Final Evaluation Report: On the Effectiveness of Little Scholars LLC's After-School Enrichment Program

Prepared By

Tenace Setor PhD

Richmond Business Consulting

Table of Contents

1.0 INTRODUCTION	**6**
2.0 PROGRAM OVERVIEW	**6**
3.0 EVALUATION OBJECTIVES	**7**
4.0 METHODOLOGY	**7**
5.1 PRE-TEST SURVEY FINDINGS (BEFORE INTERVENTION)	**21**
5.2 POST-TEST SURVEY FINDINGS (AFTER INTERVENTION)	**22**
5.3 COMPARATIVE ANALYSIS	**23**
6.0 DISCUSSION	**24**
7.0 CONCLUSION	**27**
8.0 RECOMMENDATIONS	**27**
APPENDIX	**33**
A: The ECE Classroom Observation Protocol	**33**
C: Lesson Plan: Animal Adaptation Experiment	**34**
C: Pre and Post Test Survey Instrument	**37**

Executive Summary

This report presents the findings from an evaluation of an after-school STEM enrichment program using the Classroom Observation Protocol. The evaluation aimed to assess the program's effectiveness in conveying STEM content, promoting student engagement, and addressing diverse learning needs of young learners. The protocol examined several key dimensions, including questioning techniques, play-based learning, process skills development, and the integration of scientific and engineering practices. Additionally, pre- and post-program surveys were conducted to gauge the impact on students' interest levels in pursuing STEM careers.

Key Findings:

Questioning

- The program effectively utilized a variety of questioning strategies to engage students across different cognitive levels, from recall to analysis and evaluation.
- Open-ended questions facilitated discussions and student reflection, promoting deeper understanding of STEM concepts.

Play

- The program successfully incorporated elements of play, allowing students to use their imaginations and follow instructions.
- Limited instances were observed where students were encouraged to take on different perspectives or generate their own questions based on observations.

Process Skills

- The program was effective in cultivating essential process skills among students, such as observing, describing, categorizing, communicating, and making predictions.

Scientific and Engineering Practices

- Students demonstrated strong abilities in formulating inquiry-based questions and conducting experiments.
- The program effectively fostered skills in making observations and identifying patterns and relationships.
- Minimal evidence of integrating mathematical and computational thinking into lessons was observed.

Student Interest in STEM and STEM Careers

- Pre- and post-program surveys showed a positive impact on students' levels of interest in pursuing STEM careers.
- The results indicate increases in the levels of interest in Science and Mathematics.

While the program exhibited strengths in questioning techniques, process skills development, and aspects of scientific inquiry, areas for improvement were identified in enhancing play-based learning, encouraging perspective-taking, and incorporating mathematical and computational thinking into STEM activities.

Recommendations include:

- Implementing role-playing, open-ended challenges, and storytelling activities to foster perspective-taking and inquiry-based learning.
- Integrating data analysis, coding/programming, pattern recognition, and real-world applications to develop mathematical and computational thinking skills.

By addressing these recommendations, the after-school enrichment program can further enhance its effectiveness in conveying STEM content, promoting student engagement, and equipping young learners with essential skills for success in STEM education and future endeavors. The program's positive impact on fostering interest in STEM careers among participants is also noteworthy.

1.0 Introduction

The fields of Science, Technology, Engineering, Arts and Mathematics are foundational to progress and innovation. These intertwined disciplines are central to the advancement of technology, economic growth and cultural development. STEAM education cultivates a diverse range of skills highly sought after in today's job market. It fosters critical thinking, problem-solving, creativity and adaptability – key attributes for addressing the complex challenges of our times.

Acknowledging the crucial role of STEAM education in preparing future innovators and meeting upcoming challenges, it becomes essential to investigate educational strategies that engender early interest and positive perceptions toward STEAM subjects among young learners. Ensuring all children have equal access to quality STEAM education from an early age is important for their readiness for higher levels of STEAM learning. Within this context, this report presents the findings of a study conducted to evaluate the effectiveness of an after-school enrichment program in STEAM, offered by Little Scholars LLC, on young children.

2.0 Program Overview

Since its founding in 2006, Little Scholars LLC has provided enriching learning experiences for more than 100,000 children across a wide range of subjects. Their comprehensive services include *before and after school enrichment programs*, *summer camps, in-school field trip programs, individual and group tutoring, school entry assessments* and *total program management.* Little Scholars has a strong presence in over 200 schools across 20 states. Little Scholars excels at creating programs tailored to meet the specific needs of each school or district. These programs are flexible, available in full or half-day options, and go beyond the traditional school day, providing enriching experiences, deepening students' exposure to STEAM concepts and fostering a culture of curiosity.

3.0 Evaluation Objectives

The primary objectives are two-fold:

1. Assess the instructional strategies employed by program educators, including their effectiveness in conveying STEAM content, promote student engagement, and address diverse learning needs.
2. Measure the impact of the program on students' interest in STEAM and STEAM careers.

4.0 Methodology

The evaluator undertook a multifaceted approach to thoroughly evaluate the effectiveness and impact of the program. The evaluation process comprised three key components:

Classroom Observation, Review of Recorded Video of In-Class Session, Pre and Post Test Surveys.

Classroom Observation

To evaluate the program, the evaluator used an adapted version of the Early Childhood Education Classroom Observation Protocol developed by Milford and Tippet (2015).

Observation Procedure: The evaluator conducted an in-person observation of a class session at a randomly chosen program site. The observation aimed to provide a detailed examination of instructional strategies, student engagement levels, and overall classroom dynamics within the context of the Little Scholars STEAM program.

Lesson Summary: Students construct a DNA model using gumdrops and toothpicks. The teacher supplies gumdrops, toothpicks, worksheets, and identity cards. The lesson begins with a practical introduction to DNA, emphasizing its role as the genetic material present in all living things. Students learn about DNA composition, its function as a genetic blueprint, and its importance in forensics, discovering how the slight 0.01% difference in DNA determines physical variations among individuals. During the activity, students build DNA models guided by the phenotype characteristics of a fictional individual named Amelia on the identity card. They decode Amelia's genetic information, translate the three-base code for each physical trait, and construct the DNA ladder using toothpicks and gumdrops.

Observation Site: The observation took place at Martin Luther King Jr. Middle School in Richmond, Virginia. The selected class session focused on biomedical engineering and the human body, featuring an activity where students constructed DNA models using gumdrops and toothpicks.

Observation Instrument: An adapted version of the Early Childhood Education (ECE) Classroom Observation Protocol model designed by Milford & Tippett (2015) was used as the observation instrument. This instrument facilitated the systematic assessment of various components of STEAM teaching and learning, including instructional practices, student interactions, and integration of STEAM concepts. The choice of the protocol is motivated by three main reasons: Relevance: Unlike other observation protocols, The ECE COP model demonstrates an overlap between STEAM learning and early childhood education (ECE) learning environments, as in the case of our study. Comprehensiveness: The ECE COP model encompasses various aspects and dimensions of STEAM teaching and learning, providing a comprehensive framework for evaluation. Validation: The ECE COP model is evidence-based and was developed through action research, ensuring its validity and reliability as a tool for assessing STEAM education in early childhood settings. *The ECE COP framework is provided in appendix A.*

Data Collection: During the observation, the evaluator documented observations using the adapted ECE COP model, capturing details of the instructional strategies employed, student engagement levels, and the effectiveness of the STEAM learning experience.

Video Review Analysis

In addition to the in-person evaluation, the evaluator examined and assessed a recorded lesson on animal adaptation experiments offered by program educators at Little Scholars STEAM program. The 30-minute lesson, recorded in video format, served us the primary data source for this evaluation.

Lesson Summary: Students learn about animal adaptations with a focus on venom-resistant animals and the unique features of the giant squid. The lesson incorporates hands-on experiments and activities to deepen students' understanding of venom and propulsion systems in animals. The lesson begins with an introduction to animal adaptations, covering structural, physiological, and behavioral adaptations. Examples of unusual animal adaptations are discussed, including wood frogs freezing their bodies and horned lizards shooting blood from their eyes. Students then engage in an experiment demonstrating the effects of spider venom on prey, using sugar cubes and water to mimic the process of venom digestion. This experiment highlights the importance of pre-digestion outside the spider's body and the liquefaction of tissues.

Additionally, students focus on the giant squid, learning about its physical characteristics, feeding habits, and propulsion system. They participate in an activity to create a moving squid model using balloons and streamers, simulating jet propulsion.

Participants: Participants in this study are grade 3-5 students enrolled in the Little Scholars STEAM program at Hoboken Public Schools, NJ. The lesson under evaluation was attended by students enrolled in the WOW Lab classes.

Observation Procedure: The recorded lesson, focusing on animal adaptation experiments, was reviewed multiple times to ensure comprehensive analysis. During each viewing, the ECE Classroom Observation Protocol (Appendix A) framework was applied to systematically assess various aspects of the lesson, including instructional strategies, student engagement, and alignment with STEAM principles.

Data Collection: Data were collected through detailed observation notes documenting the instructional content, teaching methodologies, student interactions, and overall classroom dynamics observed during the lesson. The lesson plan provided (Appendix B) served as a reference to guide the analysis and evaluation process.

Pre- and Post-Test Survey

A pre and post-test survey design was employed to assess changes in students' STEAM interest before and after participating in the program. Surveys were administered to parents of students enrolled in the WOW Lab classes, who then interviewed their children using the survey questionnaire to capture their responses.

Research Site and Participants: The research site consisted of students enrolled in the Little Scholars STEAM program at Hoboken Public Schools in Hoboken, New Jersey. Participants were grade 3-5 students, divided into at least six classes across three different elementary schools. The classes were titled WOW Lab and catered to either 2nd-3rd grade or 4th-5th grade students.

Survey Instrument: The survey questionnaire was designed to capture students' interest and engagement in STEAM subjects. It included questions related to their attitudes towards science, technology, engineering, arts, and mathematics, as well as their level of engagement in related activities. The survey was structured to elicit responses from students through parental interviews. *The survey instrument is provided in Appendix C*

Data Collection Procedure: Prior to the commencement of the STEAM program, parents were provided with the pre-test survey questionnaire along with instructions on how to conduct the survey with their children. Parents were instructed to interview their children using the survey questionnaire and record their responses accurately. Following the completion of the STEAM program, parents were provided with the post-test survey questionnaire and asked to repeat the process of interviewing their children to capture their post-program responses. Surveys were distributed and collected electronically.

5.0 Findings

Classroom and Video Observation Protocol

Questioning

Observation of the educator's **questioning techniques** revealed positive findings as show in Table 1. The educator used a variety of effective questioning strategies to promote student engagement and learning across different cognitive levels. The techniques including prompting students to recall, understand and apply concepts, analyze, and evaluate during the in-classroom activity. Additionally, the educator encouraged student participation by asking open-ended questions that led to discussions and student reflection.

Table 1: Questioning Skills Observation Results

Dimension	Indicator	Evaluation Remarks	Findings
Characteristics and Nature	Questions aimed at remembering, understanding, and applying	Meets expectation	The educator employs a variety of questions throughout activities that engage the students in remembering, understanding, and applying key concepts. For instance, students were asked to explain how DNA structure allows for replication, demonstrating an integrated understanding of biological concepts and application.
	Questions aimed at analyzing, creating, and evaluating	Meets expectation	The educator prompted students to analyze and evaluate concepts during the class activity. An example of this involved the educator asking about the complementary strands of DNA pairing correctly, requiring students to reflect on the rationale and consequences of biological processes.
	Questions that encourage a range of responses	Meets expectation	The educator asked questions that required students to explain and justify concepts. A noteworthy instance was the invitation for a student to ask questions about the DNA Build Color Key, fostering an environment where students felt comfortable seeking clarification and engaging in deeper understanding.
Patterns and Interactions	Open ended questions	Meets expectation	The educator asked open-ended questions on several occasions, prompting students to explain further and engage on a deeper level.
	Opportunities for questioning	Meets expectation	The educator's approach to question-asking created opportunity for students to inquire more. On several occasions, the educator paused during the lesson and solicited questions from students.
	Follow up questions	Meets expectation	On some occasions, the educator elicited responses that could be supplemented with justifications or evidence. For example, a student commented that she remembers the DNA base pairs using the analogy of trees and apples. The educator encouraged the student to elaborate and provide reasoning for their analogy.

Play

As shown in Table 2, the program is successful at fostering some aspects of play such as students' ability to use their imaginations and follow instructions. There were few instances where students were explicitly encouraged to take on the perspective of others during the class activity or generate questions based on their individual observations.

Table 2: Play Skills Observation Results

Dimension	Indicator	Evaluation Remarks	Findings
Pretend Play	Students try out different roles and scenarios	Meets expectation	1. Students were encouraged to take on different roles and placed in diverse learning scenarios. For example, before the activity, the educator explicitly asked students to pretend to be "Amelia" – an imaginary woman with specific phenotypes on the DNA identity card. 2. Students imagined themselves as venom-resistant animals or predators in their habitats
	Students are actively encouraged to take on the perspective of others during play	Below expectation	1. There was no explicit encouragement for students to take on the perspective of others. Some students however did engage in pretend play where they talked about how their DNA models looked like worms and dragons. 2. There is minimal emphasis on encouraging students to take on the perspective of others during the lesson activities.
	Students make mental representations and use imagination during play	Exceptional	1. Students used their imaginations and pretended that the gumdrops and toothpicks represented different DNA components, such as nucleotides. 2. Students imagined scenarios where animals with specific adaptations encounter challenges or opportunities in their habitats.
Socio-dramatic play	Students are adept at determining tasks and carrying them out during activities	Exceptional	1. The students were observed following the teacher's instructions and guidelines to pair up the DNA bases. 2. Students followed instructions to conduct experiments simulating the effects of spider venom by dissolving sugar cubes in water.
	Students are adept at using storytelling to describe concepts, tasks and activities	Exceptional	1. The students engaged in story-telling frequently. One student was observed recalling a Law-and-Order TV show episode about DNA. 2. Students engaged in narratives or stories around the adaptations of specific animals, explaining how these adaptations help them survive in their environments.
	Students are encouraged to make connections of concepts using environmental prints	Exceptional	1. Students made connections to real-world objects. A student, for example, noted that the double helix structure of DNA looked like "twisted spaghetti". 2. Students used diagrams of the giant squid and visual representations of venomous animals to understand concepts related to animal adaptations.

Table 2: Play Skills Observation Results

Dimension	Indicator	Evaluation Remarks	Findings
Constructive Play	Supports and encourages students in drawing and painting activities	Below expectation	1. There was no evidence of drawing and painting activities during the DNA activity. 2. For the animal adaptation experiment, Students were observed drawing diagrams of the giant squid and visualizing the adaptations discussed during the lesson.
	Actively involved in building activities and part of the program	Exceptional	1. The students were observed building a DNA model using gumdrops and toothpicks. 2. Students were involved in building moving squid models using balloons, streamers, and other materials, actively engaging in building activities as part of the lesson.
	Students make mental representations and use imagination during play	Exceptional	1. The activity encouraged students to plan and coordinate their actions by following the educator's instructions to organize the DNA bases based on colors. 2. Students were prompted to imagine themselves as animals with specific adaptations or engineers designing propulsion systems.
Exploratory Play	Students are encouraged to actively explore, think and reason about their surroundings.	Meets expectation	1. The DNA model building exercise prompted students to explore the structure of DNA and observe the double helix structure. 2. Students explore animal adaptations through hands-on experiments and discussions.
	Activities promote making observations using all senses.	Exceptional	1. Students observed the color-coded gumdrops and felt the toothpick connections to understand DNA pairing rules. One of the students ate the gumdrop after building the structure. 2. Students used their senses to observe and explore the effects of spider venom through a hands-on experiment using sugar cubes and water, engaging their sense of touch, sight, and taste.
	Students generate questions using all of their senses	Below expectation	1. There were no specific instances where the educator deliberately asked the students to generate questions about their observations of the DNA model. 2. There was limited evidence of students asking questions related to their senses during the animal adaptation experiment.

Process Skills

Findings on the aspect of process skills are presented in Table 3 below. The program effectively cultivates the process skills of young learners, fostering their abilities to observe, describe, categorize, communicate, and extrapolate observations to predict phenomena in their environment.

Table 3: Process Skills Observation Results

Dimension	Indicator	Evaluation Remarks	Findings
Observing	Activities emphasize using senses to identify properties of objects.	Exceptional	1. Students were encouraged to describe the properties of the DNA Build Identity cards, the gumdrops, and the toothpicks, as well as the structure of their DNA models. 2. Students actively engaged in observing the properties of various materials and phenomena, such as the dissolution of sugar cubes in water.
	Students are provided with tools to observe objects and events.	Meets Expectation	1. The DNA Build activity required students to create a physical model of the DNA structure using gumdrops and toothpicks. 2. Students had access to appropriate tools (Styrofoam cup, straws) to conduct experiments and made observations.
	The activities encourage the use of measurement tools to record observations.	Below Expectation	1. Students were encouraged to compare their DNA models to the diagrams in their worksheets to ensure that they were accurate. They also observed how the structure of their models changed as they added and removed gumdrops. 2. Quantitative measurements were not emphasized.
Describing	Students are encouraged to describe key attributes of objects.	Meets Expectation	1. Students were encouraged to describe the properties of the DNA Build Identity cards, the gumdrops, and the toothpicks, as well as the structure of their DNA models. 2. Students actively participated in describing various adaptations observed in animals.
	The activities support creating drawings or models depicting objects.	Exceptional	1. The DNA Build activity required students to create a physical model of the DNA structure using gumdrops and toothpicks. 2. Students created visual representations of animal adaptations.
	Students are encouraged to describe changes in objects over time.	Meets Expectation	1. Students were encouraged to compare their DNA models to the diagrams in their worksheets to ensure that they were accurate. They also observed how the structure of their models changed as they added and removed gumdrops. 2. The experiment involving sugar cubes simulated changes over time, prompting students to describe transformations.

Table 3: Process Skills Observation Results (continued)

Dimension	Indicator	Evaluation Remarks	Findings
Categorizing	Students are encouraged to describe key attributes of objects.	Exceptional	1. Students were encouraged to describe the properties of the DNA Build Identity cards, the gumdrops, and the toothpicks, as well as the structure of their DNA models. 2. Students described key attributes of venom-resistant animals,
	Students are encouraged to sort objects into groups using various attributes.	Exceptional	1. Students were encouraged to sort the gumdrops by color to represent different nucleotides. They also sorted the gene segments on their DNA models based on the order they appeared in the DNA Build Identity square. 2. While discussing animal adaptations, students sorted examples of animals into groups based on their methods of defense, such as venom resistance and camouflage.
	Students are skilled at establishing and justifying sorting criteria.	Exceptional	1. Students were able to explain why they sorted the gumdrops by color and why they arranged the gene segments in a specific order. 2. In the lesson on animal adaptations, students justified their sorting of animals based on shared characteristics related to survival strategies, such as physical defenses and behavioral adaptations.
Predicting	Students are adept at recognizing and extending patterns.	Meets Expectation	1. Students were able to identify the pattern of nucleotide pairs in the DNA Build Color Key and use it to predict the sequence of nucleotides in their DNA models. 2. During discussions about animal behaviors, students recognized patterns in behaviors such as hibernation and migration, and extended these patterns to predict how animals adapt to changing environments.
	The program encourages students to make simple predictions.	Meets Expectation	1. The teacher encouraged students to predict how their DNA models would change if they added or removed gumdrops. 2. Prior to conducting the experiments on animal adaptations, students predicted the outcomes of interactions between venomous animals and their prey based on their understanding of venomous defenses.
	Students are encouraged to compare predictions to actual outcomes.	Meets Expectation	1 Students were encouraged to compare their predictions about how their DNA models would change to the actual results. 2 Following the animal adaptation experiments, students compared their predictions of how animals defend against predators to the observed behaviors and physical features of venom-resistant animals discussed in class.

Table 3: Process Skills Observation Results

Dimension	Indicator	Evaluation Remarks	Findings
Communicating	Students are actively engaged in communicating information or design ideas.	Meets Expectation	1. Students were able to communicate their observations, descriptions, and explanations of the DNA structure to the teacher. 2. Throughout the lesson on animal adaptations, students actively communicated their observations, ideas, and design concepts while working on experiments and activities.
	The program promotes an environment where students share, listen, and discuss ideas.	Meets Expectation	1. The classroom environment facilitated student interaction, sharing ideas about DNA and the construction of the models 2. The lesson fostered an atmosphere of open communication, encouraging students to share their thoughts, actively listen to peers, and engage in discussions about animal adaptations.
	Students effectively communicate results and findings after engaging in activities.	Meets Expectation	1. Students used their DNA models to communicate their understanding of the DNA structure to their classmates and the teacher. 2. Following the animal adaptation experiments, students effectively communicated their findings, sharing observations, conclusions, and insights gained from the hands-on activities with their peers.

Scientific and Engineering Practices

The evaluation of the program's implementation concerning scientific and engineering practices revealed encouraging results in several areas, particularly in students' ability to formulate inquiry-based questions and conduct experiments to seek answers. Additionally, the program effectively cultivates students' skills in making observations and articulating relationships and patterns. However, there was minimal to no evidence suggesting the integration of mathematical and computational thinking within the lessons. Summary findings about the program's scientific and engineering practices are provided in Table 4:

Table 4: Scientific and Engineering Practices Observation Results

Dimension	**Indicator**	**Evaluation Remarks**	**Findings**
Questions and Problems	Asking questions to find more information about the natural +/or designed world(s)	Meets Expectation	1. Students demonstrated a curiosity about DNA and its role in determining physical traits. They engaged in asking relevant questions to deepen their understanding of the natural world. 2. Students demonstrated a curiosity about animal adaptations and asked relevant questions to deepen their understanding of how animals survive in their environments.
	Asking +/or identifying questions that can be answered by an investigation.	Meets Expectation	1. Students were encouraged to ask questions related to DNA structure and function that could be investigated through the activity. The lesson prompted students to think critically and identify inquiry-based questions. 2. The lesson prompted students to think critically and formulate inquiry-based questions to explore the concepts of venom and propulsion in animals.
	Defining a problem that can be solved through creating a new or improved object or tool.	Meets Expectation	1. The activity prompted students to define a problem related to genetic traits and solve it through the creation of a DNA model. 2. Students defined a problem related to animal adaptations and addressed it through the design and testing of balloon squids. They demonstrated problem-solving skills by experimenting with different designs to improve the squid's propulsion ability.

Analyzing and Interpreting	Using observations to describe patterns	Meets Expectation	1. Students demonstrated the ability to analyze patterns in DNA structure and understand their implications for phenotypic traits. They observed consistent relationships between genetic sequences and physical characteristics. 2. Students demonstrated the ability to analyze patterns in animal adaptations, recognizing common features across different species.
	Using observations to describe relationships	Meets Expectation	1. Through observations, students described the relationship between DNA sequences and phenotypic traits. They understood how specific base pair sequences determine physical characteristics. 2. Through observations, students described the relationship between animal characteristics and their survival strategies. They understood how specific adaptations contribute to an animal's ability to survive in its environment
	Recording information in pictures, drawings and/or writing	Meets Expectation	1. Students recorded genetic information using visual and written methods, including drawings, diagrams, and written descriptions. 2. Students recorded information using visual and written methods, including sketches, diagrams, and written notes.
Math and Computational Thinking	Using qualitative and quantitative data	Below Expectation	1. No evidence or observations were noted regarding the use of qualitative and quantitative data in analyzing DNA structures and phenotypic traits. 2. No evidence or observations were noted regarding the use of qualitative and quantitative data in analyzing animal adaptations and behaviors.
	Using counting and numbers to identify and describe patterns.	Below Expectation	1. No evidence or observations were noted regarding the use of counting and numerical analysis to identify and describe patterns in DNA sequences and phenotypic traits. 2. No evidence or observations were noted regarding the use of counting and numerical analysis to identify and describe patterns in animal adaptations and behaviors.

	Describing, measuring, +/or comparing attributes of objects and displaying the data	Below Expectation	1. No evidence or observations were noted regarding the description, measurement, and comparison of attributes of DNA structures and phenotypic traits. 2. No evidence or observations were noted regarding the description, measurement, and comparison of attributes of animal adaptations and behaviors.
Explanations and Designing Solutions	Making observations to construct an evidence-based account for natural phenomena.	Meets Expectation	1. The lesson involved students making observations of DNA structure and phenotypic traits to construct an evidence-based understanding of genetic concepts. 2. The lesson involved making observations of various animal adaptations and behaviors to construct an evidence-based understanding of animal survival mechanisms.
	Using tools +/or materials to design +/or build a device to solve a specific problem.	Meets Expectation	1. Students utilized tools and materials such as gumdrops, toothpicks, and DNA identity cards to design and build DNA models. 2. Students utilized balloons, streamers, and straws to design and build models representing animal propulsion systems.
	Generating +/or comparing multiple solutions to a problem	Meets Expectation	1. Although the activity primarily involved constructing DNA models using prescribed materials, students had opportunities to explore various configurations and arrangements, encouraging them to think critically and creatively about representing genetic information. 2. While the lesson primarily focused on building models to represent specific animal adaptations, students were encouraged to generate and compare multiple solutions to simulate different survival strategies. Through experimentation and design, they explored various approaches to solving the problem of adapting to environmental challenges.

Argument	Distinguishing between opinions and evidence in one's own explanations.	Meets Expectation	1. The lesson encouraged students to distinguish between opinions and evidence by providing factual information about DNA structure and function. Students learned to differentiate between subjective beliefs and empirical observations when discussing genetic concepts. Through guided discussions and hands-on activities, they were prompted to base their explanations on scientific evidence rather than personal opinions. 2. The lesson facilitated distinguishing between opinions and evidence by presenting factual information about animal adaptations and survival mechanisms. Students learned to differentiate between subjective beliefs and empirical observations when discussing animal behaviors and adaptations.
	Indicating agreement or disagreement based on evidence.	Meets Expectation	1. Students actively participated in discussions and activities where they had opportunities to indicate agreement or disagreement based on evidence. They engaged in critical analysis of genetic concepts and hypotheses, supporting their arguments with empirical evidence from experiments and observations. 2. Through inquiry-based learning activities, they were prompted to assess the validity of adaptive strategies and survival mechanisms using empirical evidence from observations and experiments.
	Constructing an argument with evidence to support a claim.	Meets Expectation	1. Students were prompted to justify their assertions using empirical evidence from DNA models, experiments, and observations. Through guided inquiry and scientific inquiry, they learned to formulate coherent arguments based on logical reasoning and empirical evidence. 2. The lesson involved constructing arguments with evidence to support claims about animal adaptations and survival mechanisms. Students were prompted to justify their assertions using empirical evidence from experiments and observations

5.1 Pre-Test Survey Findings (Before Intervention)

STEM Interest

Table 5 presents the findings of the pre-test survey. It illustrates that before joining the program, 80% of potential participants showed enthusiasm for science, while 72% expressed enthusiasm for mathematics. Conversely, 20% did not show enthusiasm for science, and 28% lacked enthusiasm for mathematics.

Science Interest: Average score: 3.00; Standard Deviation: 0.94

Mathematics Interest: 3.12; Standard Deviation: 1.204

Table 5: STEM Interest Survey Results Before Enrollment

	Very Enthusiastic 4	Enthusiastic 3	Less Enthusiastic 2	Not Enthusiastic 1
What emoji best describes how you feel about science?	8	12	2	3
	80%		20%	
What emoji best describes how you feel about math?	14	4	3	4
	72%		28%	

STEM Career Interest

The findings from the pre-test survey in Table 6 revealed that 37.5% of prospective participants expressed future career interests in science, engineering, or mathematics, while 62.5% indicated no such career interests in these fields.

Table 6: STEM Career Interest Survey Results Before Enrollment

	Yes	No
Would you be interested in a job in science, engineering or math when you grow up?	9	15
	37.5%	62.5%

5.2 Post-Test Survey Findings (After Intervention)

STEM Interest

The post-test results shown in Table 7 reveal that 96% of participants indicated feeling enthusiastic about science, while 80% expressed enthusiasm toward mathematics. Conversely, 4% of participants reported not feeling enthusiastic about science, and 20% expressed a lack of enthusiasm toward mathematics.

Science Interest: Average score: 3.36; Standard Deviation: 0.547

Mathematics Interest: Average score: 3.12; Standard Deviation: 1.107

Table 7: STEM Interest Survey Results After Program

	Very Enthusiastic 4	Enthusiastic 3	Less Enthusiastic 2	Not Enthusiastic 1
What emoji best describes how you feel about science?	10	14	1	0
	96%		4%	
What emoji best describes how you feel about math?	12	8	1	4
	80%		20%	

STEM Career Interest

The results of the post-test survey shown in Table 8 indicated that 74% of the participants had future career interests in science, engineering or mathematics and 26% expressed no career interests in science, engineering or mathematics.

Table 8: STEM Career Interest Survey Results After Program

	Yes	No
Would you be interested in a job in science, engineering or math when you grow up?	17	6
	74%	26%

5.3 Comparative Analysis

STEM Interest

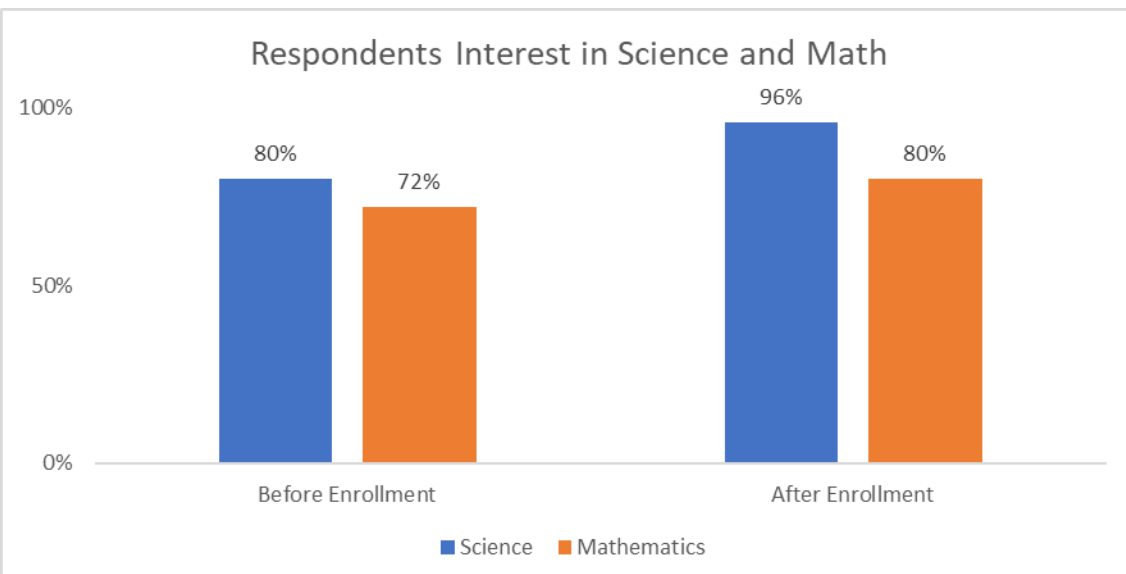
A Chi-square test was conducted to determine whether there is a significant association between the pre-test and post-test responses.

Science Interest: The Chi-Square Statistic: $\chi^2(1) \approx 3.3938$ is not significantly different than zero ($p > 0.05$).

Math Interest: The Chi-Square Statistic: $\chi^2(1) \approx 0.5440$ is not significantly different than zero ($p > 0.05$).

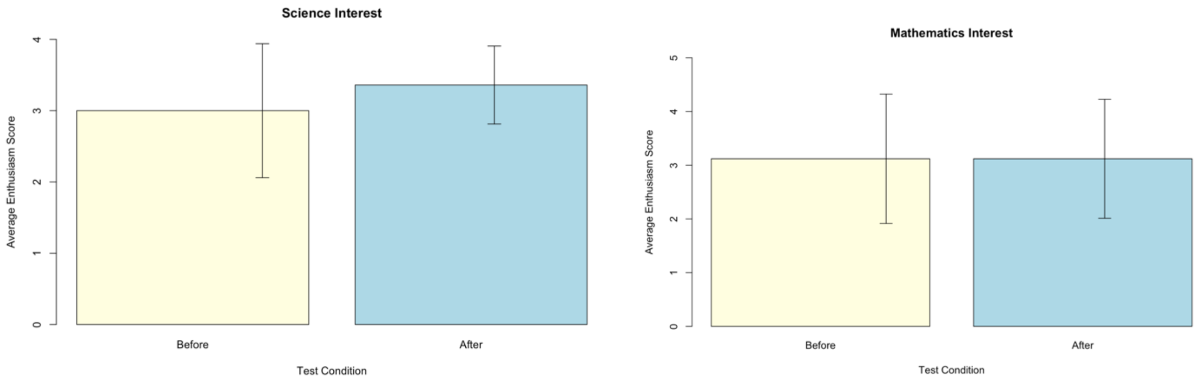
Figure 1 shows the levels of interest in Science and Mathematics before and after the program. Before enrollment, 80% and 72% of the respondents reported being interested in science and mathematics respectively. After the program, 96% and 80% of the respondents reported being interested in science and mathematics.

Figure 1: Respondents' Interest in Mathematics and Science Before and After Enrollment



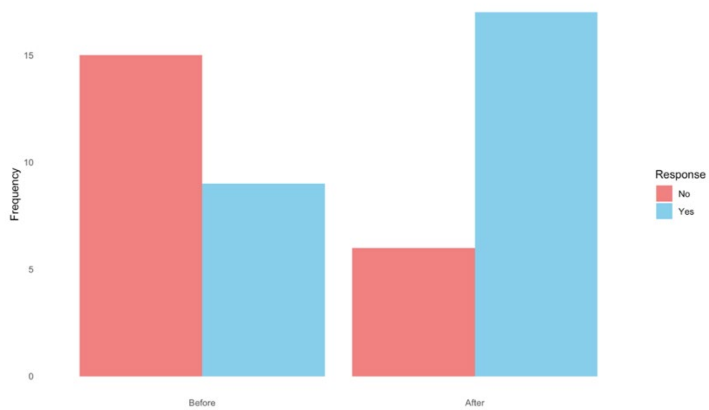
The average enthusiasm scores before and after the program are shown in the Figure 2.

Figure 2: Reported Levels of STEM Enthusiasm Before and After Program



STEM Career Interest: The chi-square statistic: $\chi^2(1) \approx 5.04$ is significantly different than zero. Figure 3 shows a graph of the pre and post-test responses.

Figure 3: Reported Levels of STEM Career Interest Before and After Program



6.0 Discussion

Questioning Techniques

Questioning techniques play a pivotal role in fostering student engagement, promoting higher-order thinking, and assessing understanding in STEM education. By employing a variety of questioning strategies, enrichment programs can stimulate cognitive processes at various levels, from recalling and understanding concepts to applying knowledge, analyzing information, and evaluating claims or solutions. Open-ended questions, in particular, facilitate discussions and encourage students to reflect on their learning, which is crucial for developing a deep conceptual understanding of STEM subjects.

The findings indicate that the program effectively utilized questioning techniques to promote student participation and learning across different cognitive levels. Encouraging learners to navigate through recall, application, analysis, and evaluation supports a multifaceted understanding of STEM concepts. Moreover, the strategic use of open-ended questions creates a dynamic platform for discussions and reflections, thereby enhancing student engagement and fostering a conducive environment for exploratory learning. This strength in the program's approach to questioning underscores its commitment to not just disseminating knowledge but also cultivating intellectual agility among the students.

Play

Play is a vital component of STEM education for young learners, as it fosters creativity, imagination, and problem-solving skills. Through play, children can explore, experiment, and make connections between abstract concepts and real-world applications. Additionally, play-based learning promotes social and emotional development, as it encourages collaboration, communication, and perspective-taking.

The findings suggest that the program successfully incorporates elements of play. The program's ability to engage students' imaginations and guide them to follow instructions through playful activities is commendable. Such experiences are instrumental in nurturing problem-solving skills and innovative thinking. However, the potential of play in stimulating empathy and collaborative skills through perspective-taking remains underleveraged. Enhanced incorporation of activities that promote perspective-taking and inquiry generation from observations could further amplify the benefits of play, transforming it into a more impactful tool for holistic STEM learning.

Process Skills

Developing process skills is fundamental in STEM education, as it equips students with the abilities to observe, describe, categorize, communicate, and make inferences about phenomena in their environment. These skills lay the foundation for scientific inquiry and problem-solving, enabling students to engage in hands-on learning experiences and develop a deeper understanding of STEM concepts.

The program was found to be effective in cultivating process skills among young learners, fostering their abilities to observe, describe, categorize, communicate, and extrapolate observations to predict phenomena. This positive finding aligns with the goals of STEM education programming. By fostering abilities to observe, describe, categorize, communicate, and predict, the program solidifies essential competencies that form the basis of scientific literacy. These skills are not only vital for academic growth within STEM fields but also contribute significantly to the development of critical thinking and effective communication.

Scientific and Engineering Practices

Integrating scientific and engineering practices into STEM education is crucial for developing students' skills in inquiry, experimentation, and problem-solving. These practices involve formulating questions, designing and conducting investigations, analyzing and interpreting data, using computational thinking, and constructing explanations based on evidence.

The evaluation revealed encouraging results in several areas of scientific and engineering practices, particularly in students' ability to formulate inquiry-based questions and conduct experiments to seek answers. Additionally, the program effectively cultivated students' skills in making observations and articulating relationships and patterns. However, there was minimal to no evidence suggesting the integration of mathematical and computational thinking within the program activities.

Incorporating mathematical and computational thinking is essential in STEM education programming, as it equips students with the ability to quantify and model phenomena, analyze data using mathematical and statistical techniques, and leverage computational tools and simulations to solve complex problems.

7.0 Conclusion

Overall, the findings provide valuable insights into the strengths and areas for improvement in the instructional strategies employed by the after-school enrichment program. While the program demonstrates effective practices in questioning techniques, fostering process skills, and promoting scientific inquiry, there is room for growth in integrating play-based learning, encouraging perspective-taking, and incorporating mathematical and computational thinking into STEM activities. Addressing these areas can further enhance the program's effectiveness in conveying STEM content, promoting student engagement, and addressing diverse learning needs.

8.0 Recommendations

General Recommendations

While the program exhibits notable strengths in questioning techniques, process skills development, and scientific inquiry, opportunities exist to bolster its play-based learning approach and integration of mathematical and computational thinking. The following recommendations aim to address areas for improvement identified in the evaluation:

Improving Perspective-Taking in Play Activities

1. **Collaborative Problem-Solving Projects:** Incorporate group activities that necessitate diverse roles, encouraging students to adopt and understand different perspectives. For instance, a project where students design a simple community garden can include roles such as planners, builders, and environmentalists, each

with its unique viewpoint. This approach not only cultivates perspective-taking but also teaches empathy and collaboration.

2. **Role-Playing Scenarios:** Develop role-playing exercises that mimic real-world situations requiring scientific or engineering solutions. By stepping into the shoes of various stakeholders (e.g., city planners facing an environmental issue), students can appreciate different viewpoints and understand the multifaceted nature of real-world problems.
3. **Story-Based Learning:** Utilize narratives that integrate STEM concepts with characters facing challenges requiring empathy and diverse perspectives. After the story, prompt discussions and activities that encourage students to reflect on and articulate different viewpoints presented in the story.

Incorporating Mathematical and Computational Thinking into STEM Activities

1. **Math-Inspired Challenges:** Design activities that inherently require mathematical reasoning. For instance, tasks that involve measuring distances, calculating speeds, or estimating resources needed for a project can seamlessly blend math skills with engineering or scientific inquiries.
2. **Computational Tools and Digital Games:** Leverage technology by integrating age-appropriate coding activities or digital games that promote logical and computational thinking. Platforms like Scratch or Tynker offer a playful yet educational approach to grasp foundational coding concepts, aligning with the playful nature of the program.
3. **Data Analysis in Experiments:** Encourage students to collect, analyze, and interpret data in their scientific inquiries. Simple statistical concepts, such as averages, medians, and graphical representations, can be introduced through hands-on experiments. This not only embeds mathematical thinking in a practical context but also enhances their understanding of scientific practices.
4. **Design Projects with a Computational Twist:** Engage students in engineering design projects that require basic programming or algorithmic thinking. For

example, designing a simple automatic watering system for plants introduces basic coding and systems thinking, stimulating interest in robotics and automation.

Specific Recommendations for the Lesson on Biomedical Engineering and the Human Body, DNA Build Activity

Incorporating Perspective-Taking

1. **Role-Playing Genetic Counselors and Clients:** To foster perspective-taking, incorporate a role-playing element where half of the class assumes the role of genetic counselors and the other half are clients seeking advice based on genetic information. Each 'client' could present a scenario requiring the counselor to explain the impact of certain genotypes on phenotypes, encouraging students to view genetics from the perspective of individuals making real-life decisions based on their DNA.
2. **Ethical Debates:** After the DNA model-building activity, initiate a debate on the ethical implications of genetic engineering, genetic privacy, or personalized medicine. Divide students into groups representing different stakeholders, including scientists, patients, lawmakers, and the general public. This encourages them to consider and articulate the diverse perspectives and ethical considerations involved in the application of genetic information.

3. **Personalized DNA Stories:** Have students create brief narratives or comic strips portraying how a character (real or fictional) might feel discovering certain traits in their DNA, highlighting how genetics can influence identity and personal choices. Share these narratives in small groups to discuss the emotional and social implications of genetic information from various perspectives.

Incorporating Mathematical and Computational Thinking

1. **DNA Sequence Analysis:** Introduce a simple computational task where students use a basic coding platform or algorithm (which could be as simple as a set of instructions on paper) to identify patterns within a sequence of DNA they have created. They could calculate the percentage of each nucleotide present or find sequences that could lead to certain traits, integrating mathematics in analyzing biological data.
2. **Model Scaling Activity:** Challenge students to scale their DNA model to reflect the actual length of a human DNA molecule if they were to extend their model using a specific scale (e.g., 1 gumdrop = 1 million base pairs). This would involve mathematical calculations to understand the immense length of DNA and the compactness required to fit it into the nucleus of a cell.
3. **Error Detection Coding:** Discuss how DNA replicates with high fidelity but not without occasional errors, much like data transmission errors in computational systems. Have students simulate DNA replication using their models and introduce 'errors' intentionally. The task involves using mathematical concepts to calculate error rates and discuss error correction mechanisms in both biology and computational data transmission.
4. **Creating a Phenotype Probability Chart:** After students decipher the genotype from the phenotype given on the identity cards, have them calculate the probability of different phenotypes arising from genotypes using simple Punnett squares. This introduces basic genetic inheritance concepts and the mathematical probability behind trait expression.

Specific Recommendations for the Lesson on Animal Adaptation Experiments

Incorporating Perspective-Taking

1. **Adaptation Journal:** Encourage students to maintain an adaptation journal. For each animal discussed, including the venom-resistant animals and the giant squid, students should write a first-person narrative from the animal's perspective. They could describe a day in their life, focusing on how their unique adaptations (like

venom resistance or jet propulsion for the giant squid) help them navigate their environment. This activity fosters empathy and helps students understand the value of adaptations from the animal's point of view.

2. **Debate on Animal Rights and Conservation:** Following the discussions on venom-resistant animals and the giant squid, organize a classroom debate on topics related to wildlife conservation, such as habitat protection or the impacts of human activity on these creatures. Assign roles to students, such as conservationists, local community members, and wildlife photographers. This exercise allows students to explore and articulate different perspectives on animal conservation and the ethical considerations involved in protecting such unique species.
3. "**Day in the Life" Role Play:** Have students role-play a day in the life of a researcher studying venom-resistant animals or the giant squid. They could simulate setting up experiments, observing animal behavior, and presenting their findings to a scientific community. This role-play can help students appreciate the efforts and perspectives of scientists dedicated to studying and preserving these remarkable creatures.

Incorporating Mathematical and Computational Thinking

1. **Squid Propulsion Math Challenge:** Introduce a mathematical challenge where students must calculate the speed and distance of their balloon squid's travel using simple equations. Provide them with a baseline measurement (e.g., the length of the classroom) and help them calculate the speed based on the time taken to traverse this distance. This activity integrates mathematical thinking into the science experiment, emphasizing the importance of quantitative analysis in scientific studies.
2. **Design Optimization Record Keeping:** For the balloon squid activity, encourage students to keep a design optimization log. In this log, they should record changes made to their squid models (e.g., length of tentacles, placement of fins, amount of air in the balloon) and note the effects on speed and distance. This fosters an

engineering mindset, engaging students in iterative design and mathematical evaluation of their modifications to optimize squid propulsion.

3. **Venom Dilution Experiment:** In addition to the discussions on venom, conduct a simple math-based experiment to explore dilution. Using water and a safe, colored liquid to represent venom, have students experiment with adding different volumes of water to the "venom" to dilute it. They can use proportions or fractions to calculate the dilution levels, mirroring the process of how venom-resistant animals might neutralize venom's effects. This provides a hands-on way to incorporate mathematics into understanding physiological adaptations.
4. **Materials Efficiency Analysis:** After the squid races, have students analyze which materials (e.g., different types of streamers, straws, or balloons) and design aspects contributed most effectively to distance and speed. They can create simple charts or graphs to compare the performance of different designs, applying mathematical concepts to analyze and present their findings. This activity not only integrates STEM skills but also encourages critical thinking about material efficiency in engineering design.

Appendix

A: The ECE Classroom Observation Protocol

Aspect	Dimension				
Questioning	Characteristics and Nature	Patterns and Interactions			
Play	Pretend Play	Socio-dramatic Play	Constructive Play	Exploring Surroundings	
Process Skills	Observing	Describing	Categorizing	Predicting	Communicating
Scientific and Engineering Practices	Questions and Problems	Analyzing and Interpreting	Math and Computational Thinking	Explanations and Designing Solutions	Argument

C: Lesson Plan: Animal Adaptation Experiment

Materials Needed:

- Water
- Three sugar cubes per child
- One styrofoam cup per child
- Diagram of the giant squid (for teacher reference)
- Masking tape
- One roll of streamers per four children
- Scissors
- One balloon per child
- One straw per child
- One medium-sized binder clip per child
- One roll of fishing line
- One sheet of paper per child
- One Sharpie per child

Objective: During this lesson, students will explore animal adaptations, with a focus on venom-resistant animals and the unique features of the giant squid. Through hands-on experiments and activities, students will understand the concept of venom and propulsion systems in animals.

Introduction:

1. Discuss the meaning of animal adaptation and its three types (structural, physiological, and behavioral).
2. Encourage students to share examples of unusual animal adaptations.

Experiment 1: Venom-Resistant Animals

1. Discuss examples of venom-resistant animals (e.g., mongooses, honey badgers, hedgehogs, snakes, opossums, pigs).
2. Explain how these animals have developed adaptations to resist venom.
3. Ask students to identify animals that use venom and discuss the deadliest venomous animal.
4. Demonstrate how spider venom dissolves its prey's body:
    - Place sugar cubes in a styrofoam cup (representing the insect's body).
    - Pour a few drops of water onto the cubes (representing the spider's venom).
    - Discuss the observed effect (water dissolving the sugar cubes).
5. Explain the science behind the experiment (spiders inject digestive enzymes to liquefy their prey's tissues).

Technology Integration: Watch the video "Extreme Adaptations: Animal Defenses" by the St. Louis Zoo (https://www.youtube.com/watch?v=DsNOP2LX4SQ).

Experiment 2: Giant Squid Propulsion System

1. Discuss the giant squid's unique features and adaptations.
2. Explain how the giant squid uses jet propulsion to move through water.
3. Activity: Create a moving squid model.
    - Cut eight streamers for the legs and draw dots for suckers.
    - Tape the legs to a balloon.
    - Make two stabilizing fins and tape them to the balloon.
    - Tape a straw on top of the balloon for the siphon.
    - Draw a large eye with a Sharpie.
4. Design a system for the squid model to travel quickly or far.
    - Inflate the balloon and clamp the nozzle with a binder clip.
    - Adjust the placement of tentacles and fins for efficiency.
    - Set up a racing string across the classroom.

    - One student holds the string tight, another pinches the nozzle, and a third releases the squid.
    - Mark the final position or time the squid's travel.
5. Discuss observations and design improvements for better propulsion.

C: Pre and Post Test Survey Instrument

STEM Interest

	Very Enthusiastic	Enthusiastic	Less Enthusiastic	Not Enthusiastic
	😍	😊	😐	😔
What emoji best describes how you feel about science?				
What emoji best describes how you feel about math?				

STEM Career Interest

	Yes	No
	👍	👎
Would you be interested in a job in science, engineering or math when you grow up?		