM Opportunities Act, 2021). The bill has been read twice by the senate and referred to the Committee on Health, Education, Labor, and Pensions.

Popular cultural media and government reports state that within the next 10 years there will not be enough skilled people to fulfill the computing related jobs of tomorrow. Based on the current number of students entering computer science related fields more women and underrepresented students of color are needed in CS (Bidwell, 2013).

[3] U.S. public school students are more than 50% people of color according to the National Center for Education Statistics (2019), hence public-school students of color are the majority not a minority

In addition to these national level policy and economic reasons, states have begun to approve CS courses to replace graduating credits for mathematics and science courses. Fifteen states have approved CS to replace mathematics courses and eight states have approved CS to replace science courses (Code.org, 2017). In the state of Georgia, the second-year AP CSP and third-year AP CS A courses can replace either a science course or a world language course for graduation credit and toward college admission (University System of Georgia, 2016). Moreover, the state of Georgia has passed a law making it mandatory for all high schools to instruct an introductory computer science course by the 2024-25 school year (Georgia General Assembly, 2019).

Although these national and state policy decisions are reason enough to conduct this computational thinking study focused on African Americans, an underrepresented minority as we are labeled above, my motivation goes beyond the economic and policy reasons. My motivation is also related to former President Obama's 2013 CSEdWeek White House webpage—

> The ability to write computer software—to code—is an important skill. It moves people from being consumers of technology to creators of it. An understanding of coding helps people learn new strategies for solving problems and harness the power of computers to realize their own visions. (Deloura & Paris, 2013, para. 2)

The ability to think computationally so that one can code allows one to create websites, games, mobile phone apps, and other computational products to inform and influence people's thinking or, as former President Obama, stated, "Don't just play on your phone, program it" (The Obama White House, 2013, 37:39). If students are going to take courses in computational thinking, and as Deloura and Paris stated, "realize their own visions" (2013), then they will need to be engaged by the content in computer science class, persist in solving computational thinking problems, and improve their computational thinking content knowledge so that they have the skills to produce computational artifacts to produce their computational visions.

What engages African American high school students to learn computational thinking? What engages African American high school students to persist in solving computational thinking problems? What pedagogies improve African American high school students content knowledge in computational thinking? What pedagogies improve all students content knowledge in computational thinking? Would a curriculum designed with a focus toward African American students improve all students content knowledge in computational thinking?

In the chapters that follow, I present the mathematics education origins of computational thinking (CT) and rationale for selecting EarSketch to introduce computational thinking during the regular school day in Chapter 2. In Chapter 3, I provide a theoretical framework, based largely in mathematics education, that was used to design an introductory computational thinking curriculum focused on engaging African American students and intended to lead to the benefit of all students to improve their computational thinking content knowledge. In Chapter 4, I explain the student engagement survey questions used to measure four student engagement constructs that have shown a strong relationship to mathematics content knowledge achievement, the modification of the Principles Assessment of Computational Thinking (PACT) instrument, and how the modified assessment was used to analyze the computational thinking content knowledge of a racially diverse set of students to respond to the research questions. In Chapter 5, I show the demographics, descriptive statistics, and the paired samples *t*-test and ANCOVA results of the five student engagement survey constructs and the CT content knowledge assessment for a racially diverse set of students and subset of African American students within this sample. In Chapter 6, I summarize the findings from Chapter 5 in relationship to the research questions of the study, the implications of these findings, and suggest recommendations for further study.

The study included 37 participants who were students in an introductory high school CT course in a suburban county in Georgia. The first year of the CAPACiTY study, the 2017-2018 school year, worked with a high school in this same school district that had over 100 racially diverse students of which almost half were African American. Unfortunately, the teachers at that school did not implement the curriculum as designed, particularly making each class chose only one problem topic that each group had to do rather than having small groups of four to six students choose a problem of interest. In addition, the teachers missed almost half of the during the year check in meetings that could have potentially averted this issue. For these reasons, the CAPACiTY study PI proposed, and team agreed, that the team change schools the following school year (2018-2019) which, while the curriculum was implemented as designed, led to fewer study participants. For this study, I chose to move forward with the data we had, though it had fewer participants, considering that the world is in a coronavirus pandemic and schooling in Georgia was disrupted during the 2019-2020 and 2020-2021 school year.

CHAPTER 2

LITERATURE REVIEW

Talk to me, So you can see
Oh what's going on

– "What's Going On" by Marvin Gaye

The purpose of this literature review is to demonstrate the gap of research in computational thinking as it relates to its mathematics education origins. In addition, I intended to show the research gap in the assessment of computational thinking content knowledge in general, and specifically, for African American high school students, as well as African American high school student engagement for introductory high school CT curricula.

Mathematics Education Origins of Computational Thinking

The origin of the term *computational thinking* (CT) is attributed to mathematician Seymour Papert. In his book *Mindstorms: Children, Computers, and Powerful Ideas*, Papert (1980) first uses the term to describe how the vision and experiments of those who want to use computers in the 1970s "to integrate computational thinking into everyday living was insufficiently developed" (p. 182). He does not explain further what he defines as computational thinking in *Mindstorms* but does elaborate 16 years later in an article on mathematics education in the *International Journal of Computers for Mathematical Learning* (Papert, 1996); he states: "The goal is to use computational thinking to forge ideas" (p. 108).

In this article, Papert's (1996) elaboration begins not with problem formulation but with the "power principle." He defines the power principle as "use leading to progressively deepening understanding" (p. 97). In the power principle "projects are primary, problems come up in the course of projects" (p. 97). There are two questions Papert asks in respect to the power principle: (a) "How can a child actually use it to do something that has real personal importance now?" and

(b) “What can your [project] do that will give them a sense of empowerment and achievement?” (p. 97)

I use these two questions as a guide toward a fifth dimension of CT that I call Power Formulation that I will discuss in detail in the theoretical framework in the next chapter. Just as there is problem formulation in the current definitions of CT that couple with problem solving using an information processing agent, so too does power formulation couple with creating computational artifacts.

How do the other four dimensions of CT compare to Papert’s (1996) definition of CT? Looking at them one by one, Papert addresses them indirectly because the article was about “alternative mathematics education” (AME) in contrast to “school mathematics education” (SME):

- Problem Formulation – used in the context of the study of motion where “decomposition of motions by starting off with the use of a tool for the construction of useful motions” (p. 103).
- Creating Computational Artifacts – used in the context that projects to create are emphasized as the method to understand problems, which Papert states, “projects are primary, problems come up in the course of projects” (p. 96).
- Algorithms – used in the context of trying different algorithms to program a screen creature to move toward another screen object.
- Abstractions – used in the context of the “Turtle Total Trip Theorem,” generalizing a programmed turtle object returning to its starting point.

Another perspective of how CT and mathematics education relate is in the K–12 Computer Science Framework (see Figure 2).

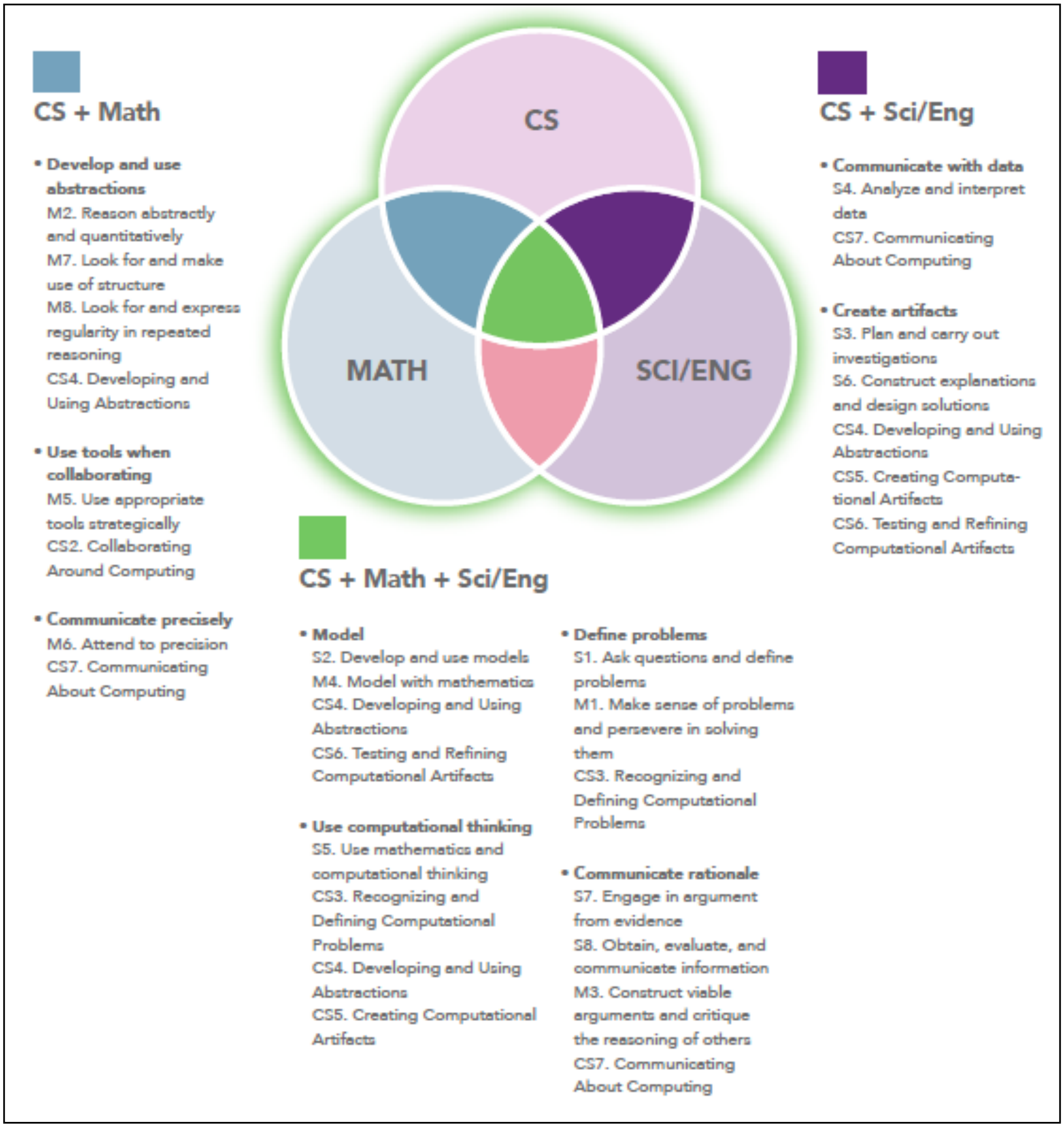

Figure 2. Relationships between computer science, science and engineering, and mathematics practices (CS Framework, 2016, p. 72).

As shown in the left and bottom of Figure 2, the Common Core Eight Standards of Mathematical Practice relate to the four dimensions of CT in the following ways:

- Problem Formulation – (M1) Make sense of problems and preserve in solving them;

- Creating Computational Artifacts – (M4) Model with mathematics;
- Abstraction – (M2) Reason abstractly and quantitatively, (M7) Look for and make use of structure and (M8) Look for and express regularity; and
- Algorithms – Not directly addressed in the Figure 2, but I propose that the CS Framework authors incorporated algorithms as part of abstractions because (M7) Look for and make use of structure and (M8) Look for and express regularity in repeated reasoning have common aspects—"repeated reasoning" and "structure"—of defining an algorithm (Carnegie Mellon University, 2017).

Often the dimensions of CT related to problem formulation, algorithms, and abstraction are instructed in discrete mathematics education courses in colleges (Knuth, 1974; Suraweera, 2002). These courses are used as a foundation and prerequisite for computer science programs of study (Carnegie Mellon University, 2017; Georgia Institute of Technology, 2017; Georgia State University, 2017). The curriculum topics include problem decomposition, introductory algorithms related conditional programming concepts, discrete iteration and recursion, and induction to abstract patterns that can be reused as part of a solution (Hunter, 2017). If discrete mathematics is the entry point to the dimensions of CT for college students, how are high school students introduced to CT?

Introductory CT Curricula for High School Students

There are various CT curricula for high school students. These curricula include ones that focus on using block-based coding games to move a robot around a playing field to coding chatbot agents that can give pre-programmed responses on Facebook (Benotti, Martinez, & Schapachnik, 2014). To keep the scope of this proposed research project reasonable, I focus on national curricula that are widely used during school. I have chosen national curricula within the

United States because the scope of looking at international curricula would be a research study all its own. I have chosen during school because the beginning motivation for this research was a group of African American students that had low computational thinking content knowledge at the start of a second CS course after having taken an introductory course during school.

There are two widely used national curricula that are formal, during-school courses that are designed to introduce CT in high school: Bootstrap and Exploring Computer Science (ECS). Both of these curricula are explored based on content with respect to the five dimensions of CT stated previously (see Table 1, with the addition of Power Formulation), student engagement, and a specific look at African American student engagement. I am emphasizing African American students because of the initial motivation of the 99% African American Destwood high school anecdote.

Bootstrap

Bootstrap is an introductory CT curriculum used in 26 states during the regular classroom schedule and as part of after school programs. Bootstrap was begun as a research study in 2005 at Brown University and continues to expand across the country offering professional development for teachers. According to their website, Bootstrap has reached nearly 25,000 students in the United States (Bootstrap, 2021). The curriculum is designed to reinforce core concepts from algebra, enabling non-CS teachers to adopt introductory materials to deliver rigorous and engaging computing content. It is free and available online for anyone to use. Bootstrap consists of nine units (Lee, Rich, & Wright, 2013), each with mathematics topics, computing topics, and game computational tasks (see Table 2).

Table 2
Bootstrap Curriculum Topics and Performance Tasks

Unit	Mathematics Topic	Computing Topic	Game Computational Task
1	Coordinates	Circles of evaluation	Locate elements on the screen
2	Domain, range, kinds of data	String and image operations	Creating text and images
3–5	Function representations as formulas and tables	Defining computational functions	Making moving images
6	Inequalities	Booleans and Boolean operators	Determine when game elements are off screen
7	Piecewise function	Conditional	Responding to key presses
8	Pythagorean theorem	(Nothing new)	Collision detection
9	Explaining mathematics concepts to others	Code reviews	Polishing game for presentation

The programming platform for the curriculum is WeScheme, a text-based online coding platform that runs in the browser (Fisler, Schanzer, & Krishnamurthi, 2011). Because it runs in the browser and the instructional materials are a free download online, schools can do the Bootstrap curriculum at no cost to the school other than the teacher learning how to implement the curriculum. The Bootstrap curriculum and teacher professional development to instruct the curriculum is funded by Microsoft and NSF. Code.org has developed a block-based programming environment for the Bootstrap curriculum. Block-based programming environments reduce cognitive load and have been shown to be a better introductory programming environment to learn computational thinking and programming (Yao, 2016).

In respect to the five dimensions of CT, Bootstrap has all dimensions based on Table 2. Problem formulation is done during the circles of evaluation unit; algorithms and abstraction are done during the functional representation; Boolean, conditionals units, and creating computational artifacts and power formulation are done from unit 2 through unit 8.

The Bootstrap curriculum has published quantitatively analyzed data for a 17 question (8 word problems, 9 function questions) pre and post Massachusetts state ninth-grade algebra test for 57 eighth-grade students at a public middle school in Massachusetts, 50 eighth-grade students at a private school in Florida, and 15 ninth-grade students at a private school (religiously affiliated) in Illinois. The *t*-test analysis shows statistically significant ($p < .02$) gains in both function composition and word problems for all classes that used Bootstrap except the Illinois class, whose sample size was small. A control group of 26 students in the Florida private school took the same 17-question assessment and did not show a statistically significant gain (Felleisen, Fisler, Schanzer, & Krishnamurthi, 2015).

Although there is algebra content knowledge assessment data for the Bootstrap curriculum, there is no CT assessment or student engagement assessment. Hence, it is not known if African American students improve their CT knowledge nor if they are engaged by its game design focused tasks.

Exploring Computer Science (ECS)

The other introductory CT high school curriculum that is widely used in 34 states and seven of the largest school districts in the United States is Exploring Computer Science (ECS) (Code.org). ECS began as a research study at the University of California, Los Angeles in 2007 and also continues to expand across the country offering professional development for teachers. The curriculum is designed to—

> engage diverse high school students with a breadth of CS topics through supported, inquiry-based, hands-on, culturally relevant instruction. This curriculum builds upon students' fascination with technology by situating technology-based skills within the context of issues that are important to students. In this way, ECS is about 'computing with a purpose' (Margolis and Fisher 2002, 49), bridging CS with students' concerns, individual creativity, and meaning making processes. ECS also attempts to build students' identities as 'doers' of CS by offering collaborative hands-on projects and experiences in which students belong to CS 'communities of practice' (Lave and Wenger 1991; Wenger 1998). ECS pedagogy is based on research that addresses how engagement and practice-linked identity—a connection between self and the activity—relate to learning (Nasir and Hand 2008). (Ryoo et al., 2013, p. 4)

It is free and available online for anyone to use. ECS consists of six units, each with computing topic and culminating performance tasks (see Table 3).

Table 3
ECS Unit Topics and Performance Tasks

Unit	Computing Topic	Culminating Performance Task
1	Human Computer Interaction	Provide advice on buying a new computer. Your task is to give them at least four options and then give them advice on which one to buy. Your project will be presented to the class as either a PowerPoint, debate, skit, video, or other approved product.
2	Problem Solving	Assume that for one day you need to carpool with the other members of the group in order to get to all of the locations you each identified on the day you visited the most different locations. Determine the shortest route in terms of miles and then determine the shortest route in terms of time.
3	Web Design	Create a website that is an ethical dilemma, a career, a worldwide or community problem, or a topic of your choice that has been approved.
4	Programming	Program a game or a story with at least three different pages or scenes. The story must have one positive thing that the student highlights and one thing to improve about their community. In addition, they must find at least one statistic to back up their conclusions, include at least one personal comment/recording and one picture.
5	Data Analysis	You will present a story to the class (it can be a series of web pages or a Scratch program) on the data you have collected using a phone application. You must include plots/graphics that support the story. You will have access to data from your classmates as well as students in other classes that have also collected data.
6	Robotics	Design and build a rescue robot. This task is based on the second level of RoboCupJunior, an international competition. More information about RoboCupJunior is available at http://rcj.robocup.org. This robot simulates robots sent to rescue people during natural disasters. It must find "victims" along the path through each "room" and avoid obstacles. The goal is to program a robot that uses sensors to respond to different stimuli.

The programming platform for the curriculum is Scratch, a block-based online coding platform that runs in the browser. Because it runs in the browser and the instructional materials are a free download online, like Bootstrap, schools can do the ECS curriculum at no cost to the school other than the teacher learning how to implement the curriculum. NSF funded the development of the ECS curriculum and currently funds teacher professional development to instruct the curriculum. Scratch, as a block-based programming environment used in the ECS curriculum, reduces cognitive load for introductory computational thinking and programming (Yao, 2016).

With respect to the five dimensions of CT, ECS has all dimensions based on Table 3. Problem formulation is done during the problem-solving unit, algorithms and abstraction are done during the programming unit, and creating computational artifacts and power formulation are done during the web design and programming units.

The ECS research team has published externally analyzed data that show student pre and post self-reporting of rating their computer science content knowledge. Student self-reported computer science content knowledge increases by at least one standard deviation from pre at the beginning of the year to post at the end of the year. These data are disaggregated by gender, but not by race or ethnicity. Female students self-reported rating of CS content knowledge rose from an average of 4 to 7 from pre to post scores. Male students self-reported CS content knowledge ratings rose from an average of 4.75 to 7.5 from pre to post scores. These findings were based on a sample of over 1,000 students (Binning, Goode, & Margolis, 2015). Additionally, 88% of the high school students who took the course reported that they would recommend the course to another student.

Content knowledge assessment data have also been published for ECS. Science Research International (SRI) through funding from the NSF has developed and validated a CT content knowledge assessment for ECS titled the Principle Assessment of Computational Thinking (PACT). These assessments are available to teachers who are members of the CS10K teacher community, mostly members of CSTA, and are aligned to ECS learning objectives and the Scratch block-based programming platform (Bienkowski, Grover, Rutstein, & Snow, 2015). An example question related to algorithms on the PACT assessment is about two students, Chantelle and Jasmine (see Figure 3 and 4). Question 4a in Figure 3 assesses applying a conditional algorithm and questions 4b and 4c in Figure 4 assesses applying an iteration algorithm.

ECS Programming Assessment Problem

Chantelle and Jasmine are programming an Opinion Game. The game will check to see if two players have the same opinion by comparing their ratings about a topic (e.g., movies, food). The two players rate a topic by entering a number from 1 to 5 where 1 means you "don't like it at all" and 5 means you "like it a lot."

The game works as follows:

1. The game asks the players for a topic.
2. The game then gives each player a turn to rate the topic from 1 to 5.
3. The game then lets the players know if their answers match or not.

For example, two players might rate what they think about vanilla ice cream by each entering a number from 1 to 5. One person rates it as a 3 while the other person rates it as a 5. The game tells them that they don't agree.

You are going to program Chantelle and Jasmine's Opinion Game. Write out the steps that a computer could follow. Make sure:

- You use precise and clear language.
- Your program addresses ALL of the requirements listed above.

Figure 3. PACT Computational thinking conditional algorithm question.

ECS Programming Assessment Problem

Name one variable used in the program.

Variable: ___________________

Describe how this variable is used to make the program work.

____

____

____

Describe how you would change the program you created to have 20 topics rated. Include in your description the programming structure (Scratch or Alice block) that you would use.

Name of the programming structure (Scratch or Alice block): ____________________________

Describe how this programming structure (Scratch or Alice block) is used to have 20 topics rated.

____

____

____

Figure 4. PACT Computational thinking iteration algorithm question.

A rubric to score each question is provided to teachers when they download the PACT assessment (see Figure 5 and 6).

ECS Programming Assessment Rubric

Task: Creating a Program - Opinion Game

Total points for Task: 9 points

Learning Objectives

- Design, code, test, and execute a program that corresponds to a set of specifications.
- Select appropriate programming structures.

Rubric for Task

Total points: 5 points

Below are the point allocations and steps the student must include in the program in order to receive each point. Each step must be clearly present to receive the corresponding point. The steps may be written in code (e.g., Scratch, Alice), in pseudocode, or as clear descriptions.

- 1 point for having the program ask for a topic (Step 1).
- 1 point for having the program ask player 1 for a rating (Step 2).
- 1 point for having the program ask player 2 for a rating (Step 3).
- 1 point for having the program provide an output when the players' ratings match (Step 4).
- 1 point for having the program provide an output when the players' ratings don't match (Step 5).

Figure 5. PACT CT assessment rubric for Task on conditional algorithms.

ECS Programming Assessment Rubric

Rubric for Task part 1

Total points: 2 points

- 1 point for identifying an appropriate variable.
  - Acceptable variables include:
    - Topic
    - Rating for Player 1
    - Rating for Player 2
  - Note: The variable may have a different name from the ones provided here as long as it's clear it is one of the acceptable variables.
- 1 point for providing an appropriate description of how the identified variable is used in the program.
  - The explanation should address at least one of the following functions of a variable:
    - Storing information
    - Referring to information
    - Reusing or recalling information
    - Having the program do something different depending on the values entered

Rubric for Task part 2

Total points: 2 points

- 1 point for identifying the Repeat Until () or Repeat () block for Scratch OR the While () structure for Alice OR some other conditional loop (e.g., Do-While loop, For loop).
- 1 point for providing an appropriate description that indicates that the identified programming structure can be used to repeat the entire sequence a set number of times.
  - To receive the point, the student must at least discuss the loop function (e.g., the Repeat part of the Repeat Until () block) of the identified conditional loop (e.g., the programming structure is used to have the program repeat the game sequence). The student does not have to discuss the conditional function (e.g., the Until part of the Repeat Until () block) of the identified conditional loop (i.e., repeating the game 20 times).

Figure 6. PACT assessment rubric for Task on iteration algorithms.

A poster of the preliminary results of teacher implementation of the ECS curriculum was displayed at the March 2017 Special Interest Group of Computer Science Education (SIGCSE) annual conference (Bienkowski, Snow, McElhaney, Xu, Rutstein, & Tate, 2017). The SRI NSF funded study #1418149 Computer Science in Secondary Schools (CS3): Studying Context, Enactment, and Impact ended July 31, 2019. This study of over 900 students that used hierarchical linear modeling demonstrated PACT assessment validation through content review by experts, cognitive think-aloud interviews with a subset of students, and reliability assessments that were moderate to high (McGee et. al., 2018).

Because the PACT assessment is validated, free and available online, it could be used to evaluate computational thinking for ECS or another curriculum. If used, the PACT assessment would have to be adapted for the block-based programming used with another curriculum, because the assessment is currently designed using Scratch programming blocks.

Comparing Bootstrap and ECS

Although ECS and Bootstrap were designed for different purposes, they have common features. Both use a project-based inquiry focus through a free online programming platform that runs in the browser. Operating free in the browser is important because it does not require schools to deal with expenses, time, and personnel to download software on to a schools' computers. Both curricula are free and available online for anyone to use. Both use mostly game-based practice task to introduce the concepts related to the CT dimensions of problem formulation, problem solving using an information processing agent, abstraction, and algorithms.

They can differ in the CT dimension of power formulation, however. The computational end product of the Bootstrap curriculum is a video game that students can play on the WeScheme platform. The computational end product of the ECS curriculum is either a game or a story with at least three different pages or scenes. The story must have one positive thing that the student highlights and one thing to improve about their community. In addition, students must find at least one statistic to back up their conclusions, include at least one personal comment/recording, and one picture (Chapman & Goode, 2013).

If the student who is taking the ECS curriculum chooses to produce a game as her or his culminating project, then ECS and Bootstrap do not differ in their power formulation. However, if a student chooses to do the community story as her or his end product then there is a difference in the power formulation. The difference would be that the Bootstrap end product is a game while the ECS end product is a community story. This community story end product is part of the ECS researchers use of culturally relevant pedagogy when designing the curriculum (Goode, Margolis, & Ryoo, 2015).

Nevertheless, the computational practice tasks of ECS and Bootstrap are more similar than different because both center on game-based tasks. In Bootstrap, as was shown in Table 1, all the computational practice task are focused on game making. This focus is expected given that the computational end product in the Bootstrap curriculum is a game. In ECS, Unit 2 of the problem-solving tasks requires students to use culturally situated design tools to solve mathematical problems related to their choice of African American hair braiding, Virtual Bead Loom, Pacific Northwest Basket Weaver, Navajo Rug Weaver, or Graffiti Art (Chapman & Goode, 2013).

Still, similar to Bootstrap the programming tasks of ECS are mostly game focused. Unit 4 of ECS, its programming unit, has nine computational tasks. Six of the nine computational tasks are on game making activities such as tic-tac-toe and rock-paper-scissors. Is there a reason to use games as computational tasks? Will making a game engage African American high school students?

There is no current research on game making as a computational practice during school and student engagement disaggregated to focus on African American high school students. An afterschool program was implemented as a dissertation study with African American high school male students that was described as successful known as the Glitch Game Testers (Bruckman et al., 2009). As part of that program, twenty metro-Atlanta students were paid to test games and then learned to computationally make games. Is computational game making engaging for both male and female African American youth? Is there an alternative way to learn computational thinking that both African American male and female students might find engaging? Can this engaging way be done to teach introductory computational thinking during school rather than after school?

An Alternative to Games: Computational Music Remixing

Based on the common features of Bootstrap and ECS a computational platform that would be used as an introduction during the school day and be an alternative to the game making pedagogy of both would need to have the following attributes:

- Free
- Online and run in the browser so that there are no downloads
- Block-based to reduce cognitive load
- Widely used so that the platform is maintained
- Alternative pedagogy to games

There are a few available platforms that satisfy the first four attributes above such as Kodable and Lightbot. However, I have chosen to look at two widely used platforms that satisfy all five attributes and could be used as an alternative to study introductory CT in a during school course: App Inventor and EarSketch.

App Inventor is a programming platform that is used to make mobile apps while EarSketch is a programming platform used to remix music sound samples. Both programming platforms are used in the high school second-year course Computer Science Principles (CSP); both platforms are sponsored by NSF to study their use in CSP. The focus of App Inventor's NSF study is on teacher professional development to "compare results between online and face-to-face PD [professional development] focusing on the significant areas identified by the Mobile CSP project and the CSP framework" (NSF, n.d.).

The focus of EarSketch's NSF study is to study student content knowledge and engagement to "measure student learning and engagement across multiple demographic categories; and determine to what extent an EarSketch-based CS Principles course promotes student achievement and engagement across different student populations" (NSF, n.d.).

As stated previously, I am part of the NSF research team that is conducting the study to teach high school students computational thinking through computational music remixing in a second-year high school course. This study uses EarSketch as the programming platform hence I am biased toward using it as an alternative to the game making pedagogy of Scratch. Beyond my bias, research from the *Journal of Vocational Behavior* has shown that a musical career is preferred to computer programming at least 1.5 times by female African Americans and more than two times by male African Americans (Howard et al., 2011). EarSketch, because of its use of music remixing on musical tracks fits this preference while App Inventor does not.

Additionally, EarSketch has been evaluated on student engagement and the researchers disaggregated the data for underrepresented high school students of color, though not specifically for African Americans (Magerko et al., 2013). The study was for 98 students in an introductory, during-school, computer class known as Computing in the Modern World in 2013. The student engagement survey instrument of 36 Likert questions scaled from 1 to 5 measured seven constructs: confidence, attitude toward success, usefulness, motivation, identity and belongingness, creativity, and intention to persist in computing. Student results were reported in two groups, majority and minority. Whites and Asians were placed in the grouping labeled majority and all other races, including the 15 African American participants, were placed in the grouping labeled minority. Both groupings showed statistically significant improvement across all constructs at the alpha level of .001. The data, however, were not disaggregated for only African American students because the sample size was low at 15 (Magerko et al., 2013). The most recent internal documents for EarSketch show this same student engagement trend for a total of 187 students in a second-year high school Computer Science Principles course. Both the grouping labeled majority, 155 Whites and Asians, and the grouping labeled underrepresented minority, 190 Blacks and Latinx, showed significant improvement across the previously noted seven constructs at the alpha level of .001 (McKlin, 2018).

The only way to mix the music samples in EarSketch is through coding, hence the computational thinking dimensions of problem solving using an information processing agent, algorithms, and abstraction are learned by making and looping the beats, musical transition conditionals, and musical functions as respective examples.

The EarSketch curriculum is integrated into the EarSketch programming platform unlike ECS and Bootstrap. Problem formulation, in the form of music design problems, and power formulation, in the form of musical end products, occurs through the integrated curriculum available on the EarSketch platform (Magerko et al., 2013). The musical design problem end products are a musical introduction for personal expression, a musical background for a client of the student's choice with teacher approval, and a jukebox that can be added as play buttons to a website.

As previously stated, ECS is designed as a high school first-year introductory computational thinking curriculum, whereas EarSketch's curriculum is aligned to the programming learning objectives of AP Computer Science Principles, a second-year high school course in the state of Georgia (Magerko et al., 2013). The AP Computer Science Principles aligned EarSketch materials are designed for text based Javascript and Python programming languages. EarSketch has a block-based feature but there is no curriculum to support it. Therefore, to be used as an introductory course a curriculum unit designed to use the block based EarSketch feature would need to be developed. Also, this unit would need to align with a state's first-year introductory CT course objectives.

How would African American students respond to using EarSketch in the introductory first-year course? How would African American students CT content knowledge compare, as measured on the PACT assessment, using EarSketch?

CHAPTER 3

THEORETICAL FRAMEWORK

Wake up everybody no more sleepin in bed
No more backward thinkin time for thinkin ahead

–"Wake Up Everybody" by Harold Melvin and the Blue Notes

In the movie *The Matrix Reloaded* (Silver & The Wachowski Brothers, 2003), there is a scene where Morpheus, a leader against the matrix, is talking with the Merovingian, a program that holds the key maker who has the key to the architect of the matrix. During this dialogue, the Merovingian says to Morpheus: "Choice is an illusion, created between those with power, and those without. … Why' is the only real social power, without it you are powerless" (Manning, 2003). How do these words relate to computational thinking? How is the question "why" of importance for computational thinking for African American high school students?

The current operational definition of computational thinking (CT) defined by CSTA and ISTE, two of the leading K–12 technology organizations, is—

> Formulating problems in a way that enables us to use a computer and other tools to help solve them • Logically organizing and analyzing data • Representing data through abstractions, such as models and simulations • Automating solutions through algorithmic thinking (a series of ordered steps) • Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources • Generalizing and transferring this problem-solving process to a wide variety of problems. (ISTE & CSTA, 2011)

As previously stated, definitions of CT emphasize four dimensions: problem formulation – decomposing problems so that they can be solved using an information-processing agent (computer); creating computational artifacts – designing, prototyping, testing and refining an artifact that requires the use of the algorithmic and/or abstraction dimensions; algorithms – a series of ordered steps; and abstraction – induction from specific examples to generalizable patterns that can be used to simplify and manage complexity. It has also been stated that Seymour Papert (1996), in an article on mathematics education, provided the "original" definition of CT. Based on Papert's original definition of the power principle, I proposed that a fifth dimension be added to the four dimensions: power formulation. I chose not to define power formulation in the previous chapter, but instead focused on Papert's (1996) two questions related to the power principle:

1. "How can a child actually use it to do something that has real personal importance now?" (p. 97)
2. "What can your [project] do that will give them a sense of empowerment and achievement?" (p. 97)

I find it important here to define *power* and *empowerment* in relation to Papert's second question because in this study I am choosing to study African American youth and these definitions provide a beneficial ideological and theoretical perspective.

Power and Empowerment

Power has many definitions within social, economic, and political contexts. Some definitions of power are a focus on power over and involve agents. These agents can be individual or collective entities such as governments or organizations. Afrocentric scholar Maulana Karenga's statement that power is "the capacity to define, defend, and develop our interests" (as cited in Gates, 1997, para. 34) is an example of a definition of power involving these agents when he uses the word defends. A more general definition of power that Karenga has expressed is: "One of the greatest powers in the world is the ability to define reality and cause others to accept it" (2008, p. 8).

Other definitions define power that align to Karenga's second definition stated focus on the power to, as in the capacity to create or produce. "Power produces; it produces reality; it produces domains of objects and rituals of truth" (Foucault, 1991, p. 194) is an example of this other definition of power. Both Karenga and Foucault define power as the production of reality. This distinction is important because as I stated in the introduction, part of my purpose in conducting this study was to have students produce their own computational visions (i.e., reality) through their computational thinking content knowledge.

Because this study is focused on African American youth, I have chosen to also look at power through the lens of the person who coined the term, black power, Kwame Ture formerly known as Stokely Carmichael. Black power as defined in his work *Black Power: The Politics of Liberation in America* is "black self-determination and black self-identity" whose "ultimate values and goals are not domination or exploitation of other groups, but rather an effective share in the total power of the society" (Ture & Hamilton, 1967, p. 44). Self-determination is defined as "full participation in the decision-making processes affecting the lives of black people, and recognition of the virtues in themselves as black people" (p. 47). Hence, power for African American youth through the combined lens of Ture and Hamilton (1967) and Foucault includes the self-determined production of reality and that there is virtue of that determination because it was done by African American youth.

Combining Karenga, Foucault, and Ture's emphasis on creating and producing reality leads to a definition of power that can connect to self-determination and seeks an effective sharing of the total power of society. The power formulation discussed earlier is then the self-determined reality that seeks an effective share in the total power of society, not the domination or exploitation of other groups, in the creation and production of computational artifacts that affect the lives of Black students. (i.e., full participation in the decision-making processes in the topics that they choose to create computational artifacts about, and the vision and narrative of those topics using computational tools).

Returning to Ture and Hamilton's (1967) ultimate value to not "dominate or exploit other groups" is the antitheses to the hegemony that African American youth experience. Therefore, to empower themselves they must not only produce a self-determined reality but also produce a self-determined hegemonic challenging reality. Will African American youth, when given the choice to determine what they will produce computational artifacts on, choose topics that challenge hegemony?

Foucault also explains the personal agency one has to resist and challenge hegemonic power:

> To challenge power is not a matter of seeking some 'absolute truth' (which is in any case a socially produced power), but 'of detaching the power of truth from the forms of hegemony, social, economic, and cultural, within which it operates at the present time.' (Foucault, as cited in Rabinow, 1991, p. 75)

John Gaventa (1980) researched the phenomenon of quiescence—the silent agreement in conditions of glaring inequality (p. 3). Gaventa describes the purpose of oppressive hegemonic power is to prevent groups from participating in the decision-making processes and also to obtain the passive agreement of these groups to this situation. Gaventa (2003) also states, "discourse can be a site of both power and resistance, with scope to evade, subvert or contest strategies of power" (p. 3). Through discourse one can both, assert one's own power, and at the same time resist hegemonic power. This discourse is the "why" of the Merovingian. This discourse is the reason I began with a dialogue from a movie about a computer program. This discourse, through the creation, production, and reflection on self-determined computational artifacts that affects African American students' lives, is a method for students to empower themselves.

Participation Rather than Empowerment

One current focus of CT in K–12 education is on broadening participation. The recently released CS Framework (2016) first guiding principle is "broaden participation in computer science" (p. 15). In the framework, the core concept Impacts of Computing and core practice Fostering an Inclusive Computing Culture are identified as ways to make equity and diversity key topics of concern. Both are defined below:

- Impacts of Computing – affecting many aspects of the world in both positive and negative ways at local, national, and global levels. Individuals and communities influence computing through their behaviors and cultural and social interactions, and in turn, computing influences new cultural practices. An informed and responsible person should understand the social implications of the digital world, including equity and access to computing. (CS Framework, 2016, p. 92)

- Fostering an Inclusive Computer Culture – incorporating perspectives from people of different genders, ethnicities, and abilities. Incorporating these perspectives involves understanding the personal, ethical, social, economic, and cultural contexts in which people operate. Considering the needs of diverse users during the design process is essential to producing inclusive computational products. (CS Framework, 2016, p. 74)

This core concept and core practice is specifically in the framework to address equity. The framework specifically states, "The choice of *Impacts of Computing* as one of the core concepts and *Fostering an Inclusive Computing Culture* as one of the core practices make diversity, equity, and accessibility key topics of study" (p. 15).

In the framework is an explanation of why there is a focus on equity. It states that the purpose of equity—

> is not to prepare all students to major in computer science and go on to careers in software engineering or technology. Instead, it is about ensuring that all students have the foundational knowledge that will allow them to productively participate in today's world and make informed decisions about their lives. (p. 23)

The focus on participation and equity has been termed a "social turn" and suggest that rather than focusing on computational thinking that we should be focusing on computational participation.

Kafai (2013) explains that this shift has occurred because of three dimensions in the change of K–12 programming education:

- From code to applications – instead of focusing strictly on writing a computer program, students focus on the user of a programming application and design software to implement the application.
- From programming tools to communities – instead of focusing strictly on a programming language like Java or Python, students focus on modifying existing code or adding code to existing code from communities of available code samples.
- From starting from scratch to remixing – instead of starting from scratch to code an application, students remix existing code and add their own code to develop applications.

These three dimensions of the social turn in computing is a focus on a theoretical framework to participate. For the power formulation to be implemented, however, equity as participation is not enough, particularly, for African Americans or any other oppressed group. As expressed by Freire (1970/2000), the oppressed must "learn to perceive social, political and economic contradictions, and to take action against the oppressive elements of reality" (p. 35).

Just as the roots of computational thinking stem from mathematics education, then a look at mathematics education and its views on equity and pedagogy to empower can provide a beneficial lens for looking at equity in computing education.

Empowerment Models from Mathematics Education

Mathematics education has not only taken a social turn, but it has also taken a socio-political turn (Stinson & Bullock, 2012). Ernest defines this as the new philosophy of mathematics. This new turn or philosophy, Ernest (2009) states is "because education concerns the welfare and treatment of other persons, especially the young, it means that additional responsibility accrues to mathematics and its social institutions to ensure that its role in educating the young is a responsible and socially just one" (p. 59).

Five examples of these socially just or inclusive mathematics education perspectives are described, briefly, below:

- Jo Boaler (see, e.g., Boaler, 2016) – advocates that mathematics classroom focus on complex instruction, a teaching method that aims to disrupt broader racial hierarchies from the inside out through the promotion of equitable classroom relations and participation.
- Na'ilah Suad Nasir (see, e.g., Nasir, 2008) – suggests that students develop practice-linked identities or feelings of connection to an activity through their experiences participating in the activity, and through the kinds of opportunities for engagement that the activity makes available to students.
- Eric "Rico" Gutstein (see, e.g., Gutstein, 2009) – argues that students understand mathematics as a sociopolitical tool to directly critique the larger social and economic structures of society.
- Robert Moses (see, e.g., Moses, West, & Davis, 2009) – contends that mathematics education is a civil right because algebra is a gatekeeper subject to advanced mathematics needed for the workplace of the future.
- Danny Bernard Martin (see, e.g., Martin & McGee, 2009) – claims that eliminating inequities in access, achievement, and persistence in mathematics is not an issue that can be separated from the larger socio-political and socio-cultural contexts in which

schools exist and in which students live, including students' racialized mathematical experiences.

These perspectives can be summarized into Stinson's (2004) "three theoretical perspectives that aim toward empowering all children": the situated perspective, the culturally relevant perspective, and the critical perspective (p. 8). While all three may be considered to be empowering, I have chosen to focus on one to provide coherence and narrow the focus of my theoretical framework and because the one I have chosen has a critical component: the culturally relevant perspective.

Culturally Relevant Pedagogy

Culturally relevant pedagogy (e.g., Ladson-Billings 1992), also known as culturally responsive pedagogy (Gay, 2010), is based on research on learning styles and their relationship to culture that have been conducted for decades. Learning styles are defined as biological and developmental characteristics and preferences that affect how students learn (Hale, 1986; Reid, 2005; Allen, Sheve & Nieter, 2011).

Ladson-Billings (1992), one of the first scholars to define culturally relevant pedagogy, states, "it is a pedagogy that empowers students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes" (p. 382). Culturally relevant pedagogy rejects the deficit-based beliefs that some teachers may hold about culturally diverse students. It recognizes student strengths and seeks to build on them.

Ladson Billings (1995) defines three criteria for pedagogy to be culturally relevant: "produce students who can achieve academically, produce students who demonstrate cultural competence, and develop students who can both understand and critique the existing social order" (p. 474). These three criteria were the basis for designing a culturally relevant purposeful music mixing curriculum.

Academic Achievement

In the introduction of this text, the description of the African American students who scored 10% on the computational thinking pre-assessment was part of the inspiration for this study. I return to this fact in relation to Ladson-Billings (1995) first criteria, academic achievement. Ladson-Billings describes academic achievement that is assessed in multiple forms based on content knowledge that is constructed, shared, and scaffolded to facilitate learning (p. 481).

While there is research on the effectiveness of high school students learning computer science content knowledge (Ryoo, 2013; Goode, Margolis, & Ryoo, 2015) there was no stated position from the Computer Science Teachers Association (CSTA) on what was effective in K–12 teaching when I began this study in 2016 though. The recent 2020 release of the K–12 Computer Science Teacher Standards are "designed to provide clear guidance around effective and equitable CS instruction in support of rigorous CS education for all K-12 students" (CSTA, 2020).

Just as the origins of computational thinking come out of mathematics education, then I decided to look at how mathematics education effectiveness research could be applied to computational thinking. The National Council of Teachers of Mathematics (NCTM) defines seven effective teaching practices based on research in mathematics education that has been developed over decades (NCTM, 2014). I aimed to apply these practices so that computational thinking content knowledge is constructed, shared, and scaffolded to facilitate learning. Rather than speak to a general application of these effective practices, I decided to do a particular application.

In particular, discourse around coding pattern identification in relationship to musical patterns was used to scaffold learning the for loop algorithmic control structure in the programming unit. This particular emphasis, which encompassed multiple NCTM effective teaching practices, was contextualized in coding the background beat for a song that the student would add to a collaborative website which aimed to elicit a mood from the listener. These multiple effective teaching practices include posing a purposeful question (beat tempo to elicit mood), a task to promote reasoning (coding repetition pattern identification), connecting representations (connecting musical repetition to coding repetition), meaningful discourse (students had to review each other's code and provide feedback with respect to the mood elicited and the replacement of repetitious code with a for loop algorithmic control structure), scaffolding conceptual understanding by using the mathematics pedagogy of concrete-representational-abstract (placing a sequence of small colored discs to identify repetitious patterns in music and code).

Cultural Competence

The second criterion for CRP is to produce students who demonstrate cultural competence: Ladson-Billings (1995) states, "culturally relevant pedagogy must provide a way for students to maintain their cultural integrity while succeeding academically" (p. 476). She describes elements of cultural integrity with respect to dress, style, and social interaction.

EarSketch, as a platform for mixing music samples whose majority consist of African American music genres (R&B, funk, dubstep, gospel, hip hop, EDM, trap, west coast hip hop…), and creating beats fulfills this second criterion. In addition, the majority of the music samples were created by Young Guru, Jay Z's audio engineer and tour DJ, hence not only allowing African American students to maintain their cultural integrity, but also making it the center of coding. Moreover, there are related theoretical areas of CRP and cultural integrity that were applied to the curriculum developed. I briefly discuss two of these areas that can be applied to all students who learn computational thinking through computational music mixing: funds of knowledge and identity and belonging. I also discuss cultural values attributed to African American youth and how computational music remixing aligns with those values to further enhance cultural integrity.

Funds of knowledge. Funds of knowledge refers to a theory which contends that household and community knowledges can provide strategic resources for classroom practice; that historically and culturally developed bodies of knowledge and skills which are used for daily well-being are in all households (Moll & Greenburg, 1990). Teachers learned about the lived realities of students and their families, and then used this knowledge to develop mathematics curricular units in the classroom (Gonzalez & Moll, 2002; Gonzalez, Moll, & Amanti, 2005). Through funds of knowledge students are learning about and solving problems that relate, directly and indirectly, to their lives rather than what a teacher may think, or a textbook provides.

There are different ways that funds of knowledge can be applied to computational music remixing. One way is to ask students to search on the internet for music that has a message, and to have them ask a member of their household that is a parent's generation or older for a song that has a message. Both small group and whole class discussions can occur on the musical similarities and differences between what the students chose and what the household members chose as message focused music. The patterns that are identified can then be discussed as guidelines for students to computationally design and create their own message focused music.

Potential guidelines that relate between musical patterns that can become design criteria include musical tempo. The impact of music on arousal and mood is well established (Gabrielsson, 2001; Sloboda & Juslin, 2001; Thayer & Levenson, 1983). People often choose to listen to music to affect their mood and level of arousal (Gabrielsson, 2001; Sloboda, 1992). Physiological responses to music differ depending on the type of music heard. Musical tempo and pitch influence emotional responses and can be used to design music with an emotional intent.

Another way that funds of knowledge can be used in computational music remixing is by recording common household or neighborhood phrases or sounds and uploading these recordings as sound samples. The household or neighborhood phrases or sounds can then be computationally remixed to be part of the musical message hook, to capture listeners' attention in the middle of the music, or as a musical transition to drop the beat right after the phrase is said in the song.

There are many ways (e.g., computationally looping a part of a kitchen conversation or daily sounds a student hears, remixing a conversation as a beat string data type, pitch shifting the words in a conversation through a computational function) that sounds from home or the community can be incorporated into students' computational music, and most importantly, it gives the student a direct connection to their computational music design. This connection is important in student identity as a computational music designer and their socialization of who is a computational thinker.

Identity and belongingness. I observed a high school computer science teacher ask her students who was a computer scientist in their class toward the beginning of the 2016 school year. The class consisted of twenty students, all African American or Latinx except for one White male student. The majority of the students in the classroom pointed at the one White male student. The students' response that the one White male student was the computer scientist could have occurred for many reasons. One of those reasons could be identity.

Identity is defined by Karenga as "who you are in the opposition of oppressive forces" (Gates, 1997). I choose to use this definition because the study of African American youth in education as mathematics educator Danny Martin (2009) states should be for "liberation" to transform oppressive structures. Studies show that African American students selection of college major and career choices are influenced by their perception of racism and identity as an African American (Tovar-Murray, Jenifer, Andrusyk, D'Angelo, & King, 2012).

African American identity, however, can also be utilized to improve educational outcomes. African American cultural identity in particular has associated values that when responded to improve educational outcomes. Research has shown that nine elements of African American cultural ethos contribute to and enhance the academic performance of African American students (Boykin, 1977, 1994). These nine elements are briefly described below:

- *Spirituality* – intuition, supreme force
- *Harmony* – versatility and wholeness
- *Movement* – rhythm of everyday life
- *Verve* – intense stimulation, action, colorfulness
- **Affect** – premium on feelings, expression
- **Communalism** – social orientation, group duty, sharing, identity
- *Expressive individualism* – distinct, genuine, personal
- **Orality** – oral and aural modes of communication
- *Social time perspective* – time is marked by human interaction

The elements in bold were directly applied in the curriculum because of their relationship to music and/or computational thinking. Affect was also applied by prioritizing the computational tasks around designing the expression and feeling influenced by music that raises awareness about a community issue.

Communalism was applied through students making the music as a group using a technique known as pair programming. In pair programming one student is the driver and designs the ideas. In curriculum the driver will design the music and write a visual representation of music sound blocks over time and work with the other student to solve errors. The other student in pair programming is the navigator. The navigator chooses the best methods and looks for potential errors to debug the code. Here, the navigator uses EarSketch to mix the sound blocks and work with the driver to solve errors in the code. A recent dissertation, Hatley (2016), on communalism and computational thinking describes the origin and effectiveness of pair programming:

> Pair programming, first used by Frank Brooks—author of the Mythical Man Month, while he was in graduate school between 1953–1956 (Brooks, 1975), is at the root of a collaborative software development approach called 'extreme programming,' intended to improve quality and responsiveness to customer needs. Pair programming requires that teams of two programmers work simultaneously at the same computer on the same design, algorithm, code, or test (McDowell, Werner, Bullock, & Fernald, 2002; Nosek, 1998; Williams and Kessler, 2000). When used in industry, teams report a variety of benefits: improved product quality, fewer bugs, clearer code, improved knowledge sharing, motivation regarding coding, increased team morale, and a host of economic and other benefits (Denner, Werner, Campe, & Ortiz, 2012; Hanks, McDowell, Draper, & Krnjajic, 2004; Sfetsos, Adamidis, Angelis, Stamelos, & Deligiannis, 2013). (p. 59)

Orality was applied by students not only through making and sharing their music but also through reflective discourse throughout the learning experience. Students reflected and discussed their musical design and its influence of feelings and mood, computational design and the identity of a computational thinker, and the combination of musical and computational design and its influence on their self-perception as a computational thinker.

Cultural Relevancy Corruption

Concerned that culturally relevant pedagogy has become coopted, Ladson-Billings (2014) now promotes culturally sustaining pedagogy. She explains—

> What state departments, school districts, and individual teachers are now calling "culturally relevant pedagogy" is often a distortion and corruption of the central ideas I attempted to promulgate. The idea that adding some books about people of color, having a classroom Kwanzaa celebration, or posting "diverse" images makes one "culturally relevant" some to be what the pedagogy has been reduced to. (p. 82)

Culturally sustaining pedagogy requires teachers and curriculum to "push students to consider critical perspectives on policies and practices that may have direct impact on their lives and communities" (p. 78). Ladson-Billings's push to consider critical perspectives is not new for African American education. Historically, some well-known African American educators' critical perspectives are quoted below:

- W. E. B. DuBois (1902) – "We have a right to inquire, as this enthusiasm for material advancement mounts to its height, if after all the industrial school is the final and sufficient answer in the training of the Negro race; and to ask gently, but in all sincerity, the ever recurring query of the ages, Is not life more than meat, and the body more than raiment?" (p. 94)
- Carter G. Woodson (1933) – "History shows that it does not matter who is in power or what revolutionary forces take over the government, those who have not learned to do for themselves and have to depend solely on others never obtain any more rights or privileges in the end than they had in the beginning" (p. 129).

- Martin Luther King Jr. (1947) – “The function of education is to teach one to think intensively and to think critically. Intelligence plus character—that is the goal of true education” (p. 10).
- Janice Hale-Benson (1986) – “In a system of colonialism, the colonizer has a dual purpose for educating the colonized. The first is socialization into accepting the value system, history, and culture of the dominant society. The second is education for economic productivity” (p. 154).
- Asa Hilliard (1992) – “The traditional American school is quite rigid and encapsulated in a style that mimics the particular cultural style of most European Americans. Yet, this is not the only way to teach. Even more importantly, it may not even be the best way to teach European American children” (p. 373).
- Joyce King (2011) – “In school, we just get it laid on us that our history begins with slavery and that ‘our African brothers and sisters sold us into slavery.’ These little ideas seem innocent but they contain powerful mental maps that prevent you from making change and recognizing injustice” (as cited in Hiskey, 2011, para. 1).

These are a mere sampling of well-known critical perspectives that align to the third criterion of CRP that is also an empowering perspective advocated by Stinson (2004).

Critical Perspectives

Critical theory is a social and political philosophy that is a critique of the society to “liberate human beings from the circumstances that enslave them” (Horkheimer, 1982, p. 244). It was developed in Germany in the 1930s as a neo-Marxist philosophy of the Frankfurt School. It maintains that ideology and the societal values as a result of that ideology is the principal obstacle to human liberation. Ladson-Billings’s (1995) third criterion to develop students who can both understand and critique the existing social order was applied to the curriculum in two ways: problem posing and critical play.

Problem Posing

As previously stated this study is within an NSF sponsored study, and I am part of a project team to develop a year-long curriculum designed to "promote the development of rigorous CT skills by engaging students in authentic and culturally relevant problem-based, inquiry learning (PBIL) projects in STEM topics, such as resource sustainability" (Usselman, 2016-2022). When the study team began this project the example problem proposed for students was a clean drinking water emergency. The topic chosen for students was seen as a way to connect to issues around clean drinking water in the news that were occurring in Georgia and Michigan as shown in PowerPoint slide below in Figure 7.

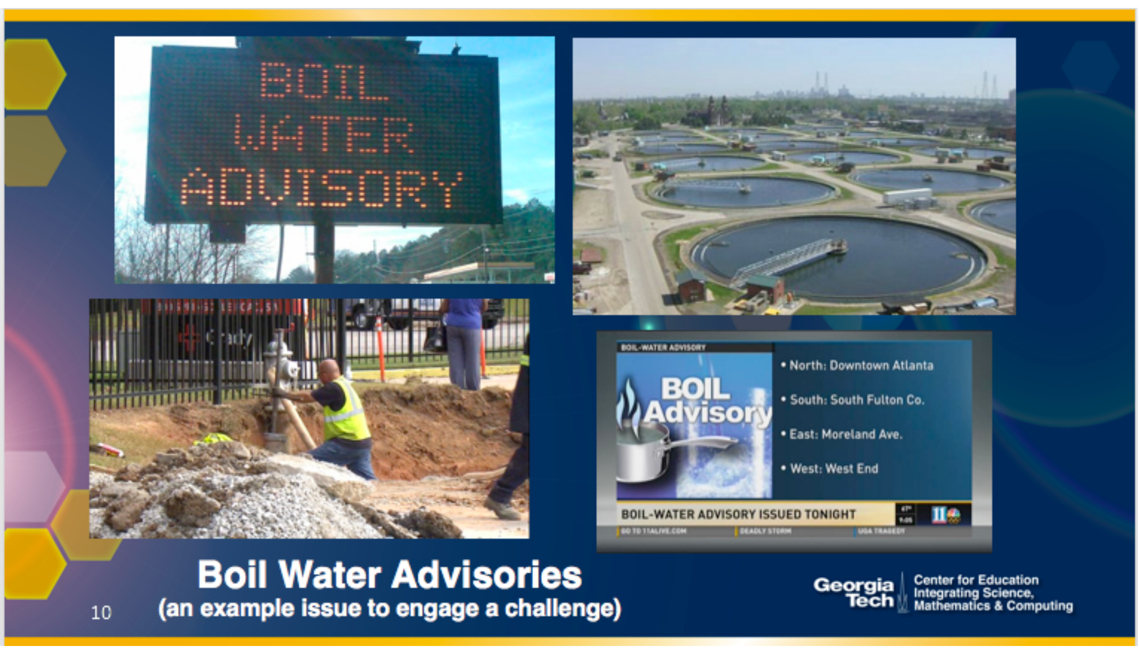

Figure 7. Researcher proposed study problem challenge for students.

On November 17, 2016, I proposed to the project curriculum team that we do not define the challenge for the students, but instead have the students define their own problem with guidance from the teacher so that problems would have a social significance. I explained to the team that underrepresented students need a pedagogy of problem choice where they can critique society because of the inequities that they experience. It was my way of expressing to them Freire's (1970/2000) critical consciousness, a sociopolitical educative tool that engages learners in questioning the nature of their historical and social situation, which Donald Macedo in the Introduction chapter of the 30th anniversary of Freire's *Pedagogy of the Oppressed* calls, "reading the world" (p. 26). I also wanted a clear goal of the power formulation to include a socio-political critique for African American students to address not just the historical inequities that are often part of their daily lives, but the present inequities that they experience in school so that students could as Freire states, "intervene in reality in order to change it" (p. 109) or as Karenga states, "critique and corrective" (2020).

The project curriculum team agreed, and we decided that students would select their problems in pairs and create a PowerPoint presentation for the first unit with the goal of convincing another pair to be part of their project. Then, the teams of four would do further research and develop a website to raise awareness on the problem that they had posed in the second unit. In the third unit, the students would go back to pairs to code a short 15-second musical introduction for the PowerPoint that they created in unit one, and then create a song to add to their website that they created in unit two, to inspire emotional engagement to those who read their website. In the fourth unit, we had the student pairs develop a game app related to the problem they posed so that participants could begin to formulate strategies for intervention in the problem leading to me sharing the concept of critical play with the curriculum project team.

Critical Play

Critical play is a means to create activities that represent one or more questions about aspects of human life. In her book *Critical Play*, Flanagan (2009) explains that critical play is "characterized by a careful examination of social, cultural, political, or even personal themes that function as alternatives to popular play spaces" (p. 6). In an earlier article Flanagan (2005), states: "The creation of technology is embedded within the ways in which people might interact with each other or view the world, after all. Therefore, creating software is in essence creating worldviews and worlds, and these constructions embed the idea of values into the technological systems" (p. 493).

Critical play requires the designer of the play activity to question the values both explicit and implicit within the game, and to choose values that "require the shifting of authority and power relations more toward a nonhierarchical, participatory exchange" (Flanagan, 2009, p. 256). Flanagan has worked with graduate students to develop play mostly in the form of games, both unplugged and software, that seek to develop nonhierarchical, participatory social change and now leads Tiltfactor, an innovation game design studio housed at Dartmouth College.

An example of an unplugged game is the card game where you decide who is a scientist based on the images on the card. This game influences the player to question their perceptions of the gender, race, style, and definition of who a scientist is and what it means to conduct science. An example of a software game is a role-play of a Tutsi mother during the 1994 civil war and genocide in Rwanda who is trying to keep her baby asleep so that they are not captured by a Hutu patrol. In the game, the player must match falling letters on the keyboard when they appear the brightest to maintain a lullaby that keeps the baby asleep (Flanagan, 2009).

Flanagan's Critical play design model is an iterative model that begins with setting both the game and values goals and ends with verifying values and goals through piloting the game with a diverse audience of players (see Figure 8).

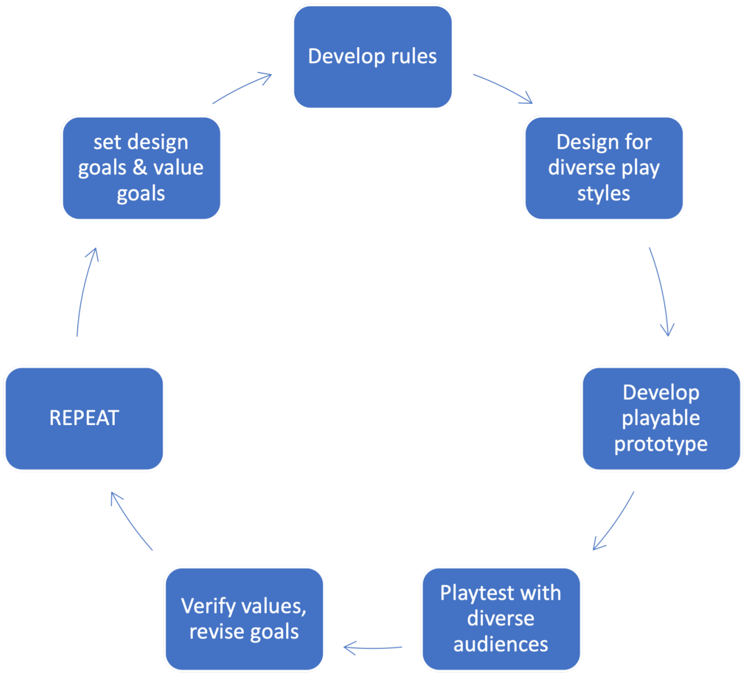

Figure 8. Critical play iterative cycle (Flanagan, 2009, p. 257).

Applied here, games were developed to teach conditional algorithms on the choices the player makes to reach a goal or raise awareness about the issue that students have chosen to address. Because I had focused on unit three and the coding of music, a colleague of mine focused on the development of unit 4 and did not develop the critical consciousness that I would have liked to have seen in this last curriculum unit. As an example, the example code that my colleague developed for the game app uses a context where the game player shoots sparkles at a pony to score points in the game. He said he chose this example because he is a "Brony," adult male fan of the children's cartoon My Little Pony. To say the least, shooting sparkles at a pony does not address the socio-historical or socio-political inequities that any oppressed group of students have experienced or continues to experience. As an alternative, I would have used example code that used a context of strategies to solve a food desert problem where points are scored based on the strategies that have been shown to be most effective. Hence, later in this text, I focus on the assessment of unit 3 on coding music to emotionally engage the reader of the students' problem-posed website.

A Purposeful Computational Learning Experience

How might we combine culturally relevant perspectives and critical perspectives using a computational music context into an introductory CT high school curriculum? In the state of Georgia, the introductory CT high school course is Introduction to Digital Technology (IDT) (Georgia Department of Education, 2013). The 11 standards of this course are:

1. Demonstrate employability skills required by business and industry.
2. Explore, research, and present findings on positions and career paths in technology and the impact of technology on chosen career area.
3. Demonstrate effective professional communication skills (oral, written, and digital) and practices that enable positive customer relationships.
4. Identify, describe, evaluate, select and use appropriate technology.
5. Understand, communicate, and adapt to a digital world.
6. Explore and explain the basic components of computer networks.
7. **Use computational thinking procedures to analyze and solve problems**.
8. Create and organize webpages through the use of a variety of web programming design tools.
9. **Design, develop, test and implement programs using visual programming**.
10. Describe, analyze, develop and follow policies for managing ethical and legal issues in the business world and in a technology-based society.
11. Explore how related student organizations are integral parts of career and technology education courses through leadership development, school and community service projects, entrepreneurship development, and competitive events. (Georgia Department of Education, 2013, pp. 1–9)

Standards 7 and 9 are in bold because they focus on computational thinking. They were combined in a curriculum unit that used the elements of culturally relevant and critical perspectives previously discussed. This unit was 8 weeks of the yearlong course; it was the third unit of the course.

In the Unit 1 of the course, the students were grouped to select a community problem. Each group used PowerPoint to begin their research and share knowledge on the issue. Unit 1 addressed standards 3, 4, and 5 of the IDT course. In Unit 2, each group addressed standard 8 by making a website to raise awareness on the issue.

Unit 3 was the computational thinking unit of the course. Students continued in their groups to develop a brief 15-second musical introduction that played at the beginning of the PowerPoint project the students created in unit 1 that was intended to influence the message and mood of the audience of the presentation. Also, in Unit 3, students developed two songs through pair programming. The two songs were intended to influence the message and mood of the audience of the website and were played while the website is being viewed.

The culturally relevant elements of funds of knowledge, communalism, and identity and belongingness were addressed through music message patterns, pair programming, and reflective discourse that occurred throughout the computational thinking unit (i.e., Unit 3). The critical elements of problem-posing, raising awareness of an issue through music, and personal agency also occurred in Unit 3. Reflective discourse throughout the unit problematized the issue that the students choose so that students would experience Freire's (1970/2000) critical consciousness. Table 4 shows the computational thinking unit in two modules. This first module is focused on funds of knowledge and musical message patterns in the creation of the 15-second musical introduction to the presentation the student pair made in unit 1. The second module is focused on coding 1 to 2 minutes of music that is added to the website to raise awareness on the community issue that was further researched in unit 2 using an iterative control structure to loop a beat rhythm. The IDT course standards to **use computational thinking procedures to analyze and solve problems** and **design, develop, test and implement programs using visual programming** are integrated throughout Unit 3.

Table 4
IDT Unit 3 Module 1 CT Curriculum - Musical Intro Challenge

Learning Goal	Learning Activity	Theoretical Framework	NCTM Effective Practice
Include the unique perspective of others and reflect on one's own perspective to organize and examine media patterns from multiple viewpoints from a diverse audience	Research music with and w/o messages and identify music and mood patterns	- Funds of Knowledge - Affect	- Facilitate meaningful discourse - Elicit and use evidence of student thinking - Pose purposeful questions
Modify an existing artifact by using variables with meaningful names (identifiers) to store data of selected types and produce varying outputs	- EarSketch Interface kahoot - Apply fitMedia function & data types matching	- Orality	- Elicit and use evidence of student thinking
Create a computational artifact that is a purposeful expression of media patterns using a library of procedures (API) that have defined parameters	- Musical Intro Challenge - Design storyboard of music based on intended mood	- Problem posing -Affect - Orality	- Pose purposeful questions - Establish goal - Facilitate meaningful discourse - Elicit and use evidence of student thinking
	- Apply fitMedia and setEffect functions to the design storyboard using pair programming	- Communalism - Orality	
Identify and fix (debug) errors of computational artifacts using systematic processes	- Syntax debug practice story	- Communalism - Orality	- Support productive struggle

IDT Unit 3 Module 2 CT Curriculum - Mood Stimulating Song Challenge

Learning Goal	Learning Activity	Theoretical Framework	NCTM Effective Practice
Demonstrate ways a given algorithm applies to other fields of study	- Colored Tiles match beat rhythm repetition patterns match visual DAW repetition patterns	- Funds of knowledge - Affect	- Facilitate meaningful discourse - Elicit and use evidence of student thinking - Use and connect representations
- Modify an existing artifact by using variables with meaningful names	- Apply makeBeat function to design beat rhythm	- Orality - Affect	- Elicit and use evidence of student thinking

(identifiers) to store data of selected types and produce varying outputs			
- Articulate ideas responsibly for computational artifacts by observing intellectual property rights and giving appropriate attribution	- Make beat rhythms with recorded sound uploads - Copyright court	- Funds of knowledge - Affect - Orality	- Facilitate meaningful discourse - Elicit and use evidence of student thinking
Plan the development of computational artifacts using an iterative process to carefully consider the diverse needs and wants of a community and evaluate whether criteria and constraints were met	- Mood Stimulating Song Design Challenge - Design storyboard of music based on intended mood	- Problem Posing - Affect - Orality	- Pose purposeful questions - Establish goal - Facilitate meaningful discourse - Elicit and use evidence of student thinking
Create team norms, expectations, and equitable workloads to create and systematically test a control structures (iterative) computational artifact	- Repetitious Code Script Search - Apply for loop to reduce repetitious code using pair programming	- Communalism - Orality	- Facilitate meaningful discourse - Elicit and use evidence of student thinking - Use and connect representations
Identify and fix (debug) errors of computational artifacts using systematic processes	- Logic debug print story	- Communalism - Orality - Affect	- Support productive struggle
Address the needs of diverse end users to produce algorithms (iterative) that are generalizable to many situations	- Feedback Friends	- Communalism - Orality - Affect	- Facilitate meaningful discourse - Elicit and use evidence of student thinking
Explore research and present findings on career paths	- Role model video reflections -Pathway prediction	- Orality	- Facilitate meaningful discourse - Elicit and use evidence of student thinking

The platform to teach computational thinking in Unit 3 was EarSketch. The EarSketch platform allowed students to make music by computationally remixing sound samples. The sound samples within EarSketch are from 20 different current popular music genres including but not limited to pop, rock, gospel, hip-hop, funk, dubstep, and trap. There are five panels in the EarSketch interface (see Figure 9).

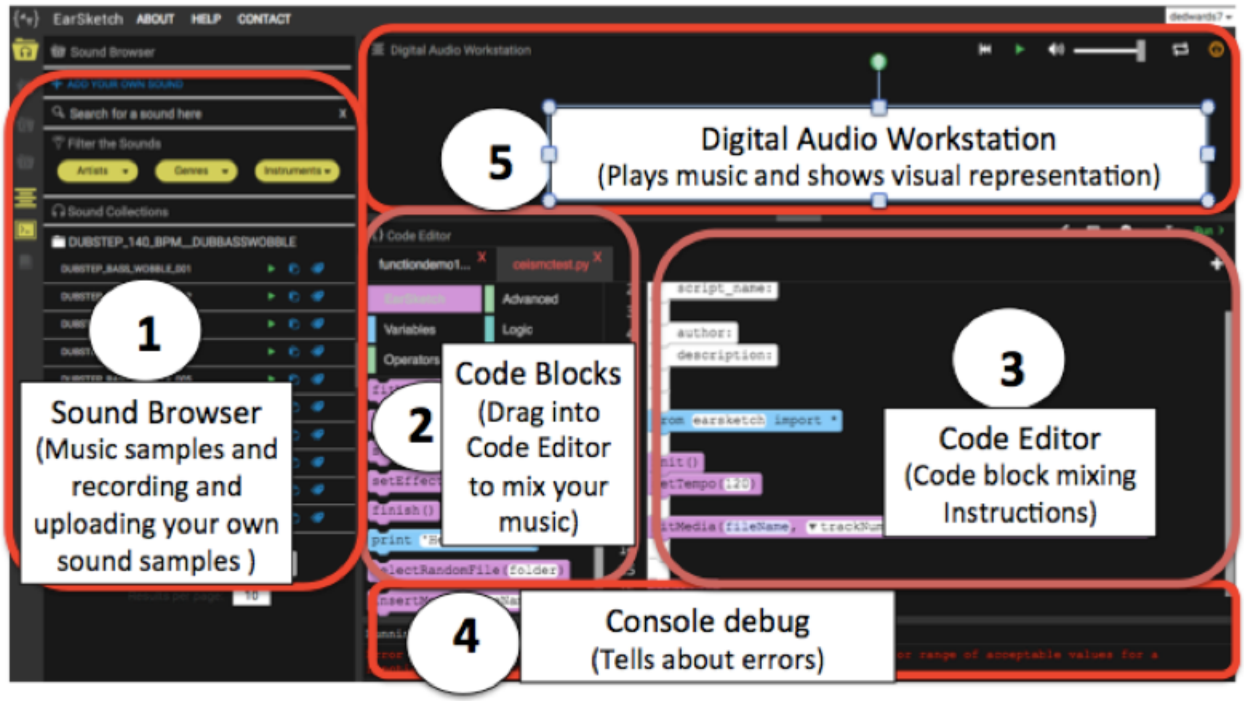

Figure 9. EarSketch programming interface panels.

An explanation of the use of each panel is below:

1. Sound samples panel – library of sound samples of 30 different instruments over 20 different musical genres, and ability to record your own sound sample or upload a sound sample not available in the library.
2. Coding blocks panel – code blocks that play sound samples, add effects like echo or fading to the samples, make beats using sound samples, and algorithmically control the flow of the sound samples.
3. Coding blocks mixing panel – algorithmically control flow of the sound samples and create abstractions of musical sections of combined sounds.
4. Debugging console panel – identifies and describes errors and shows the location of the error in the coding blocks mixing panel.

5. Digital audio workstation panel – plays and pauses music and shows visual representation of the music over time as blocks of sound samples.

Students designed their music by selecting sound samples, deciding how long they wanted the sound samples to play, and adding their message in the form of their own recording that they upload into EarSketch. Students learned how to make a visual representation of their music design that they used the representation as an outline to design their code.

After designing their music, students designed the code that plays the music by selecting coding blocks which use sequence and iteration algorithmic control flow. Students were notified of the location of errors in the debugging console panel. Once these errors were solved they see a message that their script ran successfully, and a visual representation of their music will appear in the digital audio workstation. The visual representation of blocks of sound samples over time in the digital audio workstation should match the visual representation that they made when designing their music.

The five panels of the EarSketch interface describe how students can implement the four common dimensions of computational thinking to make music: problem formulation, creating computational artifacts, algorithms, and abstraction. Students can use EarSketch to design music that is neither purposeful, does not raise awareness of a community issue, nor addresses social change toward nonhierarchical participatory exchange. However, to engage not only African American students but for all students the combined lens of culturally relevant pedagogy and critical problem-posing leads to using EarSketch to design music that has a student self-determined intended mood related to a problem that students feel is relevant to their lives. In doing so, this introductory CT curriculum promotes a purposeful, empowering environment and can respond to Papert's (1996) power formulation question, "What can your [project] do that will give them a sense of empowerment and achievement?" (p. 97)

While I have described how combining the theoretical perspectives of culturally relevant pedagogy and critical theory to CT through computational music mixing benefit African American students, I wish to explicitly state that it can benefit and engage all students. As was previously stated, in the most recent EarSketch student engagement study, Whites and Asians as well as African Americans and Latinx students showed significant increases at the alpha level of 0.001 across seven constructs: confidence, enjoyment, usefulness, motivation, identity and belongingness, creativity, and intention to persist in computing (McKlin, 2016).

CHAPTER 4

METHODOLOGY

But I'm just a soul whose intentions are good
Oh Lord, please don't let me be misunderstood

–"Don't Let Me Be Misunderstood" by Nina Simone

The purpose of this study was to investigate introductory CT content knowledge and its mathematics education origins in relationship to African American high school student engagement and purposeful computational music mixing. Purposeful in this case means designing music to "consider critical perspectives on policies and practices that may have direct impact on [students] lives and communities" (Ladson-Billings, 2014, p. 78).

Computational music mixing in this study was done using the web-based platform EarSketch. EarSketch is an integrated curriculum, programming, and Digital Audio Workstation (DAW) platform where students learn either the Python or JavaScript computer science language by writing computer code to mix music sound samples.

The research questions for this study were:

- What is the change from pre-instruction to post-instruction in the student engagement survey means of racially diverse high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform?
- What is the difference in engagement post-instruction between African American and non-African American high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform, when adjusted for their engagement previous to instruction?

- What is the change from pre-instruction to post-instruction in introductory computational thinking (CT) content knowledge of racially diverse high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform
- What is the difference in introductory CT knowledge post instruction between the African American and non-African American high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform, when adjusted for their CT knowledge previous to instruction?

Corresponding to the research questions above, the null hypotheses tested in this study are:

- H_0: There is no change from pre-instruction to post-instruction in the student engagement means of racially diverse high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform.
- H_0: There is no difference difference in engagement post-instruction between African American and non-African American high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform, when adjusted for their engagement previous to instruction.
- H_0: There is no change from pre-instruction to post-instruction in introductory computational thinking (CT) content knowledge of racially diverse high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform.

- H_0: There is no difference in introductory CT knowledge post instruction between the African American and non-African American high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform, when adjusted for their CT knowledge previous to instruction.

This quantitative study adapted the Principled Assessment of Computational Thinking (PACT) developed by Science Research International (SRI) sponsored by NSF awards CNS-1132232, CNS-1240625, CNS-1433065, and DRL-1418149. This instrument was validated as stated earlier in chapter 2 in relationship to the Exploring Computer Science curriculum. PACT was used on a large scale to assess computational thinking change for students taking the introductory CT course Exploring Computer Science (Bienkowski, Snow, Rutstein & Grover, 2015). The assessment uses multiple forms of assessment as proposed by Grover, Cooper, and Pea (2014). These forms include multiple choice and constructed response with related rubric evaluation criteria. The PACT assessment is designed partially around the Scratch platform and was modified for use in this study for use with the EarSketch platform. This modified PACT assessment is in the appendix (see Appendix A).

Instrumentation

Student engagement for the overall NSF study was measured with a survey instrument that included scales from Williams, Weibe, Yang, and Miller (2003) that were adapted by McKlin (2014), a previous computer science dissertation focused on African American males and gaming (DiSalvo, 2013), and Deci and Ryan (2011) Intrinsic Motivation Scales. For this study I chose to use the instrument items that were from Williams and colleagues that were adapted by McKlin because these items were specifically focused on computing and the instrument was validated. The reliability of the original instrument constructs for 162 students in a college introductory computing course ranged from Cronbach's alpha values of 0.83 to 0.91 (see Table 5).

Table 5
Computer Science Attitude Survey Reliability for College Students

Survey Construct	Cronbach's alpha
Confidence in learning computer programming	0.91
Attitude toward success in CS	0.86
CS as a male domain	0.83
Usefulness of CS and programming	0.91
Motivation in CS and programming	0.90

The adapted survey by McKlin was conducted with 108 high school students in a second-year high school computing course. The Cronbach's alpha values ranged from 0.72 to 0.95 (McKlin, 2016; see Table 6).

Table 6
Computer Science Engagement Survey Reliability for High School Students

Survey Construct	Cronbach's alpha
Confidence in learning computer programming	0.88
Computing enjoyment	0.72
Importance and Usefulness of CS and programming	0.77
Motivation to Succeed in CS and programming	0.85
Computing identity and belonging	0.79
Intention to persist in computing	0.95

Based on Nunnally's (1967) guidelines, the Cronbach's alphas rate a reliability that is "very good" to "excellent" for the original constructs with college student participants and rated "good" to "excellent" for the adapted constructs with high school student participants.

I also chose to use five constructs from the survey: Interest, Identity and belonging, Importance and usefulness, Motivation to succeed, and Intention to persist. I chose Identity and belonging because it is an important part of my cultural competence component of my theoretical framework as stated in the previous chapter.

There are no quantitative high school student studies that have shown a statistically significant relationship between student engagement and computing achievement including the previous EarSketch study for high school students in the second Computer Science Principles course (McKlin, 2018). However, there are mathematics education studies that have shown a statistically significant relationship between Interest, Usefulness and Persistence in Problem Solving to mathematics achievement for high school age students. Particularly, a recent study of the Programme for International Student Assessment (PISA) results showed a statistically significant relationship for affective (interest and usefulness constructs) and cognitive engagement (openness to novel problems and persistence in problem solving constructs) (Fung, Tan, & Chen, 2018). The modified set of items from Items on Participants' Interest in Computing (DiSalvo et al., 2013; adapted from Computer Attitude Questionnaire, Christensen & Knezek, 1996) align to Interest in the PISA study. The Williams and colleagues (2002) adapted by McKlin (2014) items that align with the PISA study items are Importance and Usefulness that related to Usefulness in the PISA study and Motivation to Succeed aligned with Persistence in Problem Solving. In addition, the overall NSF study, Culturally Authentic Practice to Advance Computational Thinking in Youth (CAPACiTY), in which this study is embedded, evaluated the construct Intention to Persist in Computing, so I added that part of the Williams and colleagues items to this study. Hence, the constructs and items in Table 13 below are analyzed in the next chapter. The survey items that I used were administered prior to and after instruction and all questions had Likert responses from 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree (see Table 7).

Table 7
Student Engagement Instrument Constructs

Construct	Items
Computing Interest: attracted to computing	1. I am interested in computer science. 2. I am interested in digital technology.
Computing Importance & Perceived Usefulness of Computing: viewing computing as important and useful for one's future	3. I will be able to get a good job if I learn computing. 4. I will use computing in many ways throughout my life. 5. Computing is of no relevance to my life. (n) 6. Taking computing classes is a waste of time. (n)
Computing Identity and Belongingness: feeling an affinity towards the computing domain	7. I feel like I "belong" in computer science. 8. I consider myself as a scientist, technologist, engineer, or mathematician. 9. I take pride in my computing abilities.
Motivation to Succeed in Computing: perseverance on computing tasks or problems	10. I like solving computing problems. 11. When a computing problem arises that I can't immediately solve, I stick with it until I have the solution. 12. When I am working on a computing problem that I can't immediately understand, I want to work harder to get it. 13. Figuring out computing problems does not interest me. (n)
Intention to Persist in Computing	14. I intend to get a college degree in computing. 15. Someday, I would like to have a career in computing. 16. I can see myself working in a computing field. 17. I intend to take courses related to computing in the future.

Note: (n) = negatively worded statements. Scale = 1 strongly disagree to 5 strongly agree.

Content Knowledge Assessment (CKA) Instrument

Computational content knowledge change will be measured using a modified Principled Assessment of Computational Thinking. SRI defines principled assessment as "assessment tasks to measure important knowledge and practices by specifying chains of evidence that can be traced from what students do (observable behaviors) to claims about what they know" (Bienkowski, Snow, Rutstein & Grover, 2015, p. 2).

These chains of evidence are based on the evidence centered design framework. Evidence centered design (ECD) was selected by SRI because it is "helpful when the knowledge and skills to be measured involve complex, multistep performances, such as those required in computational thinking" (Bienkowski, Snow, Rutstein & Grover, 2015, p. 6). ECD refines learning goals into a set of constructs that are transformed into tasks that are evaluated using construct-based scoring criteria and rubrics. Specifically, a curriculum's specified learning goals are used to identify the construct knowledge, skills, and attributes (KSA) to do the learning goal. Then this KSA is further analyzed to identify the potential observations and work products of the task related to the KSA. Next, the features of the products are identified to design an assessment item and associated scoring criteria and rubric for that item. The process from learning goal to features is called the design pattern. The design pattern elements go through a step-by-step process from Focal knowledge to Variable features (see Table 8).

Table 8
Evidence Centered Design Pattern Elements

Learning Goal/Construct	Description
Focal knowledge, skills, and other attributes (FKSAs)	The primary KSAs targeted by the design pattern and what researchers want to make inferences about. For initial work on computational thinking practices, researchers focused on skills rather than knowledge.
Additional KSAs	Other KSAs that may be required for successful performance on the assessment tasks but are not the target skills that researchers are trying to assess.
Potential observations	For computer science, this may include knowledge of mathematics or programming languages and tools. Additional KSAs may also be used to link across design patterns to show the interdependencies among skills.
Potential work products	Features of the things students say, do, or make that constitute the evidence on which the inference about a student's performance will be based.
Characteristic features	Potential observations are described using such qualities as accuracy, degree, completeness, and precision.
Variable features	Some possible artifacts or observations that researcher could see. Work products are scored during assessment delivery.

The potential observations, work products, and features are used to design an assessment item and its associated rubric. As an example, the design elements process can be applied to the learning goal Design Creative Solutions and Artifacts (see Table 9).

Table 9
Design Pattern for Design Creative Solutions and Artifacts

Learning Goal/Construct	Design Creative Solutions and Artifacts
Focal knowledge, skills, and other attributes (FKSAs)	• Ability to state a problem in order to identify the inputs and outputs of the problem • Ability to decompose a problem into multiple sub problems, including the specification of how solving the sub problems will lead to a solution to the problem as a whole • Ability to create a computational artifact given a purpose or intent • Ability to select appropriate techniques to develop computational artifacts
Additional KSAs	• Knowledge of terminology • Knowledge of specific programming languages

	• Knowledge of specific design environments
Potential observations	• Degree to which the identified purpose is related to the computational solution • Accuracy of the description of the design process • Completeness of the description of the design process • Degree to which the computational solution addresses the problem • Flexibility in the computational solution • Level of complexity of the computational solution • Correctness of the computational solution (e.g., the degree to which it provides the expected output given input, the degree to which it runs without errors) • Appropriateness of the use of programming structures in the computational solution • Efficiency of the computational solution • Accuracy of the explanation or description of the computational solution • Completeness of the explanation or description of the computational solution (or degree to which the explanation or description covers the aspects of the computational solution being asked about) • Accuracy of the description of the problem and problem space • Completeness of the description of the problem and problem space (or degree to which the description covers the aspects of the problem and/or problem space being asked about) • Accuracy of the explanation of the different tools
Potential work products	• Identification of the purpose (or purposes) of the computational solution • Description of the design process • The computational solution • Description or explanation of the computational solution • Description of the problem and problem space (includes a description of the subparts to a problem and boundary conditions) • Explanation of how different tools may be used or were used to create an artifact
Characteristic features	A problem or situation requiring a computational solution must be presented.
Variable features	• Level of difficulty of the computational solution required • Type of computational solution • Type of problem provided • Representation of the computational solution asked for • Whether or not the computational solution is presented or asked for • Degree to which the computational solution addresses the problem/situation/requirements of the solution

A PACT assessment item and its associated rubric were generated from the design pattern elements above. It is a three-part item that has students design an opinion game (Bienkowski, Grover, Rutstein, & Snow, 2015) (see Table 10).

Table 10
PACT Programming Assessment Item

Task	Assessment Item	Rubric	
Part 1	Chantelle and Jasmine are programming an Opinion Game. The game will check to see if two players have the same opinion by	T5	Points

	comparing their ratings about a topic (e.g., movies, food). The two players rate a topic by entering a number from 1 to 5 where 1 means you "don't like it at all" and 5 means you "like it a lot." The game works as follows: The game asks the players for a topic. The game then gives each player a turn to rate the topic from 1 to 5. The game then lets the players know if their answers match or not. For example, two players might rate what they think about vanilla ice cream by each entering a number from 1 to 5. One person rates it as a 3 while the other person rates it as a 5. The game tells them that they don't agree. a) You are going to program Chantelle and Jasmine's Opinion Game. Write out the steps that a computer could follow. Make sure: You use precise and clear language. Your program addresses ALL of the requirements listed above. You may use Scratch or Alice blocks in your steps.	Below are the point allocations and steps the student must include in the program in order to receive each point. Each step must be clearly present to receive the corresponding point. The steps may be written in code (e.g., Scratch, Alice), in pseudocode, or as clear descriptions. • 1 point for having the program ask for a topic (Step 1). • 1 point for having the program ask player 1 for a rating (Step 2). • 1 point for having the program ask player 2 for a rating (Step 3). • 1 point for having the program provide an output when the players' ratings match (Step 4). • 1 point for having the program provide an output when the players' ratings don't match (Step 5).
Part 2	Name one variable used in the program. Variable:________________________ Describe how this variable is used to make the program work.	Total points: 2 points • 1 point for identifying an appropriate variable. Acceptable variables include: o Topic o Rating for Player 1 o Rating for Player 2 Note: The variable may have a different name from the ones provided here as long as it's clear it is one of the acceptable variables. • 1 point for providing an appropriate description of how the identified variable is used in the program. Note: The explanation should address at least one of the following functions of a variable: o Storing information o Referring to information o Reusing or recalling information o Having the program do something different depending on the values entered
Part 3	Describe how you would change the program you created in part (a) to have 20 topics rated. Include in your description the programming structure (Scratch or Alice block) that you would use.	Total points: 2 points • 1 point for identifying the Repeat Until () or Repeat () block for Scratch OR the

	Name of the programming structure (Scratch or Alice block):Describe how this programming structure (Scratch or Alice block) is used to have 20 topics rated.	While () structure for Alice OR some other conditional loop (e.g., Do-While loop, For loop). • 1 point for providing an appropriate description that indicates that the identified programming structure can be used to repeat the entire sequence a set number of times. To receive the point, the student must at least discuss the loop function (e.g., the Repeat part of the Repeat Until () block) of the identified conditional loop (e.g., the programming structure is used to have the program repeat the game sequence). The student does not have to discuss the conditional function (e.g., the Until part of the Repeat Until () block) of the identified conditional loop (i.e., repeating the game 20 times).

This opinion game question is question 4 of the four questions in the PACT unit on programming. The last question assesses the CT dimensions of problem formulation, creating computational artifacts, and algorithmic control flow. The 4 PACT assessment questions and their context assess the four dimensions of CT (see Table 11).

Table 11
PACT Assessment Question Context and Related CT Dimension

Question	Context	Related CT Dimensions
1	Gabriella and Lucia each design an algorithm to have a dog run laps on the screen. The number of times the dog runs is based on user keyboard inputs.	Problem formulation Algorithmic control flow
2	Jamal creates a Scratch dialogue program that displays a sequence of numbers, the word Hello, another set of two numbers, the word Goodbye.	Algorithmic control flow
3	A Scratch program by an unknown creator has a ballerina dance across the stage and change costumes a specified number of times based on user keyboard input.	Problem formulation Algorithmic control flow
4	Chantelle and Jasmine program an opinion game (e.g., movies, food, vanilla ice cream)	Problem formulation Algorithmic control flow Creating computational artifacts

Questions 2, 3, and 4 use the Scratch programming platform, and were modified to align to our learning goals for this programming unit, and for the EarSketch programming platform by myself and a colleague on the CAPACiTY project, then reviewed by SRI consultant, Daisy Rutstein. Based on Papert's (1996) question "What can your [project] do that will give them a sense of empowerment and achievement?" the PACT assessment empowers students to design games about dogs running laps, design irrelevant dialogue, design a ballerina game, and design an opinion game. I return to Ladson-Billings statement on cultural relevancy, "consider critical perspectives on policies and practices that may have direct impact on [students] lives and communities" (Ladson-Billings, 2014, p. 78). Because games about dogs running laps, ballerinas, and opinion games about movies or vanilla ice cream are not related to policies or practices that directly impact student lives, the PACT assessment as currently defined is not culturally relevant regardless of the fact that names like Jamal and Gabriella are used in the assessment questions. Neither is it critical.

Therefore, another goal of this proposed study was to define PACT-like assessment questions that related to the critical perspectives that have a direct impact on the lives of students in alignment with the culturally authentic framework of the CAPACiTY curriculum. The context changes that I proposed for questions 2, 3, and 4 to increase the cultural relevancy of the assessment are shown below in Table 12.

Table 12
Proposed Culturally Relevant Context Changes to the PACT Assessment

Question	Context	Related CT Dimensions
1	Gabriella and Lucia each design an algorithm to have a dog run laps on the screen. The number of times the dog runs is based on user keyboard inputs.	Problem formulation Algorithmic control flow
2	Jamal codes a musical introduction for a PowerPoint project on a community issue	Algorithmic control flow
3	An EarSketch program by an unknown creator has been coded to make background music for a video on bullying.	Problem formulation Algorithmic control flow

4	Chantelle and Jasmine program an opinion game (e.g., movies, health benefits of cafeteria food).	Problem formulation Algorithmic control flow Creating computational artifacts

The context changes for questions 2, 3, and 4 were accepted by the CAPACiTY project team. In addition, I proposed that question 1 and 4 be transferred to the unit 4 assessment because of their focus on conditional statements. While EarSketch affords conditional statements, its batch programming configuration does not align directly to event centered conditional programming, while the App Inventor platform aligns directly to event centered conditional programming. App Inventor is the platform used in unit 4 of the CAPACiTY curriculum to make a game app, hence my proposal to transfer question 1 to the unit 4 assessment, which was also accepted by the CAPACiTY project team.

To replace questions 1 and 4, I proposed a multiple-choice question on variable types related to strings and a constructed response question on for loop algorithmic control structures that aligned with the unit 3 sections on the string variable type and for loop control structure. The context of the variable type item was the rhythm of the EarSketch function makeBeat and the context of the algorithmic control structure item was a student making a music score for a video in history class. These changes were also accepted by the project team. The project team also added a multiple-choice question on the sequence of the software development process that had no context to the assessment. Therefore, the assessment instrument that was used is described in Table 13 below. The assessment instrument is in appendix A.

Table 13
Culturally Relevant Context Changes to the PACT Assessment

Question	Context	Related CT Dimensions
1	Jamal codes a musical introduction for a PowerPoint project on a community issue	Algorithmic control flow
2	An EarSketch program by an unknown creator has been coded to make background music for a video on bullying.	Problem formulation Algorithmic control flow
3	Chantelle and Jasmine program a musical score for a video they are making in their history class	Problem formulation Algorithmic control flow

		Creating computational artifacts
4	Sequence of Software Development Process	Creating computational artifacts
5	A student is using EarSketch to make a beat rhythm	Abstraction

Participants

The setting for this proposed study was a public school district in a suburban county in the state of Georgia with a population of over 102,000 students. The treatment high school had almost 1,600 students. The racial demographics of the treatment high school were 3% Asian, 37% Latinx, 25% African American, 32% White, and 3% Multiracial. The school had a 40% free and reduced lunch population. (Georgia Department of Education, 2019).

All of the students in this study were taking the course Introduction to Digital Technology (IDT), the introductory course in computational thinking for high schools at that time in the state of Georgia. This course was the introductory course in all 10 of the Career Technology Agricultural Education (CTAE) Information Technology (IT) pathways for the state. Examples of these pathways include Computer Science, Cyber Security, Internet of Things, and Web Development. (Georgia Department of Education, 2020).

This study was designed toward African American student participants because I was originally inspired by the fact that a classroom of 24 African American students scored a mean of 10% on a pre-content knowledge assessment on computational thinking. I am not satisfied that these students answered only 10% correctly, considering that over half of them had taken a first introductory CT course; I wish for a better outcome from the introductory high school course. This study seeks to provide a better outcome for African American high school students with an additional goal of significant improvement for all students from a first-year CT introductory course.

Procedures

As noted previously, this study is embedded in NSF grant award #1639946 Culturally Authentic Practice to Advance Computational Thinking in Youth (CAPACiTY). As part of this study, the project team, of which I am co-PI and curriculum lead, has received approval from the local district and Georgia Institute of Technology Institutional Review Board (IRB) to conduct the study. Therefore, the data used in this study was secondary. I also submitted a research request application and detailed proposal package to the Georgia State University Institutional Review Board (see Appendix C). Specific guidelines were followed in order to protect the rights of individual students and staff in the school system, and not interfere with ongoing instruction in the schools.

The application to the local school district was an “opt out” application. Students taking Introduction to Digital Technology (IDT), the state of Georgia’s first-year introductory course, at the two schools in the district in the study received a letter from the study team to take home to parents. This letter included the purpose of the research, risks and benefits, confidentiality involved, institutional affiliation of the researchers, and contact information for the researcher. This letter informed parents/caregivers that their child was in a class where a study was being conducted and could sign the letter to **not** give their consent for their child to be part of the study. Teachers who were involved in the study received a Letter of Consent with the same information and signed to give their consent to be part of the study. Teachers from the treatment school received professional development during summer 2018 to instruct a CAPACiTY version of IDT. These teachers were paid a stipend as part of the study.

Data Collection

I solely developed the unit on computational thinking for this study. It is the third of four units in the year-long course. I developed units 1, 2, and 4 on interpersonal presentation, website design, and app development respectively, in collaboration with the CAPACiTY curriculum project team. The IDT first-year introductory CT course has 11 standards. Unit 3 was an implementation of IDT course standards 7 and 9 (bolded below):

1. Demonstrate employability skills required by business and industry.
2. Explore, research, and present findings on positions and career paths in technology and the impact of technology on chosen career area.
3. Demonstrate effective professional communication skills (oral, written, and digital) and practices that enable positive customer relationships.
4. Identify, describe, evaluate, select, and use appropriate technology.
5. Understand, communicate, and adapt to a digital world.
6. Explore and explain the basic components of computer networks.
7. **Use computational thinking procedures to analyze and solve problems**.
8. Create and organize webpages through the use of a variety of web programming design tools.
9. **Design, develop, test, and implement programs using visual programming**.
10. Describe, analyze, develop, and follow policies for managing ethical and legal issues in the business world and in a technology-based society.
11. Explore how related student organizations are integral parts of career and technology education courses through leadership development, school and community service projects, entrepreneurship development, and competitive events.

Standards 7 and 9 are in bold because they focus on computational thinking. They were combined in a curriculum unit designed to *self*-empower high school students that uses culturally relevant and critical perspectives. This unit was 8 weeks of the yearlong course and was taught from the beginning of February 2019 to the end of March 2019.

Student participants received the modified PACT pre-content knowledge assessment at the end of January 2019 and the PACT post content knowledge assessment at the end of Unit 3 instruction at the end of March 2019. The pre and post content knowledge assessment were administered by paper and pencil. There was one treatment school with two CAPACiTY version

IDT classes that use the EarSketch platform. There was a total of 51 treatment student participants out of which 37 had complete data.

The pre and post CT content knowledge was scored by me instead of by the classroom teachers to eliminate the chance of teacher bias in scoring the content knowledge assessments. The results of the CT pre and post content knowledge assessment and survey items were exported into the Statistical Package for Social Sciences (SPSS) for data analysis. The data included:

- Demographic data
- Pre and post CT content knowledge assessment data
- Pre and post engagement survey data for the Interest construct
- Pre and post engagement survey data for the Identity and Belonging construct
- Pre and post engagement survey data for the Importance and Usefulness construct
- Pre and post engagement survey data for the Motivation to Succeed construct
- Pre and post engagement survey data for the Intention to Persist construct

Data Analyses

Descriptive and inferential statistics were used to analyze the data. Data from the pre and post CT content knowledge assessment and student engagement survey constructs were analyzed for all students using SPSS. A paired samples *t*-test was done for each engagement construct and for the CT content knowledge assessment to analyze the change from pre to post for the racially diverse sample of students and the African American subset of students. The *t* statistic and level of difference was calculated using SPSS. If $p < .05$ then the difference from pre to post was considered statistically significant.

An analysis of covariance (ANCOVA) was done to control for variation in the pre-assessment and pre-survey scores. ANCOVA provides a way of statistically controlling the linear effect of variables that are not part of the study, called the covariates. For this study the pre-assessment CT content knowledge score and pre-survey engagement construct ratings are covariates (Miles & Shevlin, 2001). The F statistic and level of difference was calculated by SPSS for the following comparison between African American and non-African American students for each student engagement construct and the CT content knowledge assessment. If $p < .05$ then the difference between the two groups was considered statistically significant.

CHAPTER 5

RESULTS

I'm so glad that I know more than I knew then
Gonna keep on tryin'
'Til I reach my highest ground

–"Higher Ground" by Stevie Wonder

The purpose of this quantitative study was to investigate the change in engagement and introductory computational thinking (CT) content knowledge of a diverse set of high school students instructed in purposeful computational music mixing designed toward engaging African American high school students. The investigation used one instructional platform: EarSketch, a music mixing web-based coding and CT instructional platform in contrast to game-based computational thinking platforms like Scratch and Bootstrap. For this study, EarSketch was used in blocks mode to reduce cognitive load, hence it was CT oriented. While CT knowledge through music mixing using EarSketch has been investigated in a second-year computer science high school course (previous ES studies), this was the first study to investigate CT knowledge through a mathematics education pedagogy inspired purposeful music mixing curriculum in a first-year computer science high school course. The student engagement constructs used in this study were student interest in computing, identity and belonging in computing, importance and usefulness of computing, motivation to succeed in computing, and intention to persist in computing. Paired-samples *t*-tests were conducted to evaluate the change in scores from pre-test to post-test among the racially diverse sample as well as among the African American sample subset. ANCOVAs were conducted to test the difference in post-test means between African American and non-African American students, adjusting for pre-test scores.

Descriptive Statistics

The data presented in this chapter measured the change in Interest in Computing, Identity and Belonging in Computing, Importance and Usefulness of Computing, Motivation to Succeed in Computing, and Intention to Persist in Computing through a pre and post survey and the change in student CT content knowledge through a pre and post assessment. These measurements were for a set of African American students within a diverse set of high school students that were instructed in purposeful music mixing using the EarSketch platform. This data was collected as part of an NSF study by Georgia Tech's Center for Education Integrating Science Mathematics and Computing (CEISMC) that was designed to "promote the development of rigorous CT skills by engaging students in authentic and culturally relevant problem-based, inquiry learning (PBIL) projects in STEM topics, such as resource sustainability" (Georgia Institute of Technology CEISMC, 2016). As Co-Principal Investigator of this study, I lead the curriculum development team. As a team we developed four units. The third unit of this curriculum, that is the focus of this study, was developed by me with a focus on engaging African American high school students as described earlier in the theoretical framework of this text. The school selected for this study was a diverse high school in a suburban school district. The demographics of the high school itself and the student participants in this study are shown in tables to follow. After the participant demographic information, tables showing the means and standard deviations of the pre and post engagement survey instrument scores and pre and post CT assessment scores are displayed.

Demographic Characteristics

The participants of this study were 37 high school students from a suburban high school in the state of Georgia. Demographic characteristics of the participants were collected in the student engagement surveys. The surveys included questions on affective, behavioral, and cognitive constructs for the overall study. Because of my focus on cultural relevance, CT in relationship to mathematics, and desire to use a validated survey instrument, I chose to focus on the importance of computing, identity and belonging, importance and usefulness, and motivation to succeed constructs of the student engagement survey as was previously stated in Chapter 4. I added intention to persist in computing because that was a major focus of the overall NSF study, given that the research team was developing curriculum for a first-year high school computing course with a goal of students continuing in the computing pathway to the next course. Characteristics in the survey included the students' grade level, gender, and race/ethnicity. The participant demographics are shown in Table 14 for grade level, Table 15 for gender, and Table 16 for race/ethnicity. The high majority, 76%, of the students as shown in Table 14, in this introductory computer science course were 9th graders (n = 27) and there were no seniors amongst the participants.

Table 14
Student Grade Level

Grade level	Participant *n*	Percentage
9th	28	76%
10th	5	13%
11th	4	11%

The gender demographics in Table 15 show that there were a little more than three times the number of males (n = 28) as females (n = 9). The school itself had 45% female students, as shown in the right-hand column of Table 15, in comparison to the 24% of the participants.

Table 15
Student Gender

Gender	Participant *n*	Participant Percentage	School Percentage
Female	9	24%	45%
Male	28	76%	55%

The racial/ethnic makeup of the participants was a diverse group of African American (*n* = 11), Asian American (*n* = 1), Latinx (*n* = 13), and White (*n* = 12) students as shown in Table 16. The participant racial demographics are close in percentage to the overall school demographics as shown by the two right hand columns of the table on participant and school percentages.

Table 16
Student Participant Race/Ethnicity

Grade level	Participant *n*	Participant Percentage	School Percentage
African American	11	29.7%	25.9%
Asian American	1	2.7%	0.1%
Latinx	13	35.2%	36.8%
Multiracial	0	0%	2.5%
Not specified	0	0%	3.4%
White	12	32.4%	31.3%

The Student Engagement Survey Constructs

The interest in computing items for this survey were adapted from Items on Participants' Interest in Computing (DiSalvo et al., 2013; adapted from Computer Attitude Questionnaire, Knezek & Christensen, 1996). The identity and belonging in computing, importance and usefulness of computing, motivation to succeed in computing, and intention to persist in computing student instrument for this study is based on the scales from Williams and colleagues (2002) and Knezek and Christensen (1996) as was discussed in the previous chapter. The interest in computing survey construct consisted of two 5-point Likert items with response options ranging from 1–5, with 1 representing Strongly Disagree and 5 representing Strongly Agree. Table 17 shows the pre and post mean and standard deviation for each interest in computing survey item and the overall construct mean with standard deviation for both the Racially Diverse (RD) total (*n* =37) and African American (AA) subset (*n* =11).

Table 17
Interest in Computing Survey Results

	Pre-test		Post-test	
	RD total	AA subset	RD total	AA subset
Item	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
I am interested in computer science.	2.97 (1.25)	2.63 (1.20)	2.97 (0.95)	2.90 (1.13)
I am interested in digital technology.	2.87 (1.08)	2.82 (1.17)	3.108 (1.08)	3.00 (1.09)
Interest in Computing Construct	2.92 (1.12)	2.77 (1.06)	3.04 (0.97)	2.96 (1.06)

Note. The last line of the table are the results from averaging the items within this construct.

A higher score indicates greater interest in computing. Cronbach's alpha was .89 for pre and .89 for post, showing a high level of internal consistency. All items and the overall construct increased from pre to post. African American students were slightly lower than the overall racially diverse group on all items for both pre and post resulting in a slightly lower average interest in computing construct post score (*M*= 2.95, *SD* = 1.06) in comparison to the overall group (*M* = 3.04, *SD* = 0.97).

Table 18 shows the pre and post mean and standard deviation for each identity and belonging in computing survey item and the overall construct mean for both groups. The values of the last two items of this construct were reversed for consistency with the other items.
The identity and belonging survey construct consisted of three 5-point Likert items with response options ranging from 1-5, with 1 representing Strongly Disagree and 5 representing Strongly Agree. Table 18 shows the pre and post mean and standard deviation for each identity and belonging in computing survey item and the overall construct mean for both groups.

Table 18
Identity and Belonging in Computing Survey Results

	Pre-test		Post-test	
	RD total	AA subset	RD total	AA subset
Item	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
I feel like I "belong" in computer science.	2.89 (1.02)	2.91 (0.83)	2.70 (1.08)	2.64 (0.81)
I consider myself as a scientist, technologist, engineer, or mathematician (STEM).	2.74 (1.24)	2.46 (1.21)	2.68 (1.16)	2.37 (0.81)
I take pride in my computing abilities.	2.89 (1.17)	2.72 (1.19)	3.05 (1.05)	3.09 (1.05)
Identity and Belonging Construct	2.84 (0.96)	2.70 (0.81)	2.81 (0.99)	2.70 (0.80)

Note. The last line of the table are the results from averaging the items within this construct.

A higher score indicates greater feeling of belonging in computing. Cronbach's alpha was .89 for the post instruction and .78 for the pre instruction, showing high and good levels of internal consistency respectively. The first two items and the overall construct, on belonging in computer science and considering oneself as a STEM person, decreased from pre to post for both groups while the third item, on taking pride on my computing abilities, increased for both groups. African American students were slightly lower than the overall racially diverse group on the first two items on belonging while slightly higher for the third item on taking pride in their computing abilities. The overall construct post of the African American student sample resulted in a slightly lower average identity and belonging construct post score (*M*= 2.70, *SD* = 0.80) in comparison to the overall group (*M* = 2.81, *SD* = 0.99).

Table 19 shows the pre and post mean and standard deviation for each importance and usefulness of computing survey item and the overall construct mean for both groups. The values of the last two items of this construct were reversed for consistency with the other items.

Table 19
Importance and Usefulness of Computing Survey Results

	Pre-test		Post-test	
	RD total	AA subset	RD total	AA subset
Item	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
I will be able to get a good job if I learn computing.	3.11 (1.17)	3.00 (1.34)	3.03 (1.04)	2.91 (1.14)
I will use computing in many ways throughout my life.	3.11 (1.22)	2.91 (1.38)	2.97 (1.04)	2.91 (1.04)
Computing is of no relevance to my life. (REVERSED)	3.51 (0.99)	3.18 (1.17)	3.54 (1.19)	3.45 (1.37)
Taking computing classes is a waste of time. (REVERSED)	3.46 (0.96)	3.18 (1.08)	3.54 (0.90)	3.27 (0.78)
Importance and Usefulness Construct	3.30 (0.87)	3.07 (1.14)	3.27 (0.76)	3.25 (0.79)

Note. The last line of the table are the results from averaging the items within this construct.

A higher score indicates greater feeling of the importance and usefulness of computing. Cronbach's alpha was .60 for the post instruction and .81 for the pre instruction, showing barely acceptable and good levels of internal consistency respectively. This potentially may have occurred because students misinterpreted the two reversal questions during the post instruction as shown because when both these questions are removed the Cronbach's alpha was .87 and .85 respectively for pre and post. All items slightly decreased for the racially diverse sample, while the first item slightly decreased, second item was the same and last two items increased for the African American subset. African American students were slightly on all pre and post items. This resulted in African Americans having a slightly lower average motivation to succeed in computing construct post score (*M*= 3.25, *SD* = 0.79) in comparison to the overall group (*M* = 3.30, *SD* = 0.87).

Table 20 shows the pre and post mean and standard deviation for the engagement construct, motivation to succeed in computing, and the overall construct mean for both groups. The values of the last item of this construct were reversed for consistency with the other items.

Table 20
Motivation to Succeed in Computing Survey Scores

	Pre-test		Post-test	
	RD total	AA subset	RD total	AA subset
Item	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
I like solving computing problems.	3.08 (0.92)	2.81 (0.87)	3.08 (1.11)	3.09 (0.83)
When a computing problem arises that I can't immediately solve, I stick with it until I have the solution.	2.89 (1.04)	2.54 (0.82)	3.29 (1.17)	3.27 (1.19)
When I am working on a computing problem that I can't immediately understand, I want to work harder to get it.	3.02 (1.09)	2.81 (0.98)	3.40 (1.06)	3.36 (1.02)
Figuring out computing problems does not interest me. (REVERSED)	3.24 (1.03)	3.27 (0.78)	3.27 (1.09)	3.36 (0.92)
Motivation to Succeed Construct	3.03 (0.83)	2.86 (0.71)	3.26 (0.76)	3.27 (0.79)

Note. The last line of the table are the results from averaging the items within this construct.

A higher score indicates greater motivation to succeed in computing. Cronbach's alpha was.76 for pre and .62 for post, showing a good level of internal consistency for pre and acceptable level of internal consistency for post. This potentially may have occurred because students misinterpreted the reversal question as shown in the SPSS statistics Item Table where Cronbach's alpha was highest if the item is deleted, .79 and .75 respectively for pre and post. All items and the overall construct increased from pre to post. African American students were slightly higher than the overall racially diverse group on items one and four of the four items at post, while being slightly lower on the first three items at pre. This resulted in African Americans having a slightly higher average motivation to succeed in computing construct post score (*M* = 3.27, *SD* = 0.79) in comparison to the overall group (*M* = 3.26, *SD* = 0.76).

Intention to Persist in Computing

The last engagement construct, intention to persist in computing, consisted of four 5-point Likert items with response options ranging from 1-5, with 1 representing Strongly Disagree and 5 representing Strongly Agree. Table 21 shows the pre and post mean and standard deviation for each intention to persist in computing survey item and the overall construct mean with standard deviation for both groups.

Table 21
Intention to Persist in Computing Survey Results

	Pre-test		Post-test	
	RD total	AA subset	RD total	AA subset
Item	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
I intend to get a college degree in computing.	2.40 (0.98)	2.09 (1.04)	2.46 (0.98)	2.36 (1.02)
Someday, I would like to have a career in computing.	2.43 (0.95)	2.09 (1.04)	2.51 (0.93)	2.36 (0.80)
I can see myself working in a computing field.	2.46 (0.98)	2.00 (1.00)	2.67 (1.10)	2.81 (0.98)
I intend to take courses related to computing in the future.	2.62 (1.16)	2.54 (1.50)	2.75 (1.18)	2.81 (1.07)
Intention to Persist in Computing Construct	2.48 (0.88)	2.18 (0.95)	2.60 (0.95)	2.59 (0.86)

Note. The last line of the table are the results from averaging the items within this construct.

A higher score indicates greater interest in computing. Cronbach's alpha was .88 for pre and .92 for post, showing a high level of internal consistency. All items and the overall construct increased from pre to post. African American students were slightly lower than the overall racially diverse group on all items for both pre and post resulting in a slightly lower average intention to persist in computing construct post score (*M* = 2.59, *SD* = 0.86) in comparison to the overall group (*M* = 2.60, *SD* = 0.95).

The Computational Thinking (CT) Content Knowledge Assessment

The CT content knowledge assessment for this study was similar to questions from the Science Research International (SRI) Principled Assessment of Computational Thinking (PACT) (Chapman & Goode, 2013) as was discussed in the previous chapter. The study assessment consisted of 19 fill in the blank, 5 constructed response, and 2 multiple choice questions situated within a total of 5 items. The assessment and rubric in Appendix A were used to assess the fill in the blank and 5 constructed response items. The highest possible score was a 9. Table 22 shows the mean and standard deviation for both pre and post assessment for the overall racially diverse group and the African American student subset within the overall group. Cronbach's alpha was .61 for pre and .71 for post, showing a low and moderate level of internal consistency respectively. Both groups CT content knowledge improved from pre to post with African Americans pre (*M* = 0.67, *SD* = 0.91) to post (*M* = 2.82, *SD* = 1.56) scoring slightly lower than the overall group pre (*M* = 0.72, *SD* = 0.91) to post (*M* = 3.05, *SD* = 2.06) on the CT content knowledge assessment.

Table 22
Computational Thinking Content Knowledge Assessment Scores

Group	Pre-Mean	Pre-SD	Post-Mean	Post-SD
Racially diverse total (*n* =37)	0.72 (8.0%)	0.91	3.05 (34%)	2.06
African American subset (*n* =11)	0.67 (7.4%)	0.91	2.82 (31%)	1.56

Paired Samples *t*-Test Results

After descriptive statistics of the student engagement survey constructs and content knowledge assessment were determined, paired samples *t*-tests were conducted to respond to the first research question and its null hypothesis stated below.

- What is the change from pre-instruction to post-instruction in engagement of racially diverse high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform?
- H_0: There is no change from pre-instruction to post-instruction in engagement of racially diverse high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform.

There are four assumptions when conducting this analysis, (1) a continuous dependent variable, (2) the independent variable is categorical with two related groups, (3) there should be no significant outliers in the differences between the two related groups, and (4) the distribution of the differences in the dependent variable between the two related groups should be approximately normally distributed (Sweet & Grace-Martin, 2010).

For the survey results, assumptions 1 and 2 are satisfied for all constructs (1) the survey results are measured at the interval level and can be treated as a continuous scale and (2) the independent variable, time, is categorical with two related groups, pre and post. Assumptions 3 and 4, and results of the analysis will be shown on an individual basis for each construct and the CT content knowledge assessment.

Interest in Computing

There were no outliers in the interest in computing construct for the racially diverse participants. The assumption of normality was violated, as assessed by Shapiro-Wilk's test (p = .029). While this assumption was violated, it was not severely violated, hence conclusions will not be robust but are reasonable. Participants post instruction score (M = 3.04, SD = 0.97) was higher than the pre instruction score (M = 2.92, SD = 1.12), a non-statistically significant mean increase of 0.12, 95% CI [-0.22, 0.46], $t(36)$ = 0.73, p = .471, g = 0.12. The mean difference was not statistically significantly different from zero. Therefore, we fail to reject the null hypothesis that there is no change in student interest in computing of the racially diverse total of students.

There were no outliers in the interest in computing construct for the African American participants. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (p = .431). Participants post instruction score (M = 3.00, SD = 1.06) was higher than the pre instruction score (M = 2.73, SD = 1.06), a non-statistically significant mean increase of 0.18, 95% CI[-0.42, 0.79], $t(10)$ = 0.67, p = .519, g = 0.19. Therefore, we fail to reject the null hypothesis that there is no change in student interest in computing of the African American subset of students.

Identity and Belonging in Computing

There were no outliers in the identity and belonging in computing construct for the racially diverse participants. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (p = .087). Participants post instruction score (M = 2.81, SD = 0.89) was lower than the pre instruction score (M = 2.90, SD = 0.98), a non-statistically significant mean decrease of 0.03, 95% CI [-0.21, 0.16], $t(36)$ = -0.290, p = .773, g = -0.13. Therefore, we fail to reject the null hypothesis that there is no change in identity and belonging in computing of the racially diverse total of students.

There were no outliers in the identity and belonging in computing construct for the African American participants. The assumption of normality was violated, as assessed by Shapiro-Wilk's test (*p* = .026). While this assumption was violated, it was not severely violated, hence conclusions will not be robust but are reasonable. Participants post instruction score (*M* = 2.70, *SD* = 0.80) was the same as the pre instruction score (*M* = 2.70, *SD* = 0.81), a non-statistically significant mean change of 0.00, 95% CI [-0.17, 0.17], *t*(10) = -0.00, *p* = .997, *g* = -0.00. Therefore, we fail to reject the null hypothesis that there is no change in identity and belonging in computing of the African American subset of students.

Importance and Usefulness of Computing

There were no outliers in the importance and usefulness of computing construct for the racially diverse participants. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (*p* = .410). Participants post instruction score (*M* = 3.27, *SD* = 0.76) was slightly lower than the pre instruction score (*M* = 3.30, *SD* = 0.87), a non-statistically significant mean decrease of 0.03, 95% CI [-0.22, 0.17], *t*(36) = -0.28, *p* = .785, *g* = 0.05. Therefore, we fail to reject the null hypothesis that there is no change in importance and usefulness of computing of the racially diverse set of students.

There were no outliers in the importance and usefulness of computing construct for the African American participants. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (*p* = .308). Participants post instruction score (*M* = 3.25, *SD* = 0.79) was higher than the pre instruction score (*M* = 3.07, *SD* = 1.14), a non-statistically significant mean increase of 0.18, 95% CI [-0.24, 0.61], *t*(10) = 0.95, *p* = .363, *g* = -0.23. Therefore, we fail to reject the null hypothesis that there is no change in importance and usefulness of computing of the African American subset of students.

Motivation to Succeed in Computing

There were no outliers in the motivation to succeed in computing construct for the racially diverse participants. The assumption of normality was violated, as assessed by Shapiro-Wilk's test (p = .016). While this assumption was violated, it was not severely violated, hence conclusions will not be robust but are reasonable. Participants post instruction score (M = 3.26, SD = 0.76) was higher than the pre instruction score (M = 3.03, SD = 0.83), a statistically significant mean increase of 0.23, 95% CI [0.02, 0.39], $t(36)$ = 2.21, p = .034, g = 0.34. Therefore, we reject the null hypothesis and conclude that there was a statistically significant change in motivation to succeed in computing of the racially diverse total of students.

There were no outliers in the motivation to succeed in computing construct for the African American participants. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (p = .3). Participants post instruction score (M = 3.27, SD = 0.79) was higher than the pre instruction score (M = 2.86, SD = 0.71), a non-statistically significant mean increase of 0.41, 95% CI [-0.13, 0.76], $t(10)$ = 1.59, p = .142, g = 0.46. Therefore, we fail to reject the null hypothesis that there is no change in motivation to succeed in computing of the African American subset of students.

Intention to Persist in Computing

There were no outliers in the intention to persist in computing construct for the racially diverse participants. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (p = .299). Participants post instruction score (M = 2.60, SD = 0.95) was higher than the pre instruction score (M = 2.48, SD = 0.88), a non-statistically significant mean increase of

0.12, 95% CI [-0.17, 0.42], *t*(36) = 0.84, *p* = .408, *g* = 0.14. Therefore, we fail to reject the null hypothesis that there is no change in intention to persist in computing of the racially diverse total of students.

There were no outliers in the intention to persist in computing construct for the African American participants. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (*p* = .379). Participants post instruction score (*M* = 2.59, *SD* = 0.86) was higher than the pre instruction score (*M* = 2.18, *SD* = 0.96), a non-statistically significant mean increase of 0.41, 95% CI[-0.29, 1.11], *t*(10) = 1.30, *p* = .223, *g* = 0.38. Therefore, we fail to reject the null hypothesis that there is no change in intention to persist in computing of the African American subset of students.

CT Content Knowledge

A paired samples *t*-test was also conducted to respond to the third research question and its null hypothesis stated below.

- What is the change from pre-instruction to post-instruction in introductory computational thinking (CT) content knowledge of racially diverse high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform?
- H_0: There is no change from pre-instruction to post-instruction in introductory computational thinking (CT) content knowledge of racially diverse high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform.

There were no outliers in the interest in computing construct for the racially diverse participants. The assumption of normality was violated, as assessed by Shapiro-Wilk's test (*p* =

.004). While this assumption was violated based on Shapiro-Wilk's, it was not violated based on kurtosis and skewness values of .76 and .39 respectively (Sweet & Grace-Martin, 2010), hence conclusions will not be robust but are reasonable. Participants post instruction score (M = 3.05, SD = 2.06) was higher than the pre instruction score (M = 0.72, SD = 0.91), a statistically significant mean increase of 2.33, 95% CI [1.68, 2.97], $t(36) = 7.33$, $p < .001$, $g = 1.19$. Therefore, we reject the null hypothesis and conclude that there was a change in CT content knowledge of the racially diverse total of students.

There were no outliers in the interest in computing construct for the African American participants. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p = .675$). Participants post instruction score (M = 2.82, SD = 1.56) was higher than the pre instruction score (M = 0.67, SD = 0.91), a statistically significant mean increase of 2.15, 95% CI [0.95, 3.35], $t(10) = 3.99$, $p = .003$, $g = 1.16$. Therefore, we reject the null hypothesis and conclude that there was a change in CT content knowledge of the African American subset of students.

ANCOVA Results

ANCOVAs were conducted to respond to the second research question and its null hypothesis stated below.

- What is the difference in engagement post-instruction between African American and non-African American high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform, when adjusted for their engagement previous to instruction?
- H_0: There is no difference in engagement post-instruction between African American and non-African American high school students who are instructed in purposeful

computational music mixing designed toward African American students using the EarSketch platform, when adjusted for their engagement previous to instruction.

There are nine assumptions when conducting an ANCOVA analysis: (1) the dependent and covariate variables should be measured on a continuous scale, (2) the independent variable should consist of two or more categorical, independent groups, (3) there are independence of observations, (4) the data does not contain any outliers, (5) residuals should be approximately normally distributed for each category of the independent variable, (6) there must be homogeneity of variances, (7) the covariate should be linearly related to the dependent variable at each level of the independent variable, (8) there must be homoscedasticity, and (9) there must be homogeneity of regression slopes (Sweet & Grace-Martin, 2010).

For the survey results, assumptions 1, 2, and 3 are satisfied for all three constructs because (1) the survey results are measured at the interval level and can be treated as a continuous scale, (2) the pre and post data values are matched pairs that were defined as the African American/Black and non-African American/non-Black group, and (3) none of the participants are in both groups.

Interest in Computing Construct

There was a linear relationship between pre- and post-instruction interest in computing responses for each group. This relationship was assessed by visual inspection of a scatterplot as shown in Figure 10 below with R^2 values of .41 for African American and .24 for non-African American participants.

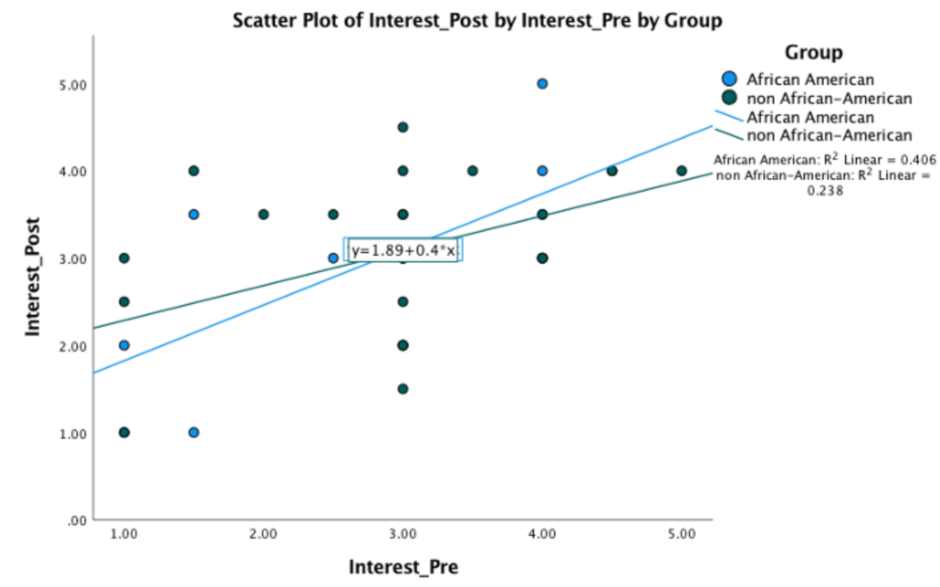

Figure 10. Scatterplot of pre and post Interest in Computing.

There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(1,32) = 0.66$, $p = .42$. Standardized residuals for both African American and non-African American participants were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$) as shown in the table in Figure 11 below.

Tests of Normality

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Standardized Residual for Interest_Post	African American	.164	11	.200*	.956	11	.726
	non African-American	.113	26	.200*	.975	26	.753

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 11. Shapiro Wilk Test of Normality of Interest in Computing residuals.

There was homoscedasticity and homogeneity of variances, as assessed by visual inspection of a scatterplot, shown below in Figure 12, and Levene's test of homogeneity of variance ($p = .717$), respectively.

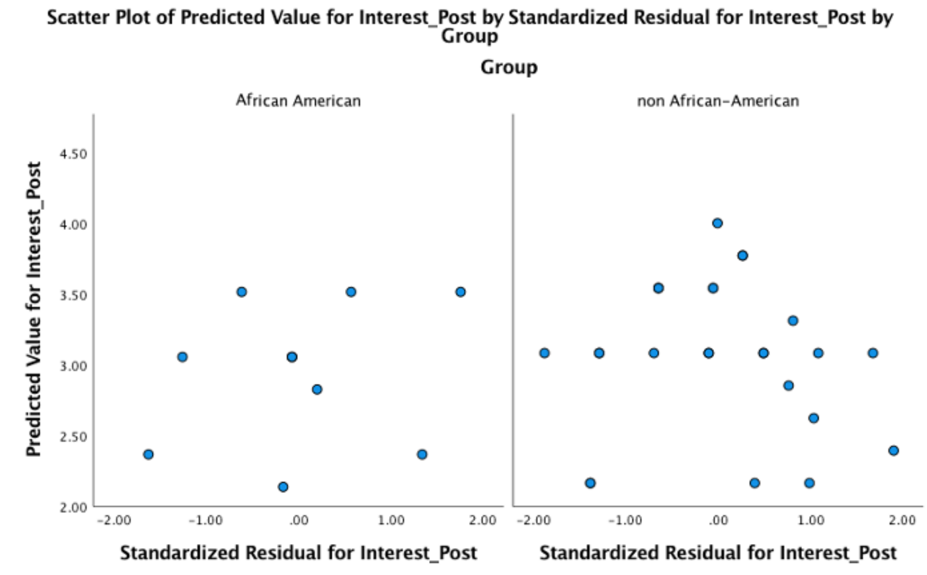

Figure 12. Scatterplot of Interest in Computing homoscedasticity.

There were no outliers in the data, as assessed by no cases with standardized residuals greater than ±3 standard deviations.

After adjustment for pre-interest in computing, there was not a statistically significant difference in post-interest in computing between African American and non-African American students, $F(1, 34) = 0.01$, $p = .931$, partial $\eta^2 < .01$ as shown in the table below in Figure 13. The effect size was very small based on the calculated value of Hedge's $g = 0.03$. Therefore, we fail to reject the null hypothesis that there is no difference in post-instruction interest in computing between the African American and non-African American students, after adjusting for the pre-instruction scores.

Tests of Between-Subjects Effects

Dependent Variable: Interest_Post

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	9.507[a]	2	4.753	6.683	.004	.282	13.367	.889
Intercept	13.110	1	13.110	18.433	.000	.352	18.433	.986
Interest_Pre	9.391	1	9.391	13.204	.001	.280	13.204	.942
Group	.005	1	.005	.008	.931	.000	.008	.051
Error	24.182	34	.711					
Total	375.750	37						
Corrected Total	33.689	36						

a. R Squared = .282 (Adjusted R Squared = .240)

b. Computed using alpha = .05

Figure 13. Interest in Computing ANCOVA results.

Identity and Belonging Construct

There was a linear relationship between pre and post identity and belonging in computing survey responses for each group. This relationship was assessed by visual inspection of a scatterplot as shown in Figure 14 below with R^2 values of .90 for African American and .70 for non-African American participants.

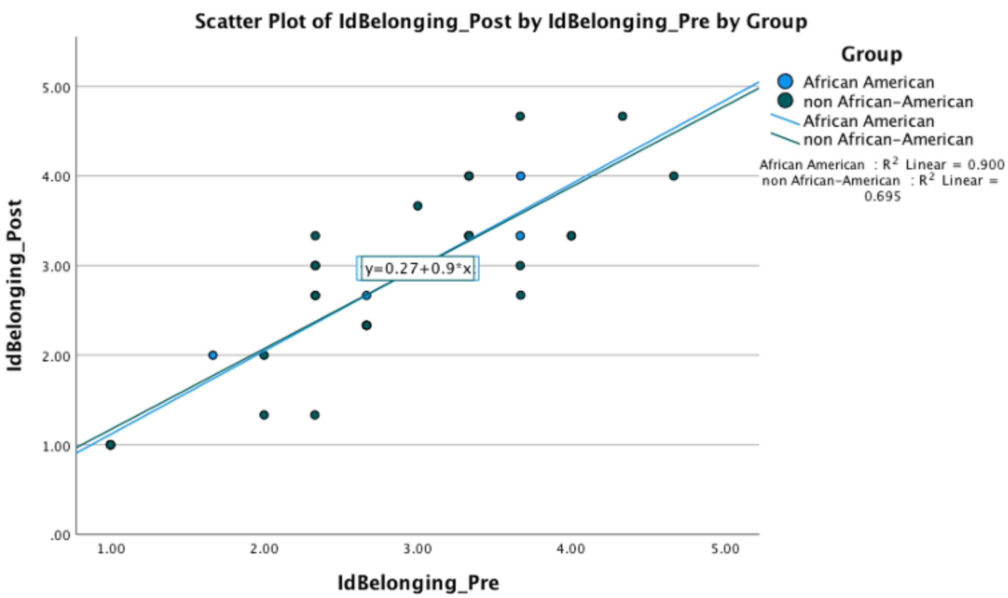

Figure 14. Scatterplot of Identity and Belonging.

There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(1,32) = 0.12$, $p = .74$. Standardized residuals for both African American and non-African American participants were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$) as shown in the table in Figure 15 below.

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Standardized Residual for IdBelonging_Post	African American	.146	11	.200*	.950	11	.640
	non African-American	.135	26	.200*	.967	26	.556

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 15. Shapiro Wilk Test of Normality of Identity and Belonging in Computing residuals.

There was homoscedasticity and homogeneity of variances, as assessed by visual inspection of a scatterplot, shown below in Figure 16, and Levene's test of homogeneity of variance ($p = .08$), respectively.

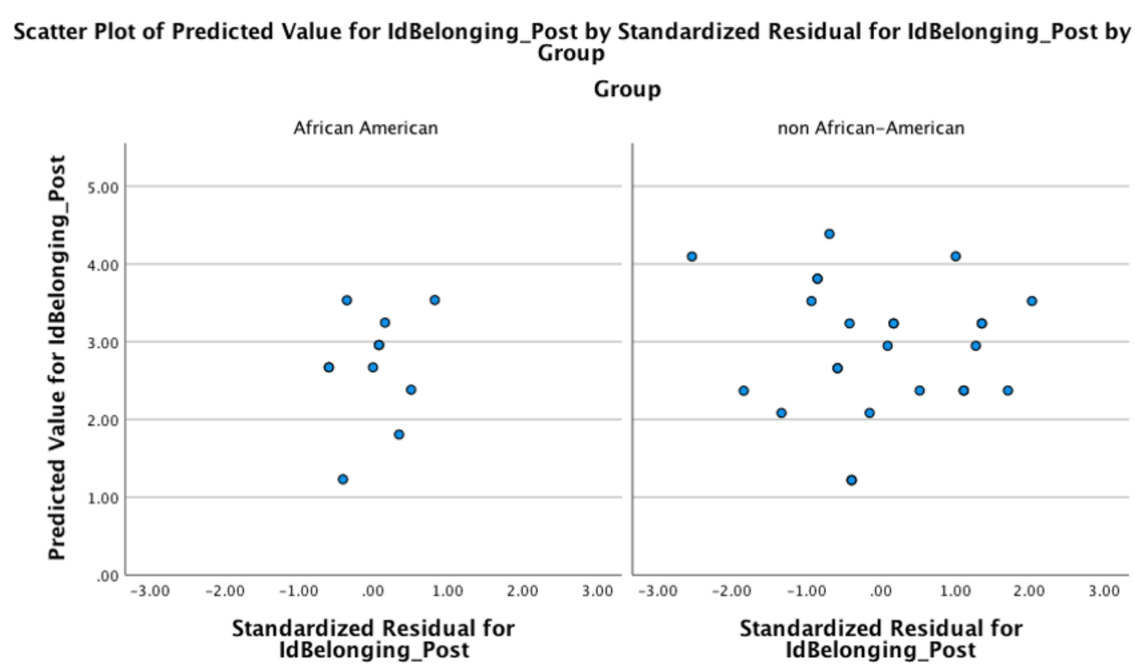

Figure 16. Scatterplot of Identity and Belonging in Computing homoscedasticity.

There were no outliers in the data, as assessed by no cases with standardized residuals greater than ±3 standard deviations.

After adjustment for pre-identity and belonging in computing, there was not a statistically significant difference in post-interest in computing between African American and non-African American students, $F(1, 34) = 0.00$, $p = .959$, partial $\eta^2 < .01$ as shown in the table below in Figure 17. The effect size was very small based on the calculated value of Hedge's $g = 0.01$. Therefore, we fail to reject the null hypothesis that there is no difference in post-instruction identity and belonging in computing between the African American and non-African American students, after adjusting for the pre-instruction scores.

Tests of Between-Subjects Effects

Dependent Variable: IdBelonging_Post

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	24.456[a]	2	12.228	38.588	.000	.694	77.176	1.000
Intercept	.478	1	.478	1.509	.228	.043	1.509	.223
IdBelonging_Pre	24.253	1	24.253	76.535	.000	.692	76.535	1.000
Group	.001	1	.001	.003	.959	.000	.003	.050
Error	10.774	34	.317					
Total	327.572	37						
Corrected Total	35.231	36						

a. R Squared = .694 (Adjusted R Squared = .676)

b. Computed using alpha = .05

Figure 17. Identity and Belonging ANCOVA results.

Importance and Usefulness Construct

There was a linear relationship between pre- and post-survey important and usefulness of computing responses for each group. This relationship was assessed by visual inspection of a scatterplot as shown in Figure 18 below with R^2 values of .71 for African American and .46 for non-African American participants.

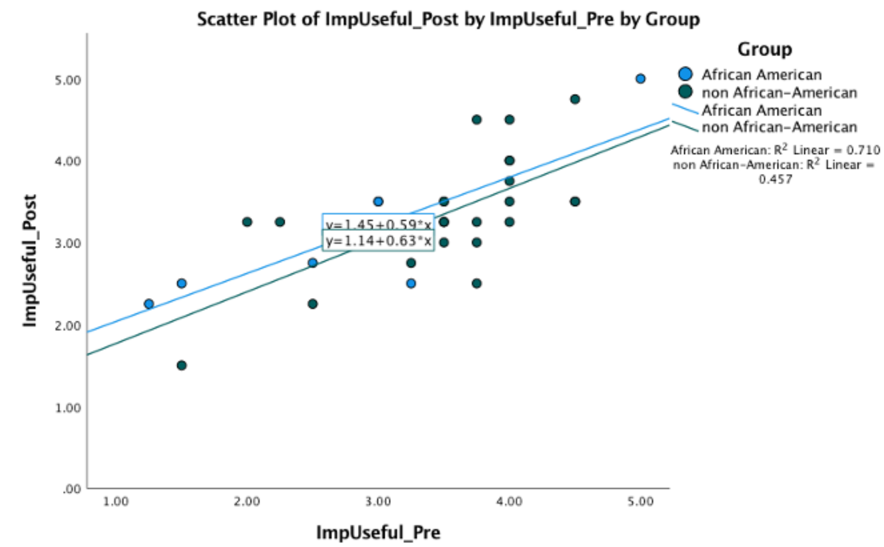

Figure 18. Scatterplot of Importance and Usefulness of Computing pre and post results.

There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(1,32) = 0.05$, $p = .821$. Standardized residuals for both African American and non-African American participants were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$) as shown in the table in Figure 19 below.

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Standardized Residual for ImpUseful_Post	African American	.236	11	.087	.896	11	.164
	non African-American	.147	26	.154	.948	26	.207

a. Lilliefors Significance Correction

Figure 19. Shapiro Wilk Test of Normality of Importance and Usefulness of Computing residuals.

There was homoscedasticity and homogeneity of variances, as assessed by visual inspection of a scatterplot, shown below in Figure 20, and Levene's test of homogeneity of variance ($p = .634$), respectively.

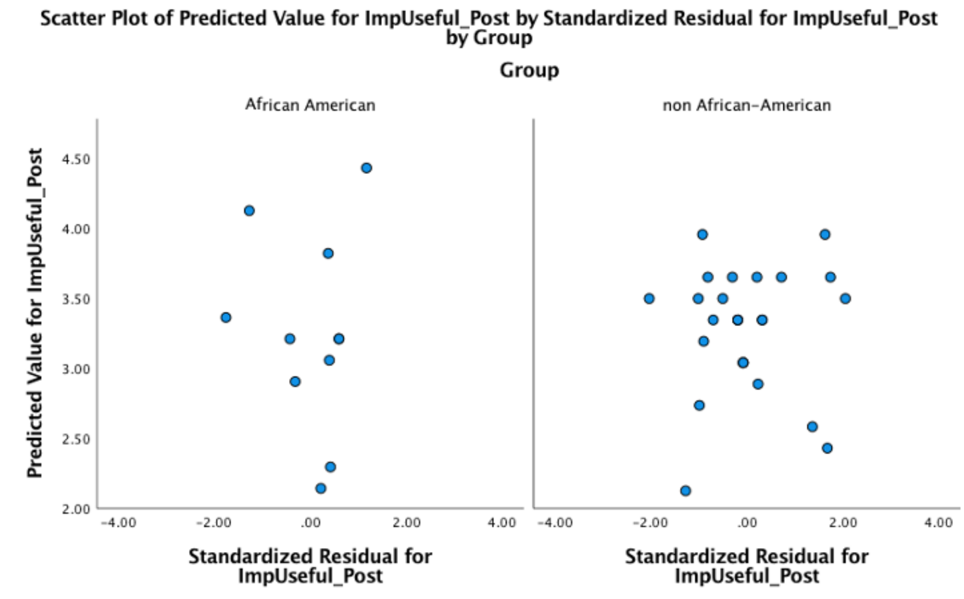

Figure 20. Scatterplot of Importance and Usefulness of Computing homoscedasticity. There were no outliers in the data, as assessed by no cases with standardized residuals greater than ±3 standard deviations.

After adjustment for pre-importance and usefulness of computing, there was not a statistically significant difference in post-importance and usefulness of computing between African American and non-African American students, $F(1, 34) = 0.90$, $p = .349$, partial $\eta^2 < .03$ as shown in the table below in Figure 21. Effect size was small based on the calculated value of Hedge's $g = 0.29$. Therefore, we fail to reject the null hypothesis that there is no difference in post-instruction importance and usefulness of computing between the African American and non-African American students, after adjusting for the pre-instruction scores.

Tests of Between-Subjects Effects

Dependent Variable: ImpUseful_Post

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	9.767[a]	2	4.884	20.360	.000	.545	40.720	1.000
Intercept	3.906	1	3.906	16.284	.000	.324	16.284	.975
ImpUseful_Pre	9.761	1	9.761	40.693	.000	.545	40.693	1.000
Group	.216	1	.216	.901	.349	.026	.901	.152
Error	8.155	34	.240					
Total	413.625	37						
Corrected Total	17.922	36						

a. R Squared = .545 (Adjusted R Squared = .518)

b. Computed using alpha = .05

Figure 21. Importance and Usefulness of Computing ANCOVA results.

Motivation to Succeed Construct

There was a linear relationship between pre and post motivation to succeed survey responses for each group. This relationship was assessed by visual inspection of a scatterplot as shown in Figure 22 below with R^2 values of .31 for African American and .66 for non-African American participants.

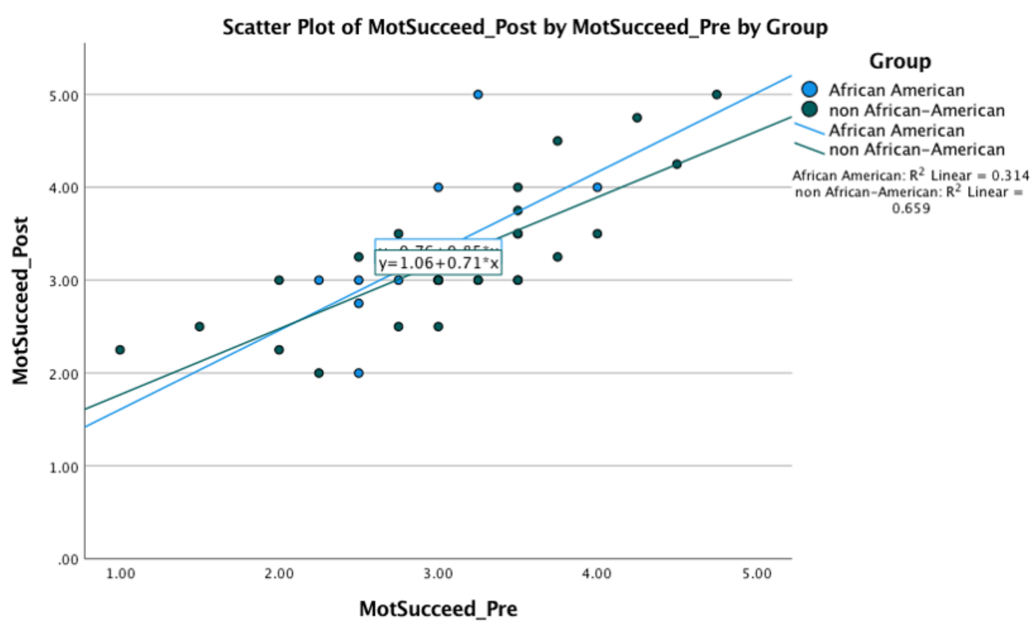

Figure 22. Scatterplot of Motivation to Succeed pre and post results.

There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(1,32) = 0.17$, $p = .680$. Standardized residuals for both African American and non-African American participants were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$) as shown in the table in Figure 23 below.

Tests of Normality

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Standardized Residual for MotSucceed_Post	African American	.193	11	.200*	.919	11	.307
	non African-American	.165	26	.068	.925	26	.058

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 23. Shapiro Wilk Test of Normality of Motivation to Succeed in Computing residuals.

There was homoscedasticity and homogeneity of variances, as assessed by visual inspection of a scatterplot, shown below in Figure 24, and Levene's test of homogeneity of variance ($p = .537$), respectively.

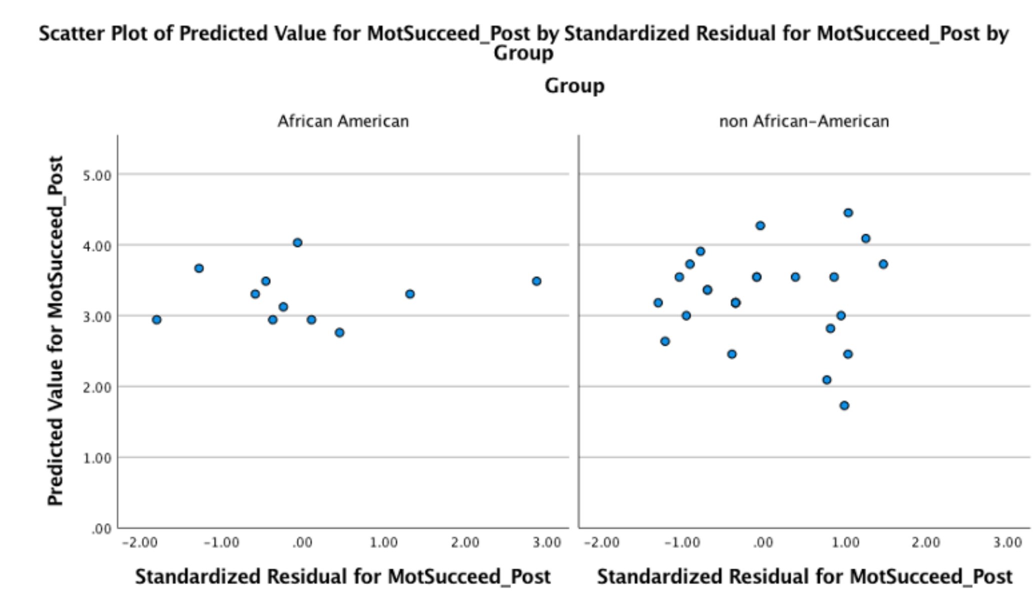

Figure 24. Scatterplot of Motivation to Succeed in Computing homoscedasticity.

There were no outliers in the data, as assessed by no cases with standardized residuals greater than ±3 standard deviations.

After adjustment for pre-motivation to succeed in computing, there was not a statistically significant difference in post-motivation to succeed in computing between African American and non-African American students, $F(1, 34) = 0.42$, $p = .52$, partial $\eta^2 = .01$ as shown in the table below in Figure 25. The effect size was small based on the calculated value of Hedge's $g = 0.15$. Therefore, we fail to reject the null hypothesis that there is no difference in post-instruction motivation to succeed in computing between the African American and non-African American students, after adjusting for the pre-instruction scores.

Tests of Between-Subjects Effects

Dependent Variable: MotSucceed_Post

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	11.616[a]	2	5.808	21.060	.000	.553	42.120	1.000
Intercept	2.519	1	2.519	9.134	.005	.212	9.134	.835
MotSucceed_Pre	11.615	1	11.615	42.115	.000	.553	42.115	1.000
Group	.116	1	.116	.421	.521	.012	.421	.097
Error	9.377	34	.276					
Total	415.063	37						
Corrected Total	20.993	36						

a. R Squared = .553 (Adjusted R Squared = .527)

b. Computed using alpha = .05

Figure 25. Motivation to Succeed in Computing ANCOVA results.

Intention to Persist

There was a linear relationship between pre- and post-survey intention to persist in computing responses for each group. This relationship was assessed by visual inspection of a scatterplot as shown in Figure 26 below with R^2 values of .12 for African American and .41 for non-African American participants.

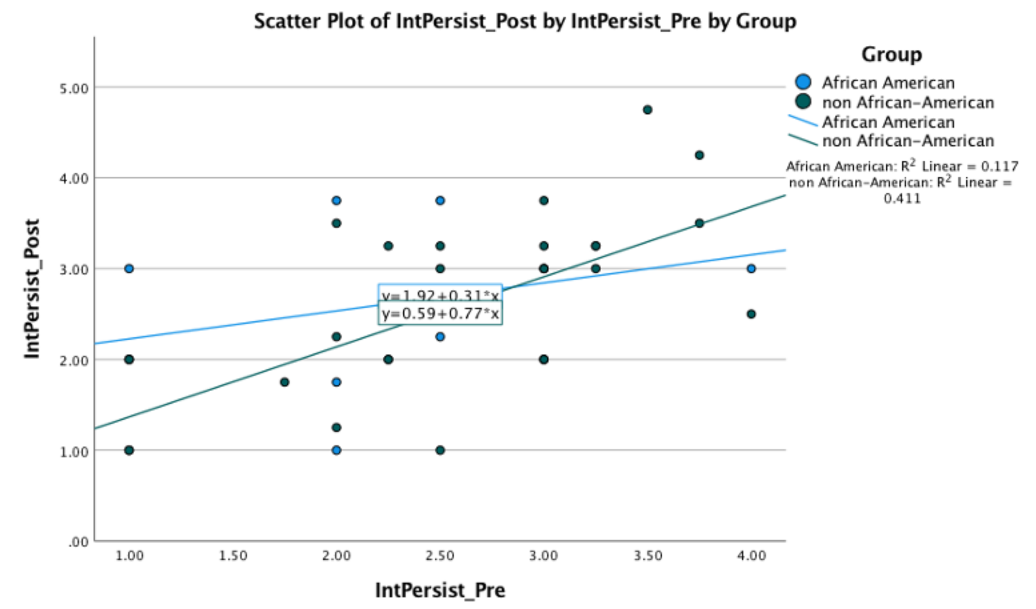

Figure 26. Scatterplot of pre and post Intention to Persist in Computing.

There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(1,32) = 1.98$, $p = .169$. Standardized residuals for both African American and non-African American participants were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$) as shown in the table in Figure 27 below.

Tests of Normality

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Standardized Residual for IntPersist_Post	African American	.166	11	.200*	.948	11	.622
	non African-American	.093	26	.200*	.979	26	.842

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 27. Shapiro Wilk Test of Normality of Intention to Persist in Computing residuals.

There was homoscedasticity and homogeneity of variances, as assessed by visual inspection of a scatterplot, shown below in Figure 28, and Levene's test of homogeneity of variance ($p = .920$), respectively.

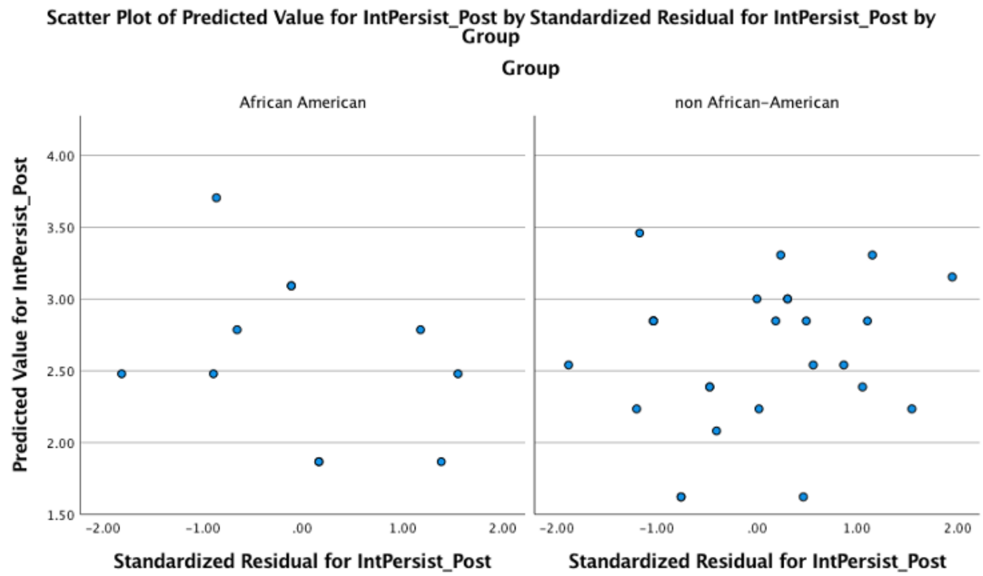

Figure 28. Scatterplot of Intention to Persist in Computing homoscedasticity.

There were no outliers in the data, as assessed by no cases with standardized residuals greater than ±3 standard deviations.

After adjustment for pre-intention to persist in computing, there was not a statistically significant difference in post-intention to persist in computing between African American and non-African American students, $F(1, 34) = 0.66$, $p = .423$, partial $\eta^2 = .02$ as shown in the table below in Figure 29. The effect size was small based on the calculated value of Hedge's $g = 0.24$. Therefore, we fail to reject the null hypothesis that there is no difference in post-instruction intention to persist in computing between the African American and non-African American students, after adjusting for the pre-instruction scores.

Tests of Between-Subjects Effects

Dependent Variable: IntPersist_Post

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	10.017[a]	2	5.009	7.472	.002	.305	14.944	.922
Intercept	5.173	1	5.173	7.718	.009	.185	7.718	.770
IntPersist_Pre	10.015	1	10.015	14.942	.000	.305	14.942	.964
Group	.441	1	.441	.658	.423	.019	.658	.124
Error	22.790	34	.670					
Total	283.188	37						
Corrected Total	32.807	36						

a. R Squared = .305 (Adjusted R Squared = .264)

b. Computed using alpha = .05

Figure 29. Intention to Persist in Computing ANCOVA results.

CT Content Knowledge

An ANCOVA was also conducted to respond to the fourth research question and its null hypothesis stated below.

- What is the difference in introductory CT knowledge post instruction between the African American and non-African American high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform, when adjusted for their CT knowledge previous to instruction?
- H_0: There is no difference in introductory CT knowledge post instruction between African American and non-African American high school students who are instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform, when adjusted for their CT knowledge previous to instruction.

For the CT content knowledge assessment ANCOVA analysis assumptions 1, 2, and 3 are satisfied for all three constructs because (1) the assessment results are measured on a continuous scale, (2) the pre and post data values are matched pairs that were defined as the

African American/Black and non-African American/non-Black group, and (3) none of the participants are in both groups.

There was a linear relationship between pre- and post-CKA for the non-African American group, but not for the African American group. This relationship was assessed by visual inspection of a scatterplot as shown in Figure 30 below with R^2 values of 5.511E-4 for African American and .21 for non-African American participants.

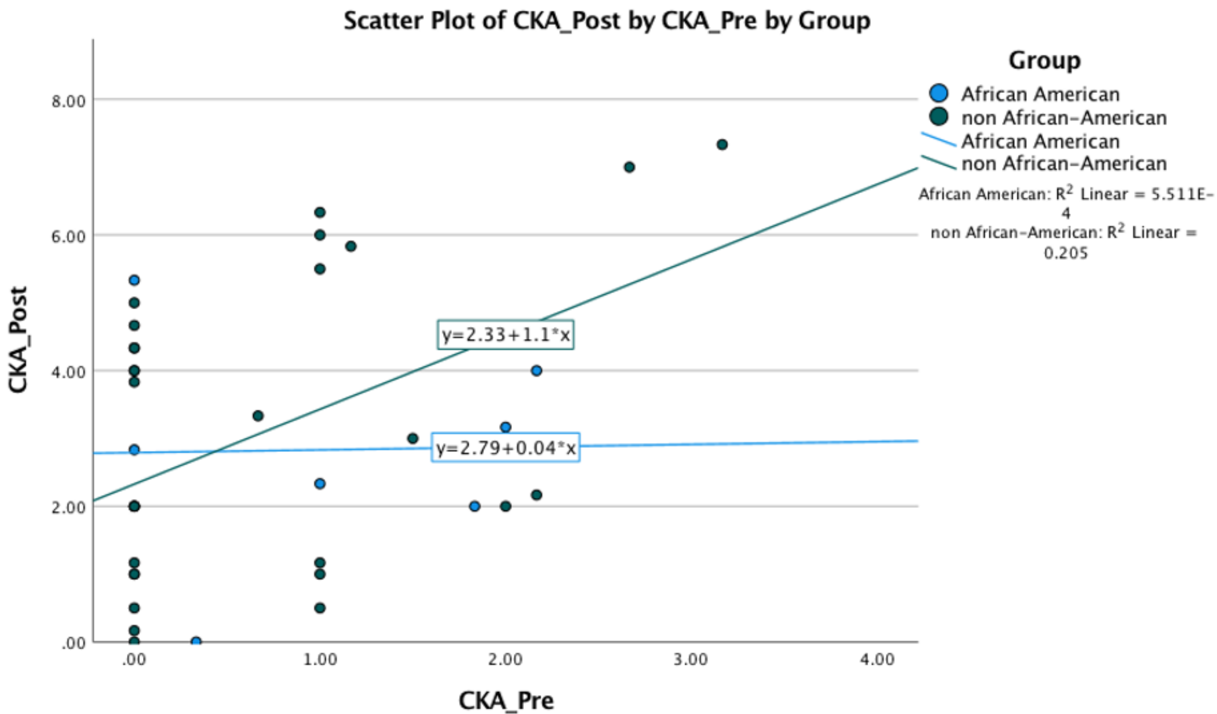

Figure 30. Scatterplot of pre and post CKA.

However, this assumption that the covariate "should" be linear with the dependent variable is a design assumption and not a model assumption. In this case, since the main categorical variable is observed (i.e., whether a participant is African American or non-African American) and not manipulated, then the assumption of covariate linearity is irrelevant, hence I continued with the ANCOVA analysis as instructed by Sweet and Grace-Martin (2010).

There was homogeneity of regression slopes as the interaction term was not statistically significant, $F(1,32) = 1.77$, $p = .192$. Standardized residuals for African American were normally distributed as assessed by Shapiro-Wilk's test ($p > .05$) but were not for non-African Americans as shown in the table in Figure 31 below.

Once again this "should be" assumption is a design assumption and not a model assumption, hence I continued the analysis.

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Standardized Residual for CKA_Post	African American	.144	11	.200*	.967	11	.856
	non African-American	.160	26	.087	.877	26	.005

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 31. Shapiro Wilk Test of Normality of CKA residuals.

There was homoscedasticity and homogeneity of variances, as assessed by visual inspection of a scatterplot, shown below in Figure 32, and Levene's test of homogeneity of variance ($p = .103$), respectively.

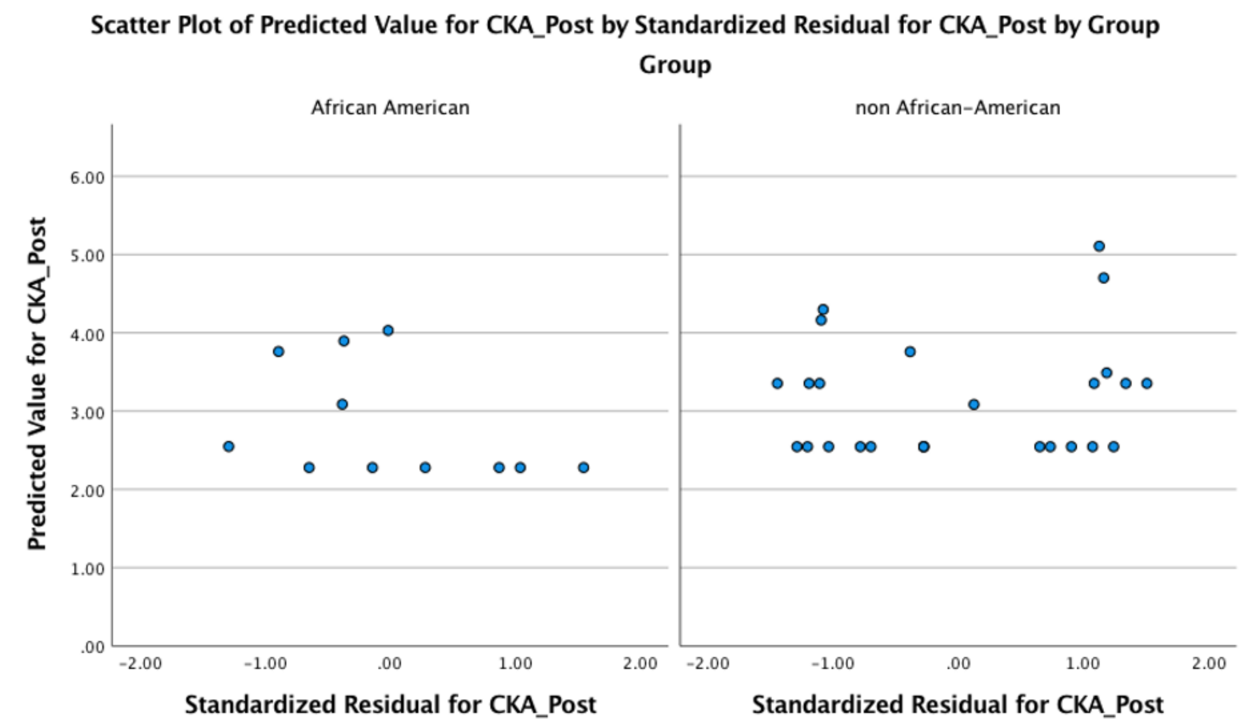

Figure 32. Scatterplot of CKA homoscedasticity.

There were no outliers in the data, as assessed by no cases with standardized residuals greater than ±3 standard deviations.

After adjustment for pre-content knowledge, there was not a statistically significant difference in post-content knowledge between African American and non-African American students, $F(1, 34) = 0.14$, $p = .710$, partial $\eta^2 < 0.01$ as shown in the table below in Figure 33. The effect size was small based on the calculated value of Hedge's $g = 0.12$. Therefore, we fail to reject the null hypothesis that there is no difference in CT content knowledge post instruction between the African American and non-African American students, after adjusting for pre-instruction scores.

Tests of Between-Subjects Effects

Dependent Variable: CKA_Post

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	20.325[a]	2	10.162	2.602	.089	.133	5.204	.483
Intercept	118.701	1	118.701	30.395	.000	.472	30.395	1.000
CKA_Pre	19.487	1	19.487	4.990	.032	.128	4.990	.583
Group	.550	1	.550	.141	.710	.004	.141	.065
Error	132.779	34	3.905					
Total	497.194	37						
Corrected Total	153.104	36						

a. R Squared = .133 (Adjusted R Squared = .082)

b. Computed using alpha = .05

Figure 33. CKA ANCOVA results

Summary

Data analyses were performed in this chapter to investigate the change in high school student engagement in five constructs (interest in computing, identity and belonging in computing, importance and usefulness of computing, motivation to succeed in computing, and intention to persist in computing) and computational thinking content knowledge for a racially diverse set of students (n = 37) and a subset of African American students (n = 11) within the racially diverse sample after being instructed in purposeful computational music mixing designed toward African American students using the EarSketch platform. Data for this study were collected as part of the NSF sponsored (award # 1639946) study Culturally Authentic Practices to Advance Computational Thinking in Youth (CAPACiTY).

Paired samples *t*-tests were conducted for each student engagement construct and the content knowledge assessment results. Figure 34 below shows the difference from pre to post for each construct for both the racially diverse set of students and the African American subset within this diverse sample. The only statistically significant student engagement construct change was the motivation to succeed in computing for the racially diverse set of students.

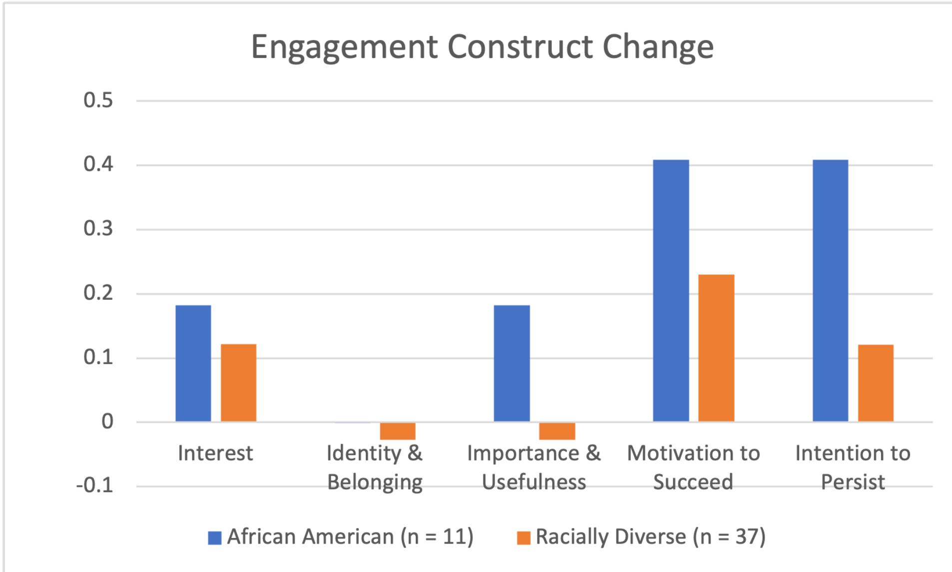

Figure 34. Student engagement construct changes from pre to post

Figure 35 below shows the pre and post of the CT content knowledge assessment (CKA) results for both the racially diverse set of students and the African American subset within this diverse sample.

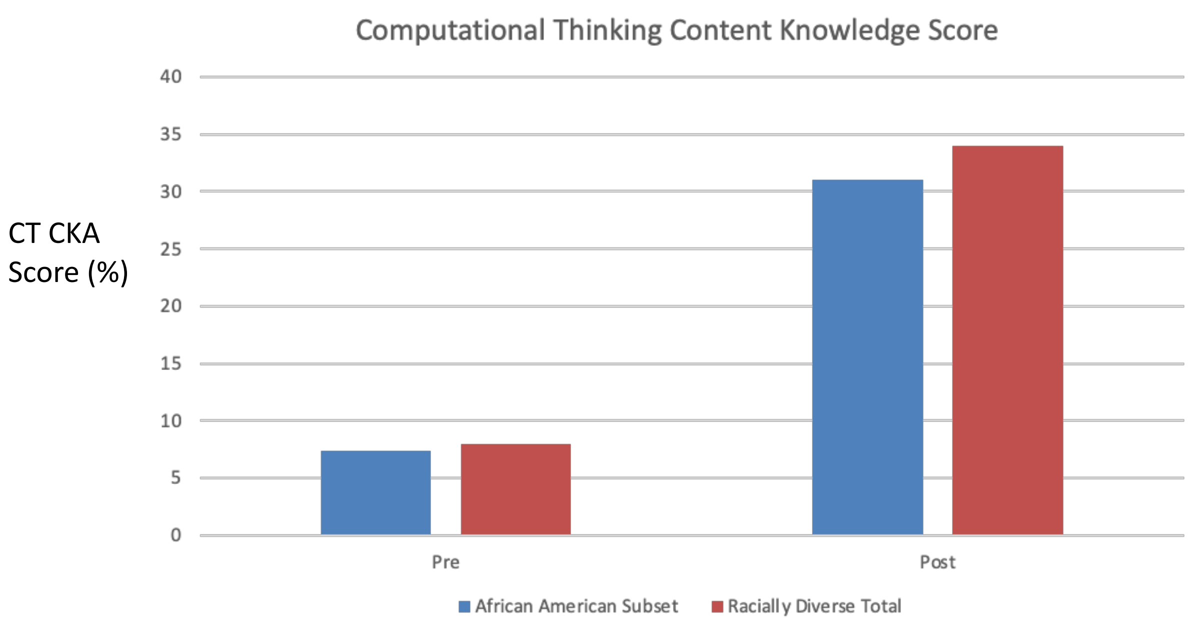

Figure 35. Computational thinking content knowledge changes from pre to post.

Both the racially diverse and African American student subset had a statistically significant change in computational thinking content knowledge from pre to post. The student engagement survey and computational thinking content knowledge assessment score changes are discussed further in the next chapter.

ANCOVAs were conducted for each student engagement construct and the content knowledge assessment results to identify whether there was a statistically significant difference in introductory CT knowledge post instruction between the African American students and non-African American students' post-engagement and post-content knowledge results when adjusted for their pre-engagement and pre-content knowledge respectively. There were no significant differences between the two groups of students for all five of the student engagement constructs results nor for the computational thinking content knowledge results when adjusted for their pre-engagement and pre-assessment scores. This statistically insignificant difference is discussed further in the next chapter.

In addition to adding further insights on these findings, Chapter 6 also discusses implications for instructing computational thinking based on the study and provides suggestions for further research.

CHAPTER 6

DISCUSSION

Ain’t gonna let nobody
Turn me ‘round
Turn me ‘round
Turn me ‘round

–“Ain't Gonna Let Nobody Turn Me 'Round” by The Freedom Singers

The research findings from this study are summarized and discussed in relationship to the findings presented in Chapter 5. The sections of this chapter include summary of the study, discussion of findings, implications, recommendations for further research, and closing thoughts.

Summary of the Study

The state of Georgia recently passed Senate Bill 108 that requires at least one computer science class be taught in all public high schools by fall 2024 (The General Assembly of Georgia, 2019). Similarly, 15 states already required at least one computer science class be taught in their public high schools (Herold, 2018). The proponents of these requirements advocate that Computational thinking (CT) is a core knowledge needed by all students—particularly, students from underrepresented groups—to prepare for the 21st century (Georgia Department of Education, 2015; Smith, 2016, 2017; The White House, 2017; Wing, 2006, 2014).

A review of the literature shows that CT was originally defined by mathematics education professor Seymour Papert (1996). Papert proposed that CT should have personal importance for the student now and give students a sense of empowerment and achievement. Additionally, the literature review shows no study that specifically addressed the quantitative change in CT content knowledge of African American high school students in their first-year course. Framed by an eclectic array of theoretical perspectives (Stinson, 2004) that includes culturally relevant pedagogy and critical play through a computational music remixing platform known as EarSketch, this study, that is embedded in a National Science Foundation (NSF) sponsored project titled Culturally Authentic Practice to Advance Computational Thinking in Youth (CAPACiTY), investigated current introductory CT curricula and their related programming platforms used in high schools, and developed and implemented a purposeful introductory CT curriculum designed to engage students to develop computational artifacts on a topic that they feel has real importance and *self*-empowers them to raise awareness on that topic through the computational artifacts. This study was designed to determine if a diverse set of students and specifically African American students instructed in the first programming unit of this curriculum that uses the EarSketch platform to code contemporary music remixing would significantly increase student engagement and CT content knowledge for both groups of students.

The study included 37 participants who were students in an introductory high school CT course in a suburban county in Georgia. The first year of the CAPACiTY study worked with a high school in this same school district that had over 100 racially diverse students of which almost half were African American. Unfortunately, the teachers at that school did not implement the curriculum as designed, particularly making each class chose only one problem topic that each group had to do rather than having small groups of four to six students choose a problem of interest. In addition, the teachers missed almost half of the during the year check in meetings that could have potentially averted this issue. For these reasons, the CAPACiTY study PI proposed, and team agreed, that the team change schools the following year which, while the curriculum was implemented as designed, led to fewer study participants.

The 37 student study participants were administered a pre and post CT content knowledge assessment that is a derivation of the NSF sponsored Principled Assessment of

Computational Thinking (PACT) and a pre and post student engagement survey that measured affective (Interest, Identity and Belonging, Importance and Usefulness), cognitive (Motivation to Succeed) and conative (Intention to Persist) constructs based on instruments used in previous NSF sponsored DRK-12 STEM studies (Chapman & Goode, 2013; McKlin 2018).

Summary of Findings

The findings that address the four research questions and hypotheses that were shown in detail in Chapter 5 and are summarized here.

Demographics

The students in this course were from two classes with the same teacher. Just over three quarters of the students in this course, 76%, were 9th graders. This percentage is expected considering that Introduction to Digital Technology is a first-year high school introductory course in computer science. The other 24% was almost split evenly between 10th and 11th graders.

The percentage of female students in the course, 24%, was a little less than one-third that of the males in the course at 76%, although the school percentages are much closer at 45% female and 55% male. The much lower percentage of female students in the study in comparison to the percentage of female students in the school is not surprising considering the current focus on increasing women in computer science because of the low female interest in majoring in computer science (Chang, 2018; Partovi, 2014).

The racial/ethnicity percentage of students in this study almost mirrors the percentage of students in the school. However, African American and Latinx students tend to take fewer computer science high school courses, major in computer science, and are not part of the computer science industry in numbers that are significantly lower than their percentage of the US population, hence these two cultural groups, indigenous peoples, and females have been labeled "underrepresented" (Kricorian et. al., 2020). The writers of the NSF proposal that this study is a subset of focused on this similar fact, stating,

> Clearly, the existing IDT course does not create enough interest in girls, Latinos and African American students for them to persist in the CS pathway. The CAPACiTY project proposes to try to change that trend by creating a new, digital media-focused IDT curriculum, specifically designed to engage students traditionally under-represented in CS. (Georgia Institute of Technology CEISMC, 2016)

RQ1 and RQ3: Change in Student Engagement and Computational Thinking Content Knowledge

After descriptive statistics were determined for the student participants, *t*-tests were conducted to respond to research questions 1 and 3 on the change in student engagement and computational thinking content knowledge. With respect to student engagement, there were three affective constructs (interest in computing, identity and belonging in computing, and importance and usefulness of computing), one cognitive construct (motivation to succeed in computing), and one conative construct (intention to persist). The analysis did not find a statistically significant change in scores from pre- to post-instruction in two of the three affective constructs, interest and importance and usefulness, as well as in the identity and belonging construct for both the racially diverse sample of the study and the subset of African Americans within the sample.

In Chapter 2 we looked at an NSF sponsored curriculum that was started in 2004 and is now used widespread throughout 34 states and Puerto Rico, Exploring Computer Science (ECS). During one of their early case studies in the 2009-10 school year with 17 schools they found that 315 students, 70% Latino and 10% African American, significantly increased from true pre to post affectively for the item that computer science was enjoyable and appealing at the alpha level of .05. This data was reported as a single item and not a construct of items (Goode & Margolis, 2011).

Previous EarSketch research with high school students in Computer Science Principles, a second-year high school course, has shown a statistically significant increase at the alpha level of .001 for all three affective constructs for what they have labeled as "under-represented minorities"… "defined as students who selected Black, Hispanic, Native American, Multiracial" and "majority," which I am to assume is all other ethnic groups because the term is not defined in the report (McKlin, 2018). However, these pre post increases for all of the student engagement constructs are not a true pre and post but rather a retrospective pre and post that were all conducted at post. In this NSF sponsored DRK-12 study, all student engagement research was done in this retrospective fashion, which beneficially provides the same frame of reference and potentially limits the impact of outside events. Yet, retrospective studies are also limited in that they potentially introduce additional bias in the survey responses because respondents may want to improve and therefore bias their answers to show improvement (Pratt, McGuigan & Katzev, 2000). The larger NSF study that this study was within did not show significant improvement in any of the affective constructs from pre to post of the year-long course.

The data of this study indicated a statistically significant increase in the motivation to succeed in computing, a cognitive construct, for the racially diverse sample of students at the alpha level of .05. For this same construct there was no statistically significant change from pre- to post-instruction for the African American subset of the sample.

In the previously mentioned 2011 ECS study there was a significant increase in the cognitive item, perseverance for working through a computer science problem or assignment, at the alpha level of .05. As well, in the previous 2018 EarSketch NSF sponsored DRK-12 study motivation to succeed, a cognitive construct, also significantly increased at an alpha level of .001 for the two groups categorized by McKlin as under-represented minority and majority. Again, the DRK-12 study design was retrospective (McKlin, 2018). The larger NSF sponsored study that this study was embedded also had a significant increase in cognitive engagement for a racially diverse group of 93 students. This data, based on a true pre-post design, was not disaggregated by race, ethnicity, or any other categorization (Usselman, Alemdar, & Edwards, 2019).

The analysis for this study did not find a statistically significant change from pre- to post-instruction in intention to persist for both the racially diverse sample of students and the African American subset. In the 2011 ECS study there was not a significant increase in intention to persist. The authors stated that though there was an increase in intention to persist, “many students who enrolled in ECS initially expressed a high interest in computer science before taking this course, making it difficult to report a statistically significant increase across large numbers of students by the end of the course” (Goode & Margolis, 2011).

In previous EarSketch studies, that were retrospective, intention to persist at the alpha level of .001 consistently increased for the two groups that were categorized as under-represented minority and majority (McKlin, 2016, 2018). As stated previously, the EarSketch NSF sponsored DRK-12 student engagement results potentially have a bias because of their retrospective design. For the larger NSF sponsored study that this study was embedded, intention to persist from pre to post also increased significantly as did cognitive student engagement. This pre to post was a true pre-post design that had students surveyed at the beginning of the year-long course and at the end. These results were not disaggregated in the report based on race, ethnicity, or any other categorization (Usselman, Alemdar, & Edwards, 2019).

The practical significant difference of the student engagement constructs was small for all of the affective student engagement constructs based on Hedge’s g effect size values ranging from 0.00 to 0.12. The conative engagement construct was also small for racially diverse total with an effect size of 0.14 while the African American subset had a medium effect size of 0.38. The cognitive engagement construct had a medium practical significance of 0.36 and 0.46 for the racially diverse total and the African American subset respectively.

In the previous EarSketch DRK-12 study effect sizes were medium for the same affective, conative, and cognitive constructs for the sample of 190 racially underrepresented students. These results were not disaggregated for African American students. The larger NSF study that this study is within has not reported effect sizes for the constructs as of this date.

Measurement reliability analysis of this study was acceptable to high for all constructs except the post-survey results of importance and usefulness based on its Cronbach alpha value of .60. This construct also had two reversal items of the four items, hence the items may have been misread by some of the participants. Qualitative inquiry into all of these constructs is recommended later in this chapter to further investigate student engagement and student responses to the survey items.

With respect to RQ3 on computational thinking content knowledge, a significant increase occurred for both the racially diverse student group at the alpha level of .001 and the African American subset within the group at the alpha level of .01. In the 2011 ECS study students were not assessed on their content knowledge. Instead, they self-reported an "increased understanding" of computer programming at the alpha level of .01 from pre to post (Goode & Margolis, 2011).

In the previous EarSketch study, content knowledge was assessed using a 20-question multiple choice assessment developed by the study team in a true pre post design. There was a significant increase in content knowledge at the alpha level of .001 for the two groups that were categorized by McKlin as under-represented minority and majority (McKlin, 2016, 2018). For the larger NSF sponsored study that this study was embedded, the CT content knowledge data of the EarSketch unit for the 93 students have engagement scores has yet to be analyzed.

The practical significant difference of the CT content knowledge scores was large for both the racially diverse total and African American subset of students with effect sizes of 1.19 and 1.16 respectively. In the previous EarSketch DRK-12 study the effect size was medium for the racially underrepresented group of 190 students at a Cohen's d value of 0.36. This result was not disaggregated for African American students. Further investigation with more participants is recommended because of the small sample size of this study to obtain a more similar comparison.

RQ2 and RQ4: Differences between African American and non-African American Students

Research questions 2 and 4 inquired about the difference between African American and non-African American students in student engagement and CT content knowledge. ANCOVA analyses were implemented to investigate whether there was a difference between African American and non-African American students in engagement when adjusted for their pre-instruction engagement. Pre-instruction scores were used as the corresponding covariate for all engagement constructs. With respect to student engagement post instruction, none of three affective constructs (interest in computing, identity and belonging in computing, and importance and usefulness of computing), the cognitive construct (motivation to succeed in computing), nor the conative construct (intention to persist) were statistically significantly different between African American and non-African American students, adjusted for their prior engagement.

Practical significant differences were small for all student engagement constructs except for the importance and usefulness construct. This construct had a medium effect size of 0.29.

However, as previously stated there is a concern about the reliability analysis of this construct because two of the four items are reversal questions, and the students may have misread these questions.

ANCOVA analyses were also implemented to investigate whether there was a difference between African American and non-African American students in computational thinking content knowledge. Pre-assessments scores were used as covariate to adjust post assessment means. There was no statistically significant difference between the two groups in computational thinking content knowledge when adjusted for their pre-assessment scores. Also, practical significant difference was a small effect size of 0.12.

Strengths and Limitations

This proposed study was within an NSF sponsored award. This was a strength, given that the IRB is supported by the Georgia Institute of Technology and the public school district which partnered with Georgia Tech as part of the CAPACiTY study. Additional strengths include:

- The CT content knowledge instrument that was used as a basis in this study was validated for reliability through a separate NSF award (McGee et al., 2018).
- The CT content knowledge instrument for this study was vetted by a consultant who is part of the project team that validated the basis CT content knowledge instrument.
- The student engagement instrument that was used in this study is based on a validated instrument that was adapted for high school students which demonstrated reliability through a separate NSF award.

As with any research, there are limitations in this research study that relate to some of the strengths in the study:

- Because the study is within an NSF award, teachers could be more motivated because they are part of an NSF study and receiving a stipend to be part of this study.
- The participants are from one school in one school district and the sample size (*n* = 37) is too low to consider generalizability to other school systems.
- Student participants were not randomly selected. Students self-select into courses and are sometimes placed in a course without their consent by counselors because of scheduling logistics.

Implications

Georgia Senate Bill 108 that was signed into law May 2, 2019, states, "Beginning in the 2022-2023 school year…(B) Each local school system shall provide that all middle schools in its school system offer instruction in exploratory computer science;" and "Beginning in the 2024-2025 school year, each local school system shall provide that all high schools in its school system offer a course in computer science" (Georgia General Assembly, 2019). The NSF sponsored curriculum for this study supports this law for high schools because it offers a curriculum that aligns to the Georgia Standards for the first high school course for computer science, Introduction to Digital Technology (IDT). With the reservation that this study had full data with a low number of student participants (*n* = 37) and therefore very low power in all of the results. However, because the student engagement construct results align to the larger NSF sponsored study that this study was embedded, I argue that the intention of this study to increase engagement and computational thinking content knowledge of high school students in computer science through culturally relevant and mathematics education pedagogies has succeeded in significantly increasing cognitive engagement and computational thinking content knowledge for a racially diverse group of students. The findings have demonstrated these increases by having students cooperatively pose problems and design and produce computationally generated music that in turn seeks to elicit an intended emotion about the problem that they have posed.

These problem-posing and cooperatively generated computational artifacts of a website, computationally generated music, and a mobile app game related to the problem posed have also shown a significant increase in cognitive engagement and intention to persist in computer science of the overall NSF sponsored CAPACiTY. In addition, the increases of the overall NSF sponsored CAPACiTY study were significantly higher than a comparison group of students that were taught in a more traditional manner of designing and producing a set of disintegrated computational artifacts with no intended purpose (Usselman, Alemdar, & Edwards, 2019).

Just as in the EarSketch unit that is the focus of this study, all the computational artifact units of the CAPACiTY curriculum include a school or community problem that may have a relationship to a national or international problem. This problem-posing focus has been shown to engage students in multiple disciplines (Kingston, 2018; Evans, 2019) and affords the critical aspect of cultural relevancy in the curriculum. Additionally, problem posing and designing computational artifacts to bring awareness and advocacy about the problem posed responds to Papert's (1996) power formulation questions:

> How can a child actually use it to do something that has real personal importance now?"
>
> What can your [project] do that will give them a sense of empowerment and achievement? (p. 97)

Other elements in this unit, designed to engage students and increase content knowledge, that are transferrable to the development of other curricula include cooperative learning; funds of knowledge; discourse on computational intent, design, and affect; and Concrete-Representational-Abstract (CRA) to develop computational conceptual understanding. All of these elements as stated in Chapter 3 were inspired by mathematics education research and multiple perspectives on power, including but not limited to Freire's *Pedagogy of the Oppressed* (1970/2000), Karenga's Kawaida Theory (2008), Foucault's *Discipline and Punish* (1979), and Ture's Black Power (1992). Because schools in Georgia will have to offer computer science, it is recommended that they use curricula that have these elements to engage and *self*-empower all students.

Recommendations for Further Research

Realizing these elements can be used to define a framework, the CAPACiTY team applied for and received NSF Research Experience for Teachers (RET) funding expansion of the grant to develop two middle school courses and a high school Advanced Placement (AP) Computer Science Principles (CSP) course using the framework. These courses were completed spring 2021 and online professional learning was done summer 2021 for the two middle school courses, Foundations of Programming and Foundations of Interactive Design, and the two high school courses, Introduction to Digital Technology and AP CSP.

Further study of the outcomes with a much larger sample of students of the framework needs to occur both quantitatively and qualitatively and be disaggregated in multiple categorizations (e.g., race, ethnicity, gender, socioeconomics, etc.). Students in this study selected problems with a range of topics including but not limited to anxiety and depression, sleep deprivation, school shootings, drugs, ocean pollution, families separated at the border, and police brutality. A qualitative evaluation of the topics and the computational products students produce can provide further insight on student engagement, learning, and empowerment.

In addition, this study viewed cultural relevancy through the lens of African American students. A new EarSketch study was proposed and awarded in the fall of 2020 to develop and implement informal curricula for after school and summer camps through a Latinx lens. This

NSF sponsored study, award #2005791, is titled Remezcla: Collaborative Research Broadening Participation of Latinx Students in Computer Science by Integrating Culturally Relevant Computational Music Practices and is being done in partnership with the University of Puerto Rico and will borrow from and add to the CAPACiTY framework. Additionally, Amazon now sponsors a yearly EarSketch competition that uses celebrity artists sounds for remixing to inspire large numbers of youth to connect to computer programming. This competition occurred after members of the CAPACiTY team presented at the Computer Science Teachers Association (CSTA) conference in 2018 and were approached by an Amazon representative afterward to discuss how we could partner. The celebrity artists that have provided sound samples so far include Ciara, Common, and Pharrell with Jay Z. This year's competition, requiring the use of sound samples from the song Entrepreneur, Pharrell's song featuring Jay Z, includes a social justice focused curriculum titled Your Voice Is Power (Amazon Future Engineer, 2019).

I was asked in the spring of 2021 to participate in an EarSketch proposal for the visually impaired and be co-PI on two NSF CSForAll proposals that were submitted in February 2021. One CSForAll proposal is to expand CAPACiTY by focusing on teacher preparation. Because of the coronavirus pandemic we provided an all-online teacher professional development in the summer of 2020 completed by 62 teachers and in 2021 completed by 24 teachers for the Introduction to Digital Technology first-year high school course. The CAPACiTY teacher preparation proposal hopes to expand this online PD to hundreds of teachers.

The CAPACiTY teacher preparation proposal was not funded by NSF. However, I recommend, that we modify and resubmit the CAPACiTY teacher preparation proposal to include an analysis and re-design of the teacher professional development so that the culturally authentic practices of the framework scaffold critical and postmodern mindset growth. As teachers encounter student self-determined problems with their associated research, evidence, and narrative it is important for them to work with students in critical and postmodern frameworks to as Freire said “read the world” so as not to oppress but rather to liberate.

The other CSForAll proposal to develop a curriculum for middle school music technology courses was funded by NSF and began September of 2021. This middle school music technology course can be cross listed with the Georgia Foundations of Programming course to prepare middle school music teachers to teach music and programming at the same time.

With all of the studies that I have just described, there is no current study proposed to use EarSketch, by itself, or in combination with other computer science platforms to look through the indigenous nor the feminist lens. Therefore, I recommend that two research proposals be done, one collaboratively with at least one indigenous nation college, also known as tribal colleges, and the other collaboratively with at least Spelman College’s STEM Center to design, develop, and evaluate a curriculum that uses EarSketch in combination with other computer science platforms to teach programming through each lens respectively.

While there are organizations that seek to increase the female tech pipeline such as Girls Who Code and Black Girls Code, it is known that the retention of female technology workers is a problem based on multiple reasons that include the “brogrammer” culture of technology companies and the lack of women in positions of power (Chang, 2018; Partovi, 2014; Schwab, 2021). An educational pipeline that prepares women for skills in technology without preparing them for organizational power does a disservice to those women they seek to entire the career field, hence the proposal to study computer programming instruction using EarSketch with a feminist lens.

These proposals could modify and add to the CAPACiTY framework for the existing middle and high school curricula and add a culminating curriculum in either or both the AP Computer Science A or Programming Games Apps and Society courses. Both of these courses are culminations in the Georgia computer science pathways and the AP CS A course is the national College Board pathway completion course for computer science.

Closing Thoughts

The purpose of this study was to investigate the change in engagement and introductory computational thinking (CT) content knowledge of a racially diverse set of high school students and a subset of African American students instructed in mathematics education pedagogy inspired purposeful computational music mixing designed toward engaging African American high school students. The investigation used one instructional platform: EarSketch, a music mixing web-based coding and CT instructional platform in contrast to game-based computational thinking platforms like Scratch and Bootstrap. The change in student engagement and CT were measured for both the racially diverse sample and the African American student subset, and the post engagement survey and CT assessment differences between the African American and non-African American students were analyzed and adjusted based on their pre-survey and pre-assessment scores. In general, the findings of the study support the literature reviewed though distinct differences exist of engagement construct significance potentially related to differences in study design, i.e., this study's engagement analyses were a true pre-post design while previous EarSketch studies were a retrospective design. While the power of this study was very low because of small sample size, the findings indicate a significant increase in cognitive engagement and computational thinking with no significant difference between African American and non-African American students. In addition to these same increases, the larger NSF sponsored study that had a good power level and this study was within, showed a positive change in and positive significant difference in cognitive engagement and intention to persist in computer science between the study participants and a comparison group.

One of the newest studies that we have been awarded by NSF (award #2005791) for $2.9M to develop informal learning spaces computer science curriculum designed toward Latinx students is both an inspiration and problematic. It is inspirational in supporting the Latinx lens and problematic as an example of how an organization with power will name a study designed toward Latinx students and have the originators of the study take out the only Spanish word in the study's name. We titled our joint Georgia Tech and University of Puerto Rico proposal, Collaborative Research: REMEZCLA, Community Narrative Remixed through Musical Coding. NSF changed our title on their website to Collaborative Research: Broadening Participation of Latinx Students in Computer Science by Integrating Culturally Relevant Computational Music Practices (NSF, n.d.). Remezcla is a Spanish word that translates into English as remix. Our proposal has as one foci, students remixing home, school and community sounds and narrative using computational thinking and computer programming with EarSketch, hence the importance of the one Spanish word in our title, remezcla. Therefore, on our Georgia Tech website and when we share it with others, we title our award as Remezcla: Collaborative Research Broadening Participation of Latinx Students in Computer Science by Integrating Culturally Relevant Computational Music Practices (Georgia Institute of Technology CEISMC, 2020). For as Fredrick Douglass stated**,** "This struggle may be a moral one; or it may be a physical one; or it may be both moral and physical; but it must be a struggle. Power concedes nothing without a demand. It never did and it never will" (BlackPast, 2007).

I have many hopes for this study and will share just a few. First, I hope that it has laid a foundation for further exploration into self-determined problem posing in computer science as an engagement strategy so that youth use computing to as Ladson-Billings states, “consider critical perspectives on policies and practices that may have direct impact on [students] lives and communities” (Ladson-Billings, 2014, p. 78). Also, I hope that it inspires other computer science educators to borrow not just from mathematics education pedagogy, but from other fields of study that have a long historical breadth and depth. In addition, I hope that it inspires the sponsored development of computer science curricula with multiple lenses for educators and students to select from, and as stated in chapter 1 for students to “realize their own visions” (Deloura and Paris, 2013). Last, I hope that these curricula go beyond problem posing and move into solving the problem posed in institutional and systemic ways that as Kwame Ture and Charles Hamilton stated, “[whose] ultimate values and goals are not domination or exploitation of other groups, but rather an effective share in the total power of the society” (Ture & Hamilton, 1967, p. 44). In the lyrics of a song by South African singer and activist who was also Ture’s spouse, Miriam Makeba, “A luta Continua [The Struggle Continues] !”

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APPENDICES

Appendix A

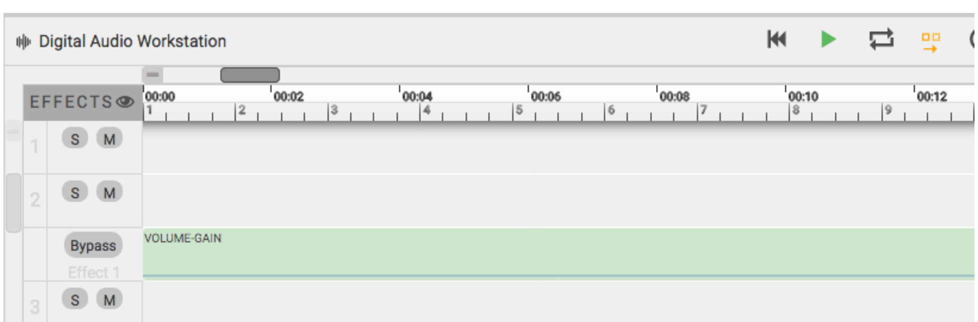
Computational Thinking Content Knowledge Assessment

Name: ____

1. Jamal creates the following musical introduction for a PowerPoint about a community issue using the EarSketch program:

```

init();
setTempo(120);

var horn = Y04_HORNS_2;
var drum = YG_NEW_FUNK_DRUMS_2;

fitMedia(drum, ▾1, 1, 5);
fitMedia(horn, ▾2, 3, 7);
setEffect(▾2, ▾VOLUME, ▾GAIN, -15);
fitMedia(drum, ▾1, 6, 8);

finish();
```

Please sketch what Jamal will see on the screen when he clicks the green Run button in the Digital Audio Workstation (DAW) storyboard below.



2. Below is EarSketch code to program background music for a video that you found related to your website topic:

```
from earsketch import *
init()
setTempo(170)

BeatString1 = "0++-0++-0++"
BeatString2 = "0---0---0---0"
beatsound = YG_TRAP_SYNTH_MELODY_1
piano = YG_TRAP_ELECTRIC_PIANO_FILTERED_1
guitar = HIPHOP_MUTED_GUITAR_002

user_change = readInput("When do you want to change the beat?")
user_change = int(user_change)

for loop1 in range(1, user_change):
    makeBeat(beatsound, 1, loop1, BeatString1)
fitMedia(piano, 2, 5, user_change)

for loop2 in range(user_change, 50):
    makeBeat(beatsound, 3, loop2, BeatString2)
fitMedia(guitar, 4, user_change, 45)
finish()
```

a) Assume you click the green Run button, and a dialog box appears, showing "When do you want to change the beat?"

You enter the number **20** and click on Okay. Therefore, the value of the variable user change is 20.

Please describe what the DAW would show for tracks and measures by filling in the missing values for each track below.

Track 1: ______________________ (instrument name); _____________________ (starting measure); _________________________ (ending measure)

Track 2: ____________________ (instrument name); ____________________ (starting measure); ________________________ (ending measure)

Track 3: ____________________ (instrument name); ____________________ (starting measure); ________________________ (ending measure)

Track 4: ____________________ (instrument name); ____________________ (starting measure); ________________________ (ending measure)

b) Assume you click the green Run button, and a dialog box appears, showing “When do you want to change the beat?”

You enter the number **55** and click on Okay. The following happens:

An error occurs and the script does not run.

What are **two possible reasons** that this error occurs?

Possible reason 1:

____

____

____

____

____

____

Possible reason 2:

____

____

____

____

____

____

3. Chantelle and Jasmine are programming a music score for a video trailer they are making for their history class. Their code is below.

```
from earsketch import *

init()
setTempo(120)
# sounds
cutepiano = RD_WORLD_PERCUSSION_KALIMBA_PIANO_1
cutebells = RD_WORLD_PERCUSSION_KALIMBA_PIANO_7
babybells = RD_WORLD_PERCUSSION_KALIMBA_PIANO_3
percDrum = RD_WORLD_PERCUSSION_DRUMPART_24
transitionDrum = RD_WORLD_PERCUSSION_DRUMPART_3
buildup = RD_WORLD_PERCUSSION_SEEDSRATTLE_1

#some beats
beatString1 = "0+0+0+0+0+000000"
beatString2 = "-00-00+++00--0-0"

makeBeat(percDrum, 1, 1, beatString1)
makeBeat(percDrum, 1, 2, beatString1)
makeBeat(percDrum, 1, 3, beatString1)
makeBeat(percDrum, 1, 4, beatString1)
fitMedia(cutebells, 4, 3, 5)

makeBeat(percDrum, 2, 5, beatString2)
makeBeat(percDrum, 2, 6, beatString2)
fitMedia(cutepiano, 5, 5, 7)
fitMedia(buildup, 7, 5, 7)
fitMedia(buildup, 7, 9, 11)

fitMedia(transitionDrum, 3, 11, 12)

makeBeat(percDrum, 1, 12, beatString1)
makeBeat(percDrum, 1, 13, beatString1)
makeBeat(percDrum, 1, 14, beatString1)
makeBeat(percDrum, 1, 15, beatString1)
makeBeat(percDrum, 1, 16, beatString1)
fitMedia(cutebells, 4, 12, 18)
fitMedia(babybells, 6, 12, 18)
fitMedia(cutepiano, 5, 12, 18)

finish()
```

a) Which lines from the code above would you replace with a for loop (please provide the line numbers of the code you would replace)? Why would you replace these lines with a for loop?

Please identify as many sets of lines to be replaced as you can (*we have given you more blanks for sets of lines than you will need*).

1st set of lines to be replaced: line number ________ to line number ________

Reason for replacing 1st set of lines with a for loop:

____

____

____

2nd set of lines to be replaced: line number ________ to line number ________

Reason for replacing 2nd set of lines with a for loop:

____

____

____

3rd set of lines to be replaced: line number ________ to line number ________

Reason for replacing 3rd set of lines with a for loop:

____

____

____

4th set of lines to be replaced: line number ________ to line number ________

Reason for replacing 4th set of lines with a for loop:

____

____

____

5th set of lines to be replaced: line number ________ to line number ________

Reason for replacing 5th set of lines with a for loop:

____

____

____

b) For each set of lines you defined above, what are the starting and ending values of the for loop range function? Please use the for loop fill in the blanks below to provide your answers for each for loop you will need to replace the lines in part a.

Please note that we have provided more for loop fill in the blanks than you will need; use as many as you need to answer the question.

For loop 1 start value: __________ For loop 1 end value: __________

For loop 2 start value: __________ For loop 2 end value: __________

For loop 3 start value: __________ For loop 3 end value: __________

For loop 4 start value: __________ For loop 4 end value: __________

For loop 5 start value: __________ For loop 5 end value: __________

4. Please select the option that has the components of the Software Development Process in the correct order (moving from start to finish in the process). Not all components of the process are included in the answer choices.
   a. Identify Problem or Opportunity; Design; Deploy to Wide Audience; Code and Debug
   b. Code and Debug; Identify Problem or Opportunity; Design, Requirements
   c. Requirements; Maintain & Update Code; Deploy to Wide Audience; Modify
   d. Requirements; Design; Code and Debug; Deploy to Wide Audience

5. For the makeBeat block, the rhythm of the beat should be an input of the data type _________________________.
   a. Boolean
   b. Number
   c. String
   d. Constant

Appendix B

Unit 3 Assessment Rubric

<table>
<tr><td colspan="3">Task 1: Concept of a Variable

Total points: 1

Learning Objectives
• Explain how a particular program functions</td></tr>
<tr><td>1</td><td>1 point</td><td>• ¼ point for indicating that drum or YG_NEW_FUNK_DRUMS_2 is on track 1
• ¼ point for indicating that horn or Y04_HORNS_2 is on track 2
• ¼ for indicating that track 1 plays from measure 1 to measure 5 and measure 6 to 8
• ¼ for indicating that track 2 plays from measure 3 to measure 7</td></tr>
<tr><td colspan="3">Task 2: Comprehending Code – EarSketch Music

Total points: 3

Learning Objectives
• Explain how a particular program functions.
• Justify the correctness of a program.</td></tr>
<tr><td>2a</td><td>2 points</td><td>• 1/6 point for each correct response of each track
o Track 1: synthmelody, 1, 20
o Track 2: piano, 5, 20
o Track 3: synthmelody, 20, 50
o Track 4: guitar, 20, 45</td></tr>
<tr><td>2b</td><td>1 point</td><td>• ½ point for each correct reason
o Loop cannot go from 55 to 50
o fitMedia measures cannot go from 45 to 50</td></tr>
<tr><td colspan="3">Task 3: Comprehending Code – EarSketch Music

Total points: 3

Learning Objectives
• Modify how a particular program functions to increase efficiency.
• Justify the modification of a program to increase efficiency.</td></tr>
<tr><td>3a</td><td>2 points</td><td>• 1/3 point for each correct identification of lines of repetitious code
o 1st set: 24, 27, repetitious makeBeat
o 2nd set: 30, 31, repetitious makeBeat</td></tr>
</table>

		○ 3rd set: 38, 42, repetitious makeBeat
3b	1 point	• 1/6 point for each correct identification of starting and ending loop values ○ 1st set: 24, 28 ○ 2nd set: 30, 32 ○ 3rd set: 38, 43

Appendix C

Georgia State University

INSTITUTIONAL REVIEW BOARD

Mail: P.O. Box 3999
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58 Edgewood
FWA: 00000129

May 12, 2021

Principal Investigator: David Stinson

Key Personnel: Edwards, Douglas; Stinson, David

Study Department: Middle & Secondary Education

Study Title: Computational Thinking and Its Mathematics Origins through Purposeful Music Mixing with African American High School Students

Submission Type: Application for Designation of Not Human Subjects Research

IRB Number: H21534

Reference Number: 364844

Thank you for your Application for Designation of Not Human Subjects Research. Based on the information provided, this submission has been determined to be not human subjects research. This correspondence should be maintained with your records.

Please do not hesitate to contact the Office of Research Integrity at 404-413-3500 if you have any questions or concerns.

Sincerely,

Jamie Zaikov, IRB Member