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Integrating Mathematics, Science, and Literacy into a Culturally Responsive STEM After-School Program

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Abstract
This manuscript shares the implementation of an after-school literacy in STEM (science, technology, engineering, and mathematics) program designed for middle grades students to increase their interest in science and mathematics learning. This program was conducted at our local Boys and Girls Club facilities where students learned about four science topics (renewable energy, water cycle, Newton's laws, and natural disasters). Students participated in culturally responsive reading and writing activities incorporating culturally relevant books, journal writing, hands-on projects, and a culminating science fair presentation on the topic of their choice. The authors determined that using literature, particularly culturally responsive picture books and graphic novels, to bridge the students' understanding of scientific and mathematical concepts was an important component of this program. The students' reactions to the program reflect the importance of offering a variety of avenues for students to represent their understanding, and they corroborate the significance of after-school programs to provide opportunities for diverse student populations to participate in culturally responsive programs to promote literacy and interest in STEM disciplines.

Introduction

There is much research reporting that people of color have been, and continue to be, underrepresented in STEM (science, technology, engineering, and mathematics) fields. How do we create opportunities that support middle grades students in becoming interested in a STEM field? Our answer—in an area of the rural southeast where over 40% of the population is non-White and 14% of the population lives in poverty (United States Census Bureau, 2019)—was to partner with the local Boys and Girls Club (BGC) to offer an engaging after-school experience for middle grades students integrating mathematics, science, and literacy skills through curriculum and pedagogy grounded in culturally responsive practices. This manuscript reports on the program design and implementation conducted at our local BGC; we present information gleaned from our program and share the perceived effect on students' interest in learning science and mathematics after participating in this program.

Why Culturally Responsive Practices?

The past two decades of educational reform efforts in the US brought the implementation of standards-based curriculum with the purpose of improving education. However, these measures have not prompted significant improvement among economically disadvantaged and underserved minority students, as demonstrated in recent national assessments (Hussar & Bailey, 2017).

The National Research Council (2012) frames science education as a cultural effort where collaborative work is highly valued and beneficial to students; collaboration strengthens the educational experience by supporting higher-level thinking skills and boosting confidence (Gates, 2018). In addition to the collaborative experience, the implementation of instructional strategies that connect with students' sociocultural and academic backgrounds and allow assessment via multiple, student-selected modalities effectively engage adolescent learners (Gay, 2018; Ladson-Billings, 2014). For this reason, we designed a literacy in STEM program grounded on culturally responsive pedagogy (Gay 2018; Ladson-Billings, 2014), where the students' cultures and experiential backgrounds are placed at the center of a curriculum that is inclusive of student choice and collaboration. This program incorporates culturally relevant literature that allowed students to make connections with their lives and with positive role models that sustain their cultural identities frequently "erased through schooling" (Paris & Alim, 2017, p.1), and purposeful, informal writing to help develop students' "skills in sharing their thoughts" (Fisher & Frey, 2016, p. 122).

Organizations such as the BGC provide youth from economically disadvantaged and underserved backgrounds with programs that are developmentally responsive, challenging, empowering, and equitable, which the Association for Middle Level Education (AMLE), formerly the National Middle School Association (NMSA, 2010) deems essential attributes. Such after-school programs have positively impacted vulnerable youths' attitudes towards school and academic achievement while also supporting students socially, emotionally, and intellectually (Hirsch, 2011). Additionally, our local BGC partners with area middle schools to provide a safe, supportive, and inclusive after-school environment; students attending BGS are provided rich learning opportunities, are engaged in challenging activities, and are supervised by staff that value young adolescents' contributions to the learning environment (NMSA, 2010). For these reasons, we felt the BGC was the perfect venue for our after-school program.

The After-School Program: The Context

Our BGC is situated within a city of over 30,000 residents in a county with a population of 80,000. The city is located in the southeastern part of the US and the surrounding communities are classified as rural; the closest urban area is an hour away. The BGC currently provides after-school programs to nearly 400 children, many of whom are in the middle grades. In September 2018, we met with the Executive Director and the Unit Director (UD) to talk about the institution's after-school program needs; they stressed the need for collaborators and volunteers to help fulfill the organization's academic goals. In particular, they were seeking support to address the STEM and literacy skills of their students – an area where they did not have any systematic efforts. Thus, our two organizations decided to partner to design and implement a middle-school-level "Literacy in STEM Program" to respond to their needs. All material expenses (less than $600) were covered by a Service Grant from our university.

The UD supported our creation of the program and recruited students to participate in the program, obtained required consent forms from parents and guardians, provided information regarding students' academic performance at school, and provided a classroom to conduct the program and store materials onsite. Additionally, the UD provided a staff member who served as an assistant throughout the duration of the program.

There were six students who completed the program—four male and two female African American children in grades 6-7 with a wide range of reading, writing, and verbal communication skills. At the beginning of the program there were 11 participants; however, due to the nature of the after-school setting at the BGC, students do not attend every day for the same amount of time. Throughout the program some students were either picked up by their parents prior to the program start time, during instruction, or did not attend after the first few sessions.

The curriculum design and implementation team are professors at the local university's College of Education. The team members have a combined total of over 30 years of experience teaching in diverse K-8 settings and are experts in their respective fields—mathematics, literacy, and science education—and were the sole instructors of the curriculum (at least two of us were present at each session); our instruction was assisted by an employee of the BGC.

We intentionally used culturally responsive instructional approaches and activities that integrated science and mathematical concepts with literacy skills development. The content was aligned with 6th-8th grade Georgia Science and Mathematics Standards, and middle grades Literacy in Science and Technical Subjects. The program was implemented for ten weeks, with two 90-minute sessions per week. Focusing on four specific topics (see Curriculum section below), students engaged in discussions; presentations; math problem solving; writing assignments; reading picture storybooks and graphic novels relevant to the student population and science concepts; and hands-on science, mathematics, and robotics lab activities. These activities served as a scaffold to the final product: a science fair project and presentation that reflected aspects of the academic content of the program.

Culturally Responsive Practices

This program was designed as an after-school program to meet the math, science, and literacy academic needs of students who have traditionally been underrepresented in STEM fields. Based on research, we knew it was important to utilize culturally responsive practices that incorporate "the cultural knowledge, prior experiences, frames of reference, and performance styles of ethnically diverse students" (Gay, 2018, p. 36) to make learning accessible and meaningful to their lived experiences. Such practices are student-centered, set high expectations for students, focus on making connections between home and school, and build on students' strengths (Ladson-Billings, 2014). The research-informed practices incorporated in this program included:

- learning about students through informal conversations and interest surveys,
- creating lessons that connected content from readings to local data (e.g., well depths, hurricanes),
- incorporating videos that used rap music as a means to engage students and provide information on concepts,
- reading books and graphic novels depicting role models that "looked like them" and were about similarly aged children,

- providing choice of product to demonstrate understanding (e.g., bricolages, written work, pictures/drawings),
- incorporating inclusive discussions where everyone had an opportunity, and was encouraged, to share their thoughts and opinions to include their voices in the learning process,
- providing student choice for the science fair project, and
- questioning throughout the program to elicit, activate, and/or apply prior knowledge and understandings.

Each of these practices allowed us to learn more about our students—what they liked to do outside of school, their involvement in creative activities, and the types of learning they found most engaging. Within the first week of the program, we also observed that students' ability levels varied—some struggled with reading and/or writing, math skills, and scientific understanding. Learning about our students' interests, skills, strengths, and academic needs allowed us to differentiate how we presented the content (e.g., visually, verbally, written), supported student understanding of the content (e.g., questioning, references to pictures in readings), and how students demonstrated their understanding (e.g., writing vs. drawing vs. singing).

Curriculum

We (university program faculty) collaboratively designed a curriculum of four topics—renewable and non-renewable energy, the water cycle, Newton's laws of motion, and natural disasters—that could be taught in a 10-week program (see Appendix A). The topics were chosen based on NGSS and state standards that could be explored in our limited time frame to further develop and support students' prior knowledge on the topics. Renewable and non-renewable energy is a topic that is addressed in 6th grade standards and has been an important topic in political debates, creating a meaningful connection to the topic. Water and the water cycle are investigated in the 4th, 5th, and 6th grades. Newton's Laws of Motion are studied in 4th grade and then reinforced in 8th grade, and Hurricanes are explored in grades 4 and 6. Literacy standards were integrated through reading, writing, representing, and speaking activities that aligned with, and supported, the science and/or math standards being addressed. All books read throughout the program were read aloud as a whole group, with students volunteering to read. The curriculum was designed to:

- infuse literacy and mathematics into mini science units, and
- provide an equitable opportunity for students to learn about, and *do*, science through purposeful, culturally responsive pedagogical practices.

We offered students access to a challenging, engaging curriculum (NMSA, 2010) by providing resources, materials, and instructional approaches designed to develop their critical thinking and awareness and express their understandings and opinions in different ways (Ladson-Billings, 2014). Although we conducted this as an after-school program, the activities shared below could be incorporated into school curricula to provide more students the opportunity to experience the engaging, hands-on literacy in STEM activities. For example, the water cycle model activity could be incorporated when students study the water cycle in 5th grade (NGSS standard 5-ESS2-1) or learn about Earth's systems in middle school (NGSS standard MS-ESS2-5).

Topic 1: Renewable and Non-Renewable Energy (2.5 weeks, five 90-minute sessions)

This topic supports NGSS standard MS-ESS3-4: Earth and Human Activity. We started by reading *The Boy who Harnessed the Wind*, a biographical picture book that illustrates the story of William, a 14-year-old African boy from Malawi who saved his village during a drought by building a windmill from recycled materials; he used available resources to bring water to the villagers. We introduced the reading by sharing the book and talking about Africa and the main character who helped his family. During the reading, we would stop and ask questions to determine student understanding of the content (e.g., What were some of the challenges facing Malawi?). Students related to William's experience; during discussions, students shared their family experiences of solving problems in situations with limited resources. As a way for students to represent their understanding of the story, we provided students with random materials and poster board to create a bricolage (a collage created from recycled materials). Students built on their understanding of the story by learning about electrical circuits by constructing several small circuits (utilizing all required safety equipment such as safety goggles and gloves) to understand how battery power and the number of lights per circuit influences the light output. Throughout this unit, students' understanding and application of content-specific vocabulary was supported through discussions and journal entries.

Topic 2: Water and the Water Cycle (2.5 weeks, five 90-minute sessions)

This topic supports NGSS standard MS-ESS2-4: Earth's Systems. We began this topic by asking students what they knew about water and the water cycle (e.g., What do you know about water? How much of Earth's water is drinkable? If you saw a clear substance, how would you be able to determine if it was water?). Students participated in a science lab to explore the properties of water, created a model to observe the water cycle, viewed videos, and created graphs based on data regarding well depths in the county over time. Also, we created a R.A.F.T activity, based upon the work of Santa et al. (2004), in which prompts were provided as a scaffold to assist students in the writing of a story (see Figure 1). *Flocabulary.com* was a source of videos to provide a visual format to help students understand vocabulary related to the water cycle; these videos incorporated rap music that students were familiar with and enjoyed. Based on the students' attraction to rap music, sharing videos that portrayed the information through a rap created learning that was engaging and responsive to students' needs and experiences (Paris & Alim, 2017). Students created a water cycle model using a small plastic bag and colored water (see Figure 2) and were able to observe the processes of the water cycle each time the class met; questions were posed to assess understanding (e.g., Why are there water droplets on the inside of the bag? Why is the water warm?). In addition to learning about the water cycle, a connection was made to the first topic as students studied wells. Students used LEGO Mindstorms EV3 robots to learn about scale factors (standards CCSSM.6.RP.A.1 and CCSSM.6.RP.A.1); the robots acted as a tool to draw rectangles and students manipulated the programming to create rectangles that were both 2.25 times larger and 0.75 times smaller than the original shape. Students later applied their understanding of scale factors to the wells they built using K'nex©.

Figure 1

R.A.F.T. Activity for Topic 2

R.A.F.T.

Role / Audience / Format / Topic

Writing a Creative Academic Narrative/Story

Role:

Pretend that you are a drop of water and you are traveling through the water cycle

Audience:

Your classmates and teachers

Format:

Creative academic narrative/story - First person (using "I").

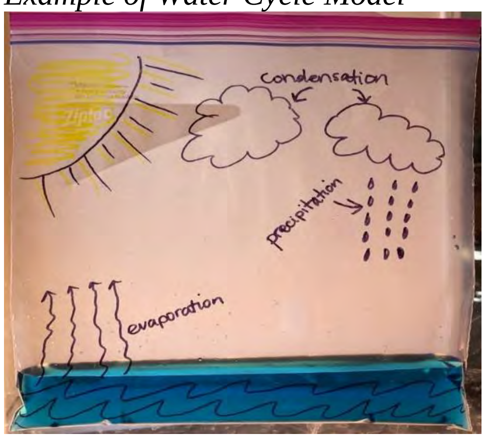
Topic:

My journey through the water cycle

Through your journey, you are expected to describe how you feel, the setting (where you are and what you see), and to use the vocabulary words learned in class.

Figure 2

Example of Water Cycle Model



Topic 3: Newton's Laws of Motion (2 weeks, four 90-minute sessions)

This topic supports NGSS standard MS-PS2-1: Motion and Stability. This topic was introduced through a graphic novel, *Isaac Newton and the Laws of Motion*. Before reading the book, we assessed prior knowledge by asking students if they knew who Isaac Newton was and what he was famous for. Additional activities with this topic included watching videos; writing/illustrating the three laws; participating in a science lab using matchbox cars; answering reflection questions; reading a second graphic novel titled, *A Crash Course in Forces and Motion with Max Axiom*; participating in a robotics lab; and writing a letter, poem, or rap using a R.A.F.T. activity as a scaffold (see Figure 3). The videos, matchbox cars, and robots provided students with multiple means to develop a deeper understanding of the laws of motion; they were able to *do* science and *see* the laws in action. For example, the LEGO activity allowed students to see how a ball moves differently depending on the force of the object *acting upon it*.

We chose the graphic novels to support our culturally responsive pedagogy as the main character of the graphic novels was Max Axiom, a Black scientist; too often books portray scientists as a White male, and Max Axiom allowed students to connect with a role model that looked like them (Ladson-Billings, 2014; Paris & Alim, 2017). The graphic novel format of the books provided a meaningful connection for the students. They would often make comments during the reading to connect the visual depictions to the content being read. We also incorporated videos from *YouTube.com* and *Flocabulary.com* to support students' development of the associated scientific vocabulary and to provide visual representations of Newton's Laws. The activity incorporating the LEGO robots allowed students to apply their understanding of Newton's Laws by predicting, and then evaluating, how speed and friction would affect the motion of objects of different masses. The students investigated, and collected data on, how the robot's movement at different speeds caused the ball to move at a different rate when *acted upon* by the robot (connection to standards CCSSM.6.RP.A.1 and CCSSM.6.SP.B.5.A). Additionally, they saw how this same movement was affected by the type of surface the ball was sitting on when it was *acted upon* by the robot – the tiled floor allowed the ball to move a longer distance than the carpet.

Figure 3

R.A.F.T. Activity for Topic 3

Writing to Isaac Newton using a R.A.F.T. Writing Assignment

Prompt: Write a letter, poem, or song to Sir Isaac Newton explaining how your evidence from the lab and/or real-life experiences demonstrates Newton's Three Laws of Motion. Be sure to include the essential academic vocabulary you learned during this lesson and lab.

Role	Yourself
Audience	Sir Isaac Newton
Format	Personal Letter, Poem, Rap, Jingle, or Song
Topic	How I proved you right about the Three Laws of Motion

Topic 4: Natural Disasters and Hurricanes (1 week, two 90-minute sessions)

This topic supports NGSS standard MS-ESS2-5: Weather and Climate. We read the graphic novel, *The Whirlwind World of Hurricanes with Max Axiom* and viewed videos to support the students' understanding. We specifically chose the topic of hurricanes as we live in a region where hurricanes have become common and students have been impacted by hurricanes, on some level, during each of the three previous hurricane seasons. Before beginning the reading, we initiated a brief discussion with the students to determine their experiences with the hurricanes that had affected our county over the past several years. To adhere to our culturally responsive pedagogical practices we chose to use a graphic novel that featured a Black scientist and utilized videos from *Flocabulary.com* to support the reading.

Each aforementioned topic incorporated purposefully designed activities to support the readings and provided additional opportunities for students to gain understanding about the concepts. Some of the activities highlighted areas of weakness for the students, such as when students were asked to create graphs (standard CCSSM.6.SP.B.4) during the well-depth activity. To ensure student success with the task, instruction and guidance were provided to support understanding of dependent and independent variables, creating scales, and creating titles. As we covered each topic, similar scaffolds were provided during activities, as needed, to support the development of new knowledge or strengthen existing understandings.

The four topics and the embedded activities served three purposes: activate and reinforce prior knowledge and/or introduce new concepts, practice how to conduct experiments following the scientific process, and act as a scaffold for their final project, the science fair. The students were asked to choose a topic they would like to know more about, apply the scientific process to investigate the topic, and report their findings. The science fair projects were completed in pairs and presented to over 100 of their K-5 peers attending the BGC, at the request of the UD. This provided an opportunity for younger, elementary-aged students to attend and ask questions with the hopes of inspiring and motivating them to participate in similar projects and "Science Fair" events at their local schools.

Data Collection

The data collected consisted of pre- and post-surveys, journal writings (reflections and creative written responses), student artifacts (e.g., graphs, bricolage project), researchers' field notes, final whole group interview, and a final "science fair" presentation. Data were qualitatively analyzed; each source was analyzed, classified, and coded recursively using a naturalistic, interpretive approach. Correlations across the data were highlighted and analyzed further to develop emergent themes. Observational notes, researcher journals, and discussions between the researchers about the data were used to triangulate and corroborate findings.

Reflecting on the Program

Our observations led us to believe this culturally responsive literacy in STEM after-school program was beneficial for all students, but especially for the students who faced difficulty in the areas of reading and writing. The hands-on activities created engagement for the students and the reading and writing activities supported the students' literacy development and provided students the opportunity to demonstrate their understanding.

Student Interest and Engagement

Students' interest in the topic of renewable energy was positively impacted by the story of William; students were particularly impressed because William never gave up and used items from the junk yard to develop the electrical resource for his village. We witnessed students' engagement when learning about the water cycle during the videos and lab activities. The students were excited to come into the session each day to view the changes in their water cycle model; they would immediately run to the window (where the models were hanging) to look for changes. During the topic on water, we shared that we lived in a closed system here on earth where our water is the same from when the dinosaurs were here; this model helped them to see a closed system at work. The investigation into Newton's Laws of Motion was also well received by the students, especially the activity requiring them to use matchbox cars to calculate the distance travelled when applying different amounts of force.

The culminating activity, the science fair presentation, was deemed the most enjoyable because the students stated they were doing it by themselves and were working on "what we wanted to do," as Ismael stated (all student names are pseudonyms). Arianna and Zenith designed a project to determine if a lightbulb could heat water (see Figure 4), Calvin and Ismael designed a project to determine if the wattage of a lightbulb affected the rate of evaporation of water (see Figure 5) and Malcolm and Anthony designed a project to determine how light output is affected by the type of electrical circuit – parallel or series (see Figures 6 and 7). Although Malcolm and Anthony designed the project together, they chose to create separate tri-fold

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boards. Each of these projects reflects interest in one of the topics taught during the program – the two topics which had the most instructional sessions. When students were asked if having a choice for their science fair topic influenced their attitude toward the project all students quickly responded, "YES!" Their interest was evidenced when they asked us, "Can we take them [tri-folds] home?"

Figure 4
Science Fair project by Arianna and Zenith

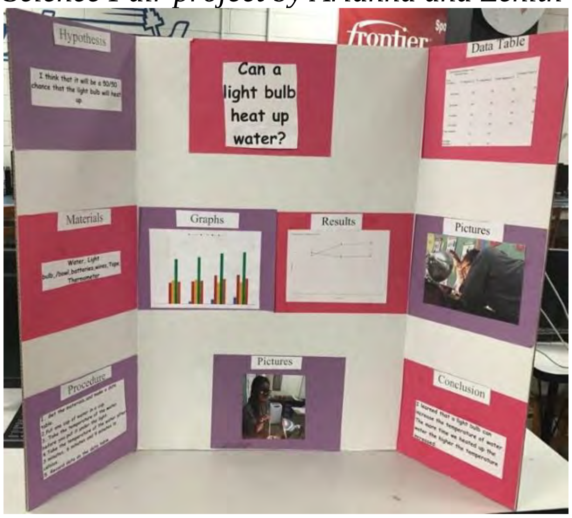

Figure 5
Science Fair project by Calvin and Ismael

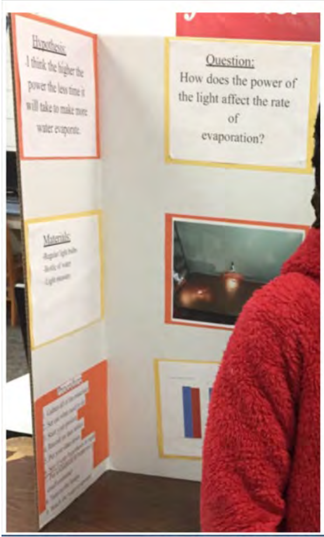

Figure 6
Science Fair Project by Malcolm

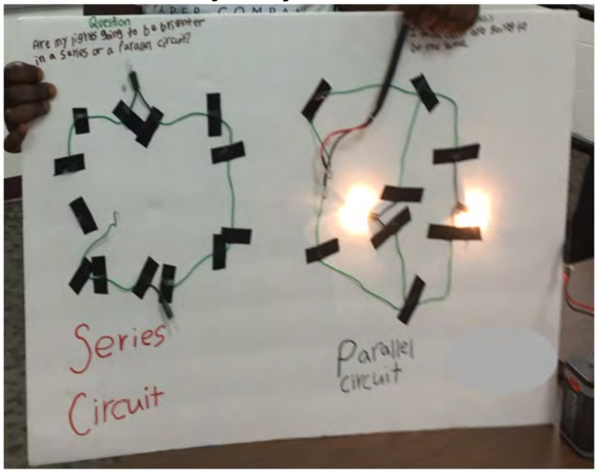

Figure 7
Science Fair Project by Anthony

Interest surveys were completed by students during the first day of the program and on the second-to-last day of the program (two days before the science fair; see Appendix B). The responses illuminate the effect this program had on students' attitudes and perceptions of their math, science, and literacy understanding, enjoyment, and ability. More specifically, at the end of the program the following was determined:

- increased number of students felt math was a subject they were good at
- fewer students reported to become upset when asked to complete math problems
- increased number of students felt they learn math concepts easily
- increased number of students reported to write poetry and creative stories in math
- increased number of students felt science was a subject they were good at
- increased number of students enjoyed science experiments that allowed them to work with *real things*
- fewer students "strongly disliked" writing in science and there was in increase in those who felt "neutral"

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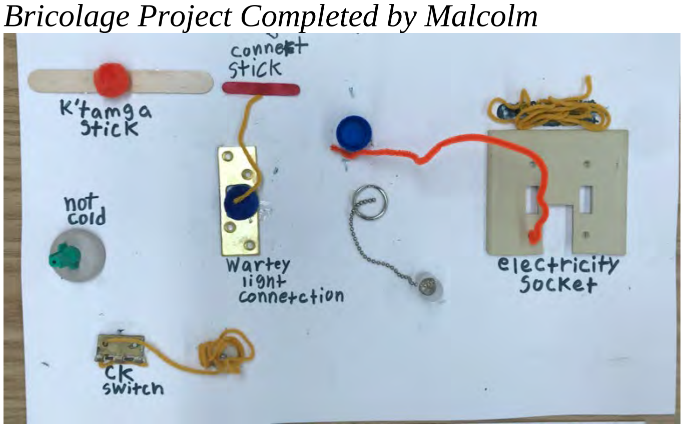
- there was a positive shift in students who felt they learn science concepts easily
- increased number of students reported to write poetry and creative stories in science

The interest surveys are possibly the most informative feedback as it is a reflection of the students' own feelings regarding the impact of this program. The students may not have fully transitioned to students who strongly enjoy math, science, and literacy activities, but there is evidence in their responses to show the beginning of a shift; further support must be provided to continue to encourage these students to participate in programs and/or activities of this nature.

Demonstration of Understanding

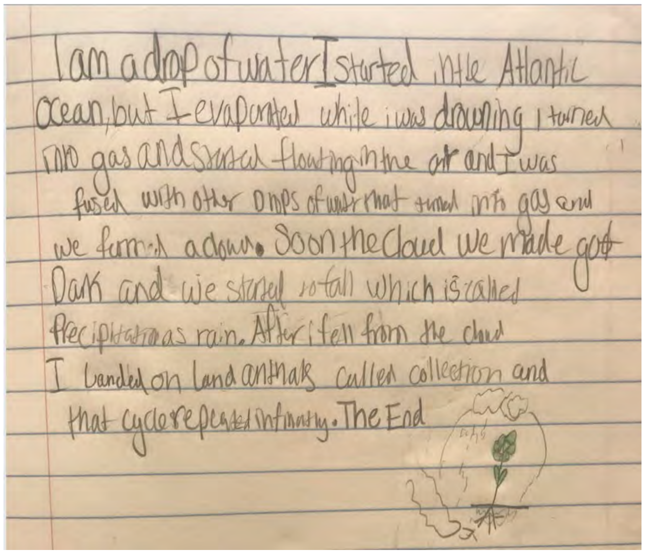
Malcolm was a student who faced the most difficulty with reading and writing; he required scaffolding to improve his comprehension in reading and to understand the mathematics and science topics presented. However, with support and by providing different modes to represent learning, he was able to demonstrate his understanding. In fact, Malcom provided the representation that most closely aligned with the ideas presented in *The Boy who Harnessed the Wind* and the lessons during the bricolage activity (see Figure 8). This activity also confirmed that allowing students to create responses using materials, drawings, and hands-on-activities is an effective way to represent their understanding.

Figure 8
Bricolage Project Completed by Malcolm



The water cycle model provided a physical, hands-on representation for students. Their understanding was demonstrated, for example, when students were able to accurately describe the visible processes of precipitation and condensation. The R.A.F.T. activity also illuminated students' understanding of the different stages in the water cycle (see Figure 9). After analyzing this writing activity, it was clear that students understood the vocabulary related to the water cycle and were able to use it appropriately. Throughout the program, students' writing improved both in quality and quantity – journal entries and R.A.F.T activities became more reflective of their learning and the length of the activities increased (e.g., rather than completing 1-2 sentences, students were writing a full paragraph of 5+ sentences); the students improved their "skills in sharing their thoughts" (Fisher & Frey, 2016, p. 122).

Figure 9
R.A.F.T. Activity About the Water Cycle Completed by Ismael



Students' understanding of Newton's Laws was demonstrated by their pictures representing the three laws (see Figures 10 and 11); these pictures provide evidence that the students' understanding was developed through the videos and learning activities as Calvin's picture (Figure 10) represents learning via the videos and Malcolm's picture (Figure 11) reflects learning via the robotics and matchbox car activities.

Figure 10
Representation of Newton's Laws of Motion by Calvin

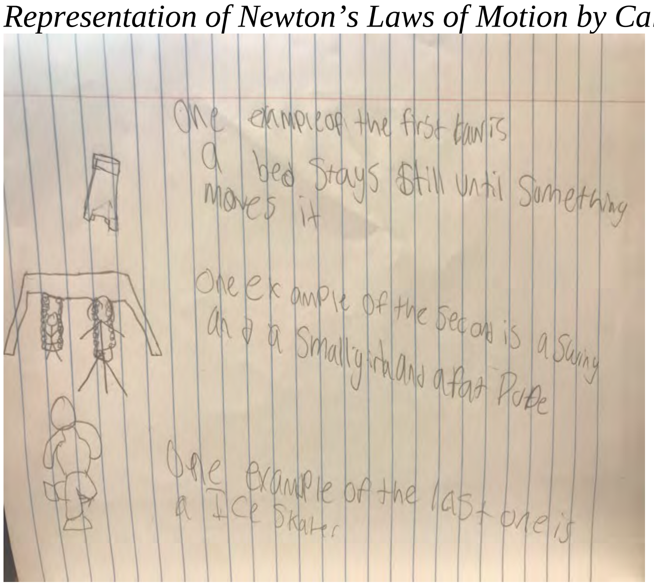
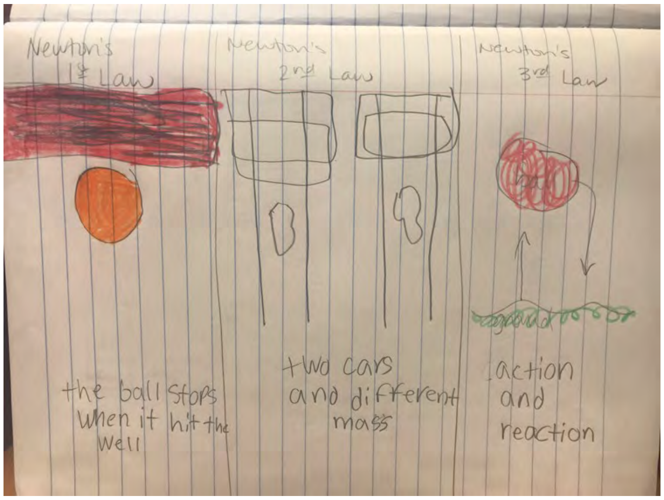


Figure 11
Representation of Newton's Laws of Motion by Malcolm



One of the most relevant topics to the students was *hurricanes*, which connected to their experiences with hurricanes in the past few years. The students gained knowledge of the components of a hurricane, which was evidenced by their writing with such statements as “[w]e learned about eyewalls, the eye, what we need to do to prepare” (Zenith, journal entry) and “I learned how to save water for the hurricanes [and] how to stay safe” (Malcolm, journal entry). Students were also able to make meaningful connections between the content being learned and their personal experiences.

What Did We Learn?

Make Meaningful Connections

Overall, our observations lead us to believe the students’ experiences in this program were positive, which are reflected in the students’ words. Ismael reported “[m]y experience in S.T.E.M. is fun. We learn about stuff we didn’t know about …” (journal entry). Calvin reported, “…I learned how to make stuff with trash people don’t use and another good thing I learned about some of Black history” (journal entry). This was significant given we included the discussion of Black scientists Louis Latimer and Granville T. Woods based on their value to the content as a culturally responsive teaching practice. Although all students seemed to have benefitted from the program, we observed that the student who benefitted the most was Malcolm, who felt validated, acknowledged, and *smart* (Malcolm would often use this term to refer to himself when he achieved success).

Use Culturally Relevant Literature

We found the effect of using literature, particularly culturally responsive picture books and graphic novels, to bridge the students’ understanding of scientific and mathematical concepts was an important component of this program. The books were directly related to the content and served as an introduction to each topic. Through these readings, we were able to assess students’ understanding and build upon background knowledge to address all concepts and topics included in this program. The contextualized language and engaging stories kept students interested. Their enthusiasm for the graphics was demonstrated in their comments during our reading sessions and in their journal responses. Throughout the readings, we would stop to ask questions and invite students to ask questions as well. Therefore, using literature was essential during the delivery of each lesson. As a means to support and reinforce the information provided through the literature, hands-on activities were created that allowed students to *see* what they were reading about (e.g., robotics, water cycle model).

Engage Students in Hands-on STEM Activities

This program underscores the significance of providing after-school programs for middle grades' students grounded in culturally responsive pedagogies to create connections between the content and the students' lived experiences and to increase the students' interest in STEM activities. Also, it highlights the importance of offering the students different opportunities to participate and demonstrate their learning. The student benefits were apparent to the BGC staff and administration as well. Each day of the program the UD would express her gratitude to us for taking the time to conduct this program and provide the students with an enriching, memorable experience. Most importantly, our reflection on the student impact of this program reveals and corroborates the significance of after-school programs guided by school-community partnerships (NMSA, 2010), and more specifically, challenging, equitable (NMSA, 2010), hands-on, engaging activities to provide opportunities for diverse student populations to participate in culturally responsive programs to promote literacy and interest in the STEM disciplines.

Next Steps

Although we found this program to be beneficial to students, we know it is not enough. These practices need to be replicated with additional after-school programs to engage a much larger student population. Additionally, we believe that the instructional strategies we incorporated in the program can be taken into the science classroom. Although reading a graphic novel may be time consuming, we argue the rewards far outweigh the time spent as opportunities for student discourse – both verbal and written – provide avenues for students to create meaningful connections to the material and evidence of their prior knowledge and understanding. Also, exposing students to different science lab activities and allowing them the opportunity to choose how to display their understanding or what to investigate for the science fair provided students with a sense of ownership and created engagement with the topics.

We challenge you, the readers, to integrate at least one aspect of this program (e.g., read a graphic novel, create a rap song, or write a story using the R.A.F.T. activity as a scaffold) into your classroom to elicit evidence of understanding from your diverse learners; you may find that your students benefit as much as Malcolm did. We have challenged ourselves as well. We incorporated some of these activities into our teacher education courses and our work with area schools. For example, we shared information about the Max Axiom stories with in-service science teachers, modeled the use of R.A.F.T activities in our teacher education classes, and incorporated hands-on activities, such as robotics and circuit building, in content methods courses. These opportunities have benefitted area middle grades students and the pedagogical understanding of our teacher candidates. We will continue to implement what we learned from this after-school program with the teacher candidates and middle grades students we work with by creating and implementing meaningful, engaging lessons that are relevant to students' lives and allow options for providing evidence of learning.

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Appendix A

Curriculum for Ten-Week After-School Program

<u>Unit 1 - Renewable and Non-Renewable Energy (5 sessions, 90 minutes each):</u>

- Reading of *The Boy Who Harnessed the Wind*
    - Kamkwamba, W. & Mealer, B. (2012). *The boy who harnessed the wind*. The Penguin Group.
- Introduced vocabulary
- Viewed videos
    - "William Kamkwamba - How I Harnessed the Wind"
    - "Moving Windmills: The William Kamkwamba Story"
    - "William and the Windmill"
- Bricolage project
- Inclusion of handouts of life of Louis Latimer and Granville T. Woods to connect to electricity introduction and activity
- Electricity activities:
    - making simple circuits
    - testing for conductors and insulators
    - independent project creating a circuit with a switch using recycled materials
- Several written reflections to answer questions posed such as:
    - What were some of the challenges facing Malawi? If you are aware, tell me about challenges facing economically disadvantaged countries.
    - Can you imagine living without electricity?
    - What encouraged William's love of science? What motivated him to build the windmill?
    - What did you like the most about the story? Why?
    - What did you like the least about the story? Why?

Unit 2 - Water and the Water Cycle (5 sessions, 90 minutes each):

- Participated in lab testing properties of water to identify which liquid was water
- Introduced vocabulary
- Created a model of the water cycle using a sandwich bag and colored water
- Viewed videos of the water cycle
    - "The Water Cycle" (Flocabulary.com)
    - "Water Cycle Song"
    - "The Water Cycle" (Youtube.com)
- R.A.F.T. activity used to write a story
    - **R**ole: Pretend you are a drop of water and are traveling through the water cycle.
    - **A**udience: Your classmates and teachers.
    - **F**ormat: Creative academic narrative/story using first person ("I").
    - **T**opic: My journey through the water cycle.
- Created graphs to represent water depths – students were provided information on well depths (over time) for the county in which they lived; they created graphs to view and discuss the change in depth over time
- Used K'nex to build a replica of a well (this connected to drinking water and the reading from Unit 1)
- Used LEGO robotics to learn about scale factors – students used the robots to draw rectangles and then predicted how the programming would need to change to create a larger (and then smaller) rectangle. Their predictions were tested and evaluated.

Unit 3 - Newton's Laws of Motion (4 sessions, 90 minutes each):

- Read *Isaac Newton and the laws of motion*
    - Gianopoulos, A. (2007). *Isaac Newton and the laws of motion.* Capstone Press.
- Read *A crash course in forces and motion with Max Axiom*
    - Sohn, E. (2016). *A crash course in forces and motion with Max Axiom.* Capstone Press.
- Introduced vocabulary
- Viewed videos in reference to the laws of motion
    - "Newton's 3 (three) Laws of Motion"
    - "Forces Brainpop"
- Science lab based on Newton's Laws
    - Water splat activity to compare the size of the splat in regard to height of the drop
- LEGO Robotics lab enacting Newton's Laws
    - Students used the robots to create ball movement on different surfaces; the balls were different sizes and weights
- R.A.F.T. choice activity – create a letter, poem, or rap
    - **R**ole: Yourself.
    - **A**udience: Sir Isaac Newton.
    - **F**ormat: Personal letter, poem, rap, jingle, or song
    - **T**opic: How I proved you right about the three laws of motion.

Unit 4 - Natural Disasters (Focus on Hurricanes) (2 sessions, 90 minutes each):

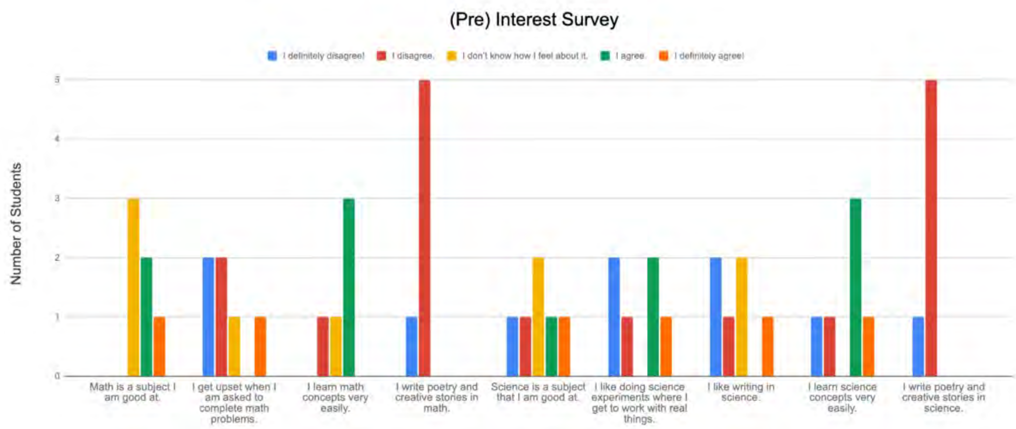
- Read *The whirlwind world of hurricanes with Max Axiom*
    - Krohn, K. (2011). *The whirlwind world of hurricanes with Max Axiom.* Capstone Press.
- Introduced vocabulary
- Viewed Videos
    - "Hurricane Katrina Day by Day - National Geographic"
    - "Hurricanes"
- Science Lab
    - Wind activity using a model wind turbine; students evaluated the energy created with different wind speeds
- Writing Activities
    - Students journaled to share their own personal experiences with hurricanes

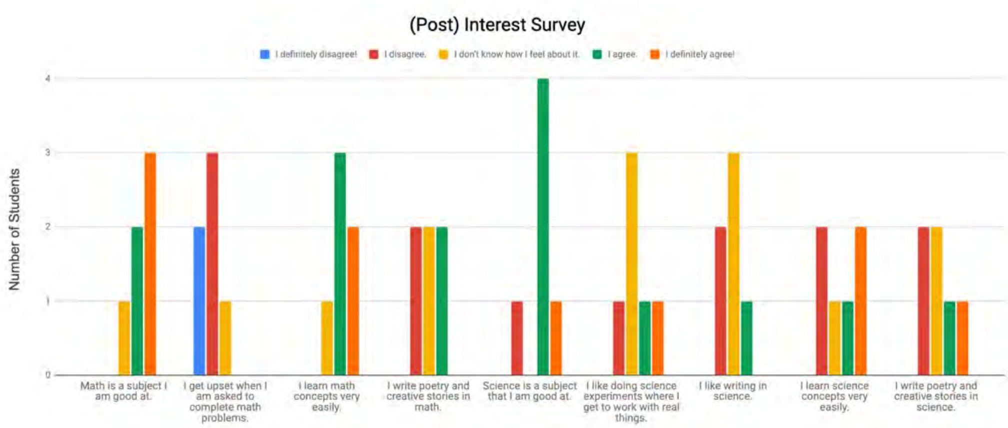
Culminating Project (4 sessions, 90 minutes each, including presentation day):

- Development of a "science-fair type" project

Appendix B

Results of the Pre- and Post-Interest Surveys





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