A Case Study: Partnership with DC Public Savoy Elementary School

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1. Introduction

1.1. Program Introduction

In response to the rapid changes in the industrial structure, the government has provided STEAM education to more children nationwide to help them develop future science and technology skills. However, there is a significant disparity in the availability of STEAM education among different socio-economic groups.

To address this inequality, our nonprofit organization is committed to providing STEAM programs at no cost in underprivileged communities. We aim to enhance access to STEAM education for children and raise awareness about its importance. This initiative aligns with our vision of reducing inequality in STEAM education.

More specifically, the organization provides community-based, informal STEAM programs at the DC Public Libraries and school-based STEAM afterschool programs in partnership with DC Public Schools, making STEAM education more accessible and demand-driven to meet the needs of students. Additionally we provided math tutoring program at a DC public school and organized field trips to places such as the National Children's Museum, where children can engage in various STEAM activities.

Our STEAM programs are designed for students in grades K-5, as introducing STEAM concepts during early education is crucial for fostering children's creativity and innovation for the future. The programs are delivered through hands-on activities that utilize a variety of STEAM kits. Students engage in project-based work in groups, leading to the creation of final projects as outcomes. Throughout these group activities, our instructors actively engage with the students and assess their performances.

1.2. Savoy Elementary School Partnership Background and Purpose

Despite advancements in STEAM education, public schools in Washington, DC, especially those in underserved communities, still lack adequate resources and curriculum for STEAM subjects. Additionally, there is limited time to teach these subjects during school hours. Savoy DC Public School, located in the heart of the Anacostia region in Southeast DC, faces similar challenges. The school lacks both sufficient time and resources to provide effective STEAM education, despite school leaders recognizing the urgent need for STEAM education to enhance student achievement in these subjects.

To address the issues, our organization offered the STEAM program during after-school hours to fill the gaps in STEAM education. Through partnership, the organization provided STEAM educational content, resources, and highly qualified instructors, while the school provided classrooms, recruited children, and assigned two school staff members to support the program. Having a secure classroom, registered students, and competent school teachers, as offered by the school, were essential to making the program successful and achieving our shared goals of reducing STEAM disparities.

1.3. Research Scope and Methodology

This case study aims to analyze the effectiveness of our STEAM after-school program operated at Savoy Elementary DC Public School from various perspectives and identify the factors contributing to its success and areas for improvement. To this end, we set out to explore the following key research questions.

Research Questions:

- Did the STEAM after-school program have a significant positive impact on the STEAM learning abilities, problem-solving skills, and collaboration abilities of participating students?
- How do the subjective learning experiences and satisfaction levels of program participants differ from the objective skill assessments of instructors? What insights do these differences provide regarding the program's specific strengths and areas for future improvement?

Research Scope and Approach:

This study focused on two main aspects to evaluate the effectiveness of the program. The first is the overall participation status of the participants, and the second is the participants' subjective perceptions and objective evaluation of their collaborative and problem-solving skills.

To analyze participants' participation, attendance records for each session were examined to identify overall participation trends. An analysis of the participants' satisfaction and their collaborative and problem-solving skills was conducted using two different data sources. (Please refer to Appendix 1 for the survey results and Appendix 2 for the evaluation items.)

- **Participant Survey** (Subjective Perception): A survey was conducted for 18 participants at the end of the program, and responses were collected on a scale of 1 (very negative) to 5 (very positive). This survey aimed to understand students' subjective perceptions, including their perceived improvement in problem-solving skills resulting from program participation. This data provides essential information for understanding internal changes in students, such as learning satisfaction, confidence, and initiative. For example, questions such as an increase in STEAM knowledge (Q10), an increase in confidence in STEAM learning (Q11), and an increase in problem-solving ability (Q12) were used to evaluate subjective perceptions of overall improvement.

- **Instructor Evaluation** (Objective Instructor Evaluation): To complement the subjective perceptions of the participant survey, instructors evaluated 13 students' performance on a scale of 1 (poor) to 5 (excellent). This evaluation provides an objective assessment of collaborative and problem-solving skills. The instructors assessed specific behaviors and outcomes, such as how students approached problems, presented creative solutions, applied step-by-step procedures, analyzed results, and made suggestions for improvement. These evaluations help identify specific strengths and weaknesses in students' current problem-solving abilities, providing practical directions for improvement. For example, problem-solving ability was broken down into sub-components such as "problem approach," "creative solutions," "step-by-step approach," and "result analysis and reflection," enhancing the diagnostic value.

By integrating and analyzing data from two distinct measurement perspectives—the instructors' objective evaluations and children's subjective surveys—we gained a more precise and comprehensive understanding of both the program's successful aspects and the areas for improvement. This thorough understanding will inform future improvements and ensure the program's continued success.

***Table 1* Perspectives on comparing evaluation data to survey data**

Classification	Evaluation data	Survey data
What is measured	Individual students' problem-solving and collaboration skills (observer ratings)	Participants' program experience and perceptions (self-assessment)
How it is measured	1-5 scale scores (per student, per item)	Percentage of responses on 1-5 scale (for all participants)
Key categories	Problem-solving skills, participation in	involvement in team projects, learning

	collaborative activities	outcomes, and problem-solving skills
Characteristics	Objective measures of performance	Subjective measures of satisfaction and perception

Table 2 Difference in measurement perspectives: objective ability vs. subjective cognition

	Instructor's observation and evaluation	**Students' survey responses (self-perception)**
Perspective	An objective observation and assessment of students' actual performance by instructors. Scores (1-5) based on specific behaviors and outcomes, such as how the student approaches a problem, comes up with creative solutions, applies step-by-step procedures, analyzes results, and suggests improvements.	The students' subjective perception of how much they feel their problem-solving skills have improved as a result of participating in the program.
Strengths	Diagnoses specific strengths and weaknesses in a student's current problem-solving skills, providing a clear picture of where they need help.	Helpful in identifying internal changes, such as students' satisfaction with their learning, confidence, and initiative. Essential for understanding learner-centered experiences.

Table 3 Differences in the specificity and diagnostic value of assessments

Instructor's observation and evaluation	**Students' survey responses**
Assesses problem-solving skills by breaking them down into several subcomponents, such as "approaching the problem," "creative solutions," "step-by-step approach," and "analyzing and reflecting on results. This provides diagnostic value in specifically identifying where students demonstrate strengths and weaknesses throughout the process, from understanding the problem to finding solutions and reflecting.	"How much have your problem-solving skills increased?" (Q12) is a broad question that asks about overall improvement. Many of the questions are wider in scope, such as increased STEAM knowledge (Q10) or confidence in learning (Q11), making it difficult to get specific information about which aspects of their problem-solving skills students feel have improved specifically.

2. STEAM Program and Partnership Operations

2.1. Demographic Characteristics of the School

Savoy ES is located in the Anacostia region, which is the heart of Southeast DC (Ward 8). According to DC data, this region is "a predominantly African American community, and approximately 39% of the Ward 8 population is comprised of children and youth. Compared to other District wards, residents of Ward 8 are about 11% less likely to work in the city's labor force. The median income is 38% lower in Ward 8, as compared to other District wards. The percentage of families in poverty is almost twice as high in Ward 8 as compared to the district overall." (Profile of Health and Socio-Economic Indicators DISTRICT OF COLUMBIA DEPARTMENT OF HEALTH Center for Policy, Planning and Epidemiology State Center for Health Statistics). Savoy school's student demographics indicate that 95% of the total enrolled students (199 students) are African American. The school offers an aftercare program, and the students who participate in our STEAM program are those who are in the school's aftercare program.

2.2. Partnership Operations and Program Progress

2.2.1. Partnership establishment and collaboration model

Our organization has established a strategic partnership with the DCPS central office and Savoy Elementary School (ES). In this partnership, Savoy ES provided its facilities and two staff members to support the program. Unlike other partnered DC public schools, Savoy ES secured STEAM activities during academic hours from 3:30 to 4:30 PM. This unique arrangement has enabled students to remain fully engaged throughout the entire 50-minute period, resulting in high attendance rates.

In exchange, the organization offered the program content, resources, and instructors. We enriched Savoy's after-school program by providing STEAM subjects and expanded STEAM education opportunities for Savoy students through this program. This approach successfully addressed the gap in STEAM education during regular class hours, creating a mutually beneficial partnership that enhances the overall STEAM educational experience for the students.

2.2.2 Program curriculum and content

During the 2024-2025 school year, 18 registered students participated in the program at Savoy ES. Participants learned about the five core areas of the curriculum outlined below.

Science: Our senior instructor introduced science and engineering concepts via hands-on activities using various science, engineering, and robotics kits. The students constructed kits and performed various scientific actions during interactive experiments with the instructor. For instance, by utilizing kits, the students incorporated motors, gears, and other mechanical components and explored concepts such as optical illusions, wind power, solar power, gear transmission, and machine drawing. They also produced bubbles by using these machines.

Technology: Computer Science: Our computer specialist instructor provides a hands-on computer hardware lesson, consisting of interactive activities that allow students to see the inside of a computer, touch each part (motherboard, CPU, memory, etc.), and gain a hands-on understanding of its role and how it works. Instead of rigid theories, our program emphasizes hands-on interactive activities that allow children to explore a disassembled computer and learn about the functions of each part, sparking their curiosity and increasing their interest in computer science.

Technology: Virtual Realty (V.R.): We use virtual reality (V.R.) to improve science education and for virtual field trips, as it is an invaluable tool for teaching STEAM subjects. V.R. helped students visualize complex concepts, processes, and environments, making it easier for them to comprehend and remember what they've learned. In addition, V.R. allowed students to take virtual field trips to museums, natural environments, historical sites, and outer space. These simulations enable students to visualize and interact with concepts that may be difficult to observe in the physical world. We ensured that students had VR experiences of no more than 5 minutes each, under supervision.

Engineering and Science: Early exposure to engineering education helps children think critically and tackle challenges systematically by identifying problems and developing solutions. Furthermore, early engineering education sparks curiosity and helps children understand how science and math are applied in real-life situations. We utilized various engineering kits to provide hands-on, engaging experiences that help students develop problem-solving, critical thinking, and creativity skills. For example, the kits introduced basic electronics, motors, and other components, allowing students to build various models and learn about structures and mechanics in a fun and engaging way. As the students built kits with team members, they shared ideas for solving the

problems, fostering a sense of teamwork and collaboration. Also, assembling these kits enhanced hand-eye coordination, fine motor skills, electronic understanding, and practical abilities. The team was also encouraged to produce a team project as an outcome product.

Arts and Engineering: Introducing children to 3D concepts is a vital investment in their future, as it enhances skills in spatial reasoning, problem-solving, and creativity —essential for success in STEAM fields such as animation, game design, and architecture. Using 3D pens, we introduced students to three-dimensional thinking, enabling them to design and construct simple structures while understanding the engineering design process. 3D modeling helped students visualize and manipulate objects, fostering critical thinking about structure, size, and materials. Also, through teamwork, students shared ideas and refined their designs to produce a team project as an outcome product.

Math: By using various hands-on educational resources, we support children's better grasp of mathematical concepts and number senses. We help students build confidence in their mathematical abilities and motivate them to tackle more complex ideas.

- **Math games for number senses:** To improve the students' math skills, we utilized interactive electronic math game toys specifically designed to help children practice essential math skills such as addition, subtraction, multiplication, division, and understanding greater and lesser values in a fun and engaging way.
- **Money Games**: We used fake money to teach mathematical concepts in a practical context. The money game is entertaining and compelling for developing essential financial skills for real-life situations. The game format generates interest and boosts participation, fostering a positive attitude toward learning using hands-on experiences.

2.2.3. How it is delivered

Our STEAM programs are designed and managed by Dr. Lan Joo, the Founder and CEO of the organization. Dr. Joo is responsible for developing the content and curriculum, preparing STEAM learning resources, securing instructors, and ensuring the quality and effectiveness of the programs. Additionally, she writes the program's impact evaluations and establishes partnerships with individual schools and institutions. Dr. Joo focuses on developing STEAM programs specifically for children, recognizing the importance of introducing these concepts at an early age. These STEAM experiences help shape children's cognitive and reasoning abilities, fostering their creativity and innovation for the future.

The programs are delivered through hands-on group projects led by instructors, emphasizing both theoretical concepts and their practical applications. The modalities of the programs include:

First, the programs emphasize **hands-on projects** that encourage children to apply concepts to real-world situations. This approach helps them understand the connections between ideas and their everyday lives. Overcoming challenges during a project teaches valuable lessons in perseverance, resilience, and problem-solving. Additionally, completing these hands-on projects gives children a sense of accomplishment, which boosts their self-esteem and confidence in their abilities. When children are actively engaged in projects and take ownership of their learning, their motivation increases, making the learning process more enjoyable and effective.

Second, we utilize **team-based group activities** that offer children valuable experiences in the collaborative problem-solving process. This approach encourages discussion and teamwork, enabling children to share their ideas, listen to one another, and collaborate to find the best solutions. Through these activities, children learn to collaborate effectively by leveraging each other's strengths and compensating for weaknesses. Engaging in group work also teaches children how to cooperate with different individuals and teams as they strive to achieve a common goal.

Third, our instructors present students with realistic and complex problem situations, along with **guided questions** to enhance problem-solving skills. This approach encourages children to find solutions actively. For example, our instructors ask open-ended questions such as, "How could you approach this differently?", "What do you think will happen?", "Why do you think this has occurred?", and "Are there alternative solutions you can consider?" These questions stimulate students' thinking processes and encourage them to explore various problem-solving options.

Fourth, what sets our programs apart is not just teaching science and engineering as separate disciplines, but our emphasis on **an interdisciplinary approach** to learning. This method ensures that understanding scientific principles facilitates engineering design, while engineering tools and methods enhance scientific inquiry. The activities with science kits, which cover scientific concepts such as gear transmissions and wind/solar power, while also involving the design and construction of working machines (like bubble machines), are excellent examples of how we integrate both subjects, making our program both innovative and effective.

3. Data-driven Performance Analysis

3.1. Attendance Data Analysis

The Attendance Rates data reveal several implications regarding participant engagement and program success. The findings are as follows:

Fifty percent of the participants in the range recorded an attendance rate above 75% (approximately). This high level of attendance indicates high satisfaction and engagement with the program, suggesting that these children find significant value in the experiences offered. The participants' active involvement makes them key contributors to the program's overall success, reflecting their commitment and the program's effectiveness in meeting their needs.

Forty-four percent of participants have an attendance rate of 42-67%. This group consistently demonstrated a willingness to participate in the program; however, their moderate attendance rates suggest that they may have faced barriers that prevented them from attending more sessions. Further analysis of factors such as varying schedules and personal circumstances could help identify ways to increase their participation in the future. By understanding challenges faced by this group, we can enhance overall participation levels.

Overall, 94% of all participants' attendance rates were above 44%, highlighting the program's demand and effectiveness. Our efforts to identify the factors that hindered their attendance could further enhance the program's overall success.

Table 4 Attendance rate ranges

Attendance range	Number of students in the range	Attendance rate range (%) (approx.)[1]	% of students in the range[2]
9-12 times	9	75-100	50
5-8 times	8	42-67	44
Less than 4 times	1	less than 25	6
Total	**18 students**		**100%**

[1] **How to calculate the attendance ranges (approximately)**

These values are expressed as a percentage by dividing the number of sessions students attended by the total number of sessions (12).
Calculate based on the minimum and maximum values for each range.
Group with 9 to 12 attendances:

- Minimum attendance: (9 / 12) × 100% = 75%
- Maximum attendance: (12 / 12) × 100% = 100%

⇨ the attendance range is 75% to 100%.

A group that attended 5 to 8 times:

- Minimum attendance: (5 / 12) × 100% ≈ 41.67% (approx. 42%)
- Maximum attendance: (8 / 12) × 100% ≈ 66.67% (approx. 67%)

⇨ the range of attendance is 42% to 67%.

The group that attended less than 4 times (for example, 1 to 3 times):

- This group attends less than 4 times, so we calculated based on the highest number of times, which is 3.
- Maximum attendance: (3 times / 12 times) × 100% = 25%

⇨ the attendance range as less than 25%. (Note: it starts at about 8% for a single attendance.)

[2] **How we calculated the percentage of students in this group**

This value is a percentage of the number of students in each attendance range divided by the total number of students (18).

- 9-12 attendance group (9 students): (9 / 18) × 100% = 50%
- Group of 5 to 8 attendances (8 students): (8 / 18) × 100% ≈ 44.44% (rounded to 44%)
- Group with less than 4 attendances (1 student): (1 student / 18 students) × 100% ≈ 5.56% (rounded to 6%)

This way of calculating gives a clear picture of the range of attendance for each group and what percentage of the total students they represent.

3.2. Survey Data Analysis

The survey focused on understanding three areas: (1) participants' satisfaction with the program, (2) their experiences with teamwork, and (3) their perceptions of improved learning outcomes and problem-solving skills. Responses were collected using a scale from 1 (negative) to 5 (very positive), and overall, the results were very positive. The survey questionnaire and results can be found in Appendix 1.

3.2.1. Findings from survey data

Analysis of Interest in Activities: This section assesses enjoyment of participating in the program, willingness to participate again, willingness to recommend, and increased interest in the STEAM field.

Q1. How interesting and enjoyable was your participation in the program? All respondents selected a 4 (33%) or 5 (67%), showing that the program itself was delightful and interesting. This is one of its biggest strengths.
Q2. How likely are you to participate in the program again? 100% of respondents chose a 4 or 5, and 83% stated that they would be very likely to participate again, indicating a high level of willingness to participate in the program.
Q3. How likely are you to recommend this activity to a friend? Eighty-nine percent of respondents said that they would positively recommend the program, and 11% were neutral.
Q4. How much did the program increase your interest in STEAM? Eighty-nine percent responded positively to increasing their interest in STEAM, indicating that the program effectively increased children's interest in STEAM fields.

Overall, the program provided a delightful and positive experience for the students, which led to a strong interest in participating again and increased interest in STEAM subjects.
The item the children rated most positively was "Would you like to participate in the program again?" These results show that 83% of all respondents gave the highest possible score of 5, and the remaining 17% also gave a score of 4, indicating that all children expressed a strong desire to participate in the program again. This is the clearest indicator that the program provided the students a delightful and satisfying experience.

Analysis of Team Project Engagement: This section assesses teamwork, communication, and collaboration, and increases confidence in team activities

Q5. How well did you work with your teammates? Eighty-three percent responded positively, while 17% were neutral. This suggests that most students worked well together, but some may have felt there was room for improvement in their collaboration.
Q6. How well did team members communicate and collaborate? Ninety-five percent responded positively, indicating that communication and collaboration within the team were excellent.
Q7. How well did your team work together to solve the problem? Eighty-eight percent responded positively. Teamwork during the problem-solving process was generally good.
Q8. How much has your confidence in team activities increased? Eighty-eight percent responded positively to increased confidence in team activities. While most children gained confidence in teamwork, a small percentage (5%) (1 student) reported that their confidence did not improve.

Overall, participation in the team project was successful, with communication and collaboration being strengths. While most children gained confidence in working in teams, some may have needed more support in collaboration.

Analysis of the Learning Outcomes/Problem-Solving Skills: This section assesses participants' increase in STEAM knowledge, confidence in STEAM learning, and improvement in problem-solving skills.

Q10. How much did you increase your STEAM knowledge during this program? Eighty-four percent responded positively to the increase in STEAM knowledge, indicating that the program was effective in enhancing STEAM knowledge.
Q11. How much has your confidence in learning STEAM subjects increased? Eighty-three percent responded positively, but the percentage of 5-point responses (33%) is relatively low compared to other positive statements. While there was an increase in knowledge, the "large" increase in learning confidence may have been limited for some students.
Q12. How much have you increased your problem-solving skills? Seventy-eight percent responded positively, but the proportion of 2-point responses (11%) suggest that a handful of participants still felt that their problem-solving skills had not improved.

Overall, the program had a positive impact on participants' problem-solving skills. As for the first dataset (Q10), 69% of participants scored a 5 (significantly increased), and 25% scored a 4 (increased), resulting in a total of 94% of participants reported an increase in their problem-solving skills. Regarding the second dataset (Q11), 50% of participants scored a 5 (significantly increased), and 28% scored a 4 (increased), indicating that 78% of participants felt their problem-solving skills had improved. In both cases, the majority of participants reported that their problem-solving skills had improved, suggesting that the program effectively provided problem-solving-focused activities. The children perceived that their abilities improved through encountering and solving real-world problems, rather than simply acquiring knowledge.

However, it should also be noted that the second dataset (Q11) showed some significant changes compared to the first (Q10). First change is a decrease in 'significantly increased (5-point)' responses. 5-point responses, which were 69% in the first dataset, decreased to 50% in the second dataset, meaning that the percentage of participants who felt a 'very significant improvement' decreased. Second change is that there was an emergence of 'moderate (3-point)' and 'barely increased (2-point)' responses. 2-point responses, which were 0% in the first dataset, increased to 11% in the second dataset.

3.2.2. Implications drawn from survey data

First, **there should be a higher frequency and intensity of successful experiences**. For children to feel that they have improved their problem-solving skills, they must experience successful problem-solving. The decrease in the proportion of 5-point responses from Q10 to Q11 suggests that the frequency or intensity of "overwhelming success experiences" may have decreased somewhat. It is essential to balance difficulty levels appropriately so that all participants have enough opportunities to feel a sense of accomplishment.

Second, **problem-solving skills are closely related to teamwork**. The survey data indicate that activities that contributed the most to improved problem-solving skills are Team-based projects, as evidenced by a high correlation between Q12 and Q7. This high correlation suggests that students are likely to have felt that solving problems with their teammates improved their ability to solve problems. Q12 received a high favorable rating in both datasets (94% in the first and 78% in the second), indicating that the program was effective in improving problem-solving skills. Q7 directly asks, "How well did the team work together to solve the problem?" and received high favorable ratings in both datasets (93% in the first, 88% in the second). These Q7 responses indicate that the students perceived the experience of working in teams to solve problems as very positive. Furthermore**,** the high scores on Q5, Q6, and Q8 show that this teamwork is efficacious in improving problem-solving skills.

3.2.3. Strengths and areas for improvement based on the analysis of survey data

Strengths of the program:

- **High satisfaction and willingness to participate**: The students enjoy the program and are eager to participate again.
- **Increased STEAM interest and knowledge**: The program successfully increased children's interest in STEAM fields.
- **Strong team communication and collaboration**: The students communicated well on team projects.
- **The hands-on team project activities**: The activities effectively enhance problem-solving skills. By working collaboratively to complete various projects, students are required to apply their knowledge and learn through trial and error with their teammates. This process fosters both logical thinking and creativity, making it an effective way to develop comprehensive problem-solving skills.

Areas for improvement:

- **Increasing confidence in STEAM Learning**: Although there was an increase in knowledge, relatively few "substantial" increases in confidence through individualized feedback and a sense of accomplishment. To foster a greater understanding of success and accomplishment and to help students acknowledge their growth, we can celebrate small wins and take time to reflect together after they solve complex problems.

3.3. Evaluation Data Analysis

This analysis is based on data assessing (1) students' problem-solving skills, (2) collaborative work, and (3) feedback and reflection, rated on a scale of 1 to 5, where 1 indicates the lowest performance and five the highest. The instructors observed their group students and evaluated their performances. We analyzed overall student performance in each of the key assessment areas. The detailed scores for each student are shown in Appendix 2.

3.3.1. Findings from evaluation data

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Problem-Solving Skills: The instructors assessed students' ability to define a problem, gather information, propose a creative solution, apply a step-by-step approach, analyze results, and suggest improvements. Detailed item average scores for problem-solving skills are shown in Table 5.

Table 5

Items	**Scores**
Problem Approach	4.07
Creative Solution	3.86
Evaluate step-by-step approach	4.07
Analysis of Results and Reflection	3.93
Category Average	**3.98**

The students performed well with an average score of 3.98. While students scored relatively well on 'Problem Approach' and 'Evaluate step-by-step approach,' there is room for growth in 'Creative Solution' and 'Analysis of Results and Reflection'. This presents an opportunity for targeted support and improvement.

Collaborative Work: The instructors assessed students' ability to distribute roles well within a team, communicate effectively, and collaborate in solving problems and finding solutions. Detailed item average scores for collaborative work are shown in Table 6.

Table 6

Items	**Scores**
Role distribution	3.79
Degree of cooperation	4.07
Problem-Solving Approach (Team)	4.00
Solution (Team)	3.93
Category average	**3.95**

The students' ability to work collaboratively was acceptable, with an average score of 3.95. Particularly noteworthy were the areas of 'Degree of cooperation' and 'Team-Based Problem-Solving Approach'. However, the aspect of 'Role distribution' is crucial and may require some improvement. As strengthening teamwork skills is an essential goal of STEM programs, we can support this area more intensively.

Feedback and Reflection: The instructors assessed team members' ability to provide effective feedback to each other. Detailed item average scores for feedback and reflection are shown in Table 7.

Table 7

Items	**Scores**
Feedback and Reflection	3.86
Category average	**3.86**

Feedback and reflection skills averaged 3.86, which is in line with the other key areas. This is an essential aspect of team learning and can be enhanced with ongoing practice and guidance, such as regular peer feedback time and structured reflection exercises.

3.3.2. Implications drawn from evaluation data and suggestions

Problem-solving skills: Students have demonstrated exceptional problem-solving skills, particularly excelling in their approach to problems and the step-by-step evaluation of solutions. This is a testament to the program's effectiveness in instilling a robust problem-solving framework in our students. However, there was room for improvement in "creative solutions" and "analysis and reflection on results." This indicates that the program was successful in helping students understand and apply the problem-solving framework; however, it suggests that the following areas need to be addressed.

- **Foster creativity and critical thinking**: Activities should be strengthened to encourage students to approach problems from various perspectives beyond fixed frameworks and derive unique solutions.
- **Encourage in-depth analysis of results**: Learning should be deepened by providing more opportunities for students to analyze their problem-solving processes and reflect deeply on the results, rather than simply solving problems.

Collaboration skills: Students' collaboration skills were generally good, but the "role sharing" item scored lower than other areas of collaboration (e.g., "degree of cooperation" and "team-based problem-solving approach"). This indicates that the following points should be considered to strengthen teamwork.

- **Provide clear division of roles and strengthen responsibilities**: It is essential to provide specific guidelines and training so that all team members clearly understand their roles and fulfill their duties effectively. This will help improve the efficiency of team activities and prevent certain students from taking on too many roles.

Feedback and reflection skills: Feedback and reflection skills scored similarly to other key areas. Considering that these skills are essential elements of team learning, the following measures can be taken to strengthen them further.

- **Introduce regular peer feedback time**: It is effective to hold regular feedback time when students can practice giving each other constructive feedback.
- **Design structured reflection activities:** We can consider incorporating structured reflection activities into the program to help students systematically review their learning process and teamwork experiences and identify areas for improvement.

3.4. Analysis of evaluation data in connection with survey results

3.4.1. Findings from analysis of evaluation data in connection with survey results

Our analysis of the correlation between evaluation data conducted by instructors and the survey data answered by students helps us understand the context of the survey results. We quantified students' problem-solving and collaboration skills through the evaluations, which helped us interpret the survey data more effectively. The findings are as follows:

Problem-solving skills: The low rating responses to improved problem-solving skills in the survey results (11% of 2-point responses to Q12) are consistent with the individual assessment data showing that some students scored relatively low in areas such as defining the problem, taking an organized approach, and analyzing results. This suggests that, despite overall positive trends, some students require more intensive guidance on problem-solving skills.

Collaboration skills: Overall, in the survey, communication and collaboration in teamwork was an extreme strength (95% positive responses in Q6), but there were 17% who were neutral in Q5 and 5% who did not feel confident in Q8, which connects to students who scored in the 2-3 range on some collaboration items in the assessment data. These students demonstrate that they require additional support in areas such as role distribution, teamwork to solve problems, and collaborative problem-solving.

3.4.2. Implications drawn from the findings and suggestions

The survey data clearly demonstrate the significant success of the STEAM afterschool program. Participants expressed overwhelming enjoyment of the program, a strong desire to participate again, and an increased interest in STEAM subjects, all of which are strong indicators of its effectiveness. Additionally, the excellent communication and collaboration within the team deserve commendation.

When we compared the individual student evaluation data with the survey results, we found that, while there were generally positive trends, some students scored low in areas related to problem-solving and collaboration. This correlation helps clarify some of the lower ratings recorded in the survey. We gained further insight into the implications of these findings, which include:

- **Individual differences amidst high agreement**: Most students performed well as assessed by their instructors and as perceived by themselves, indicating that the program provides an overall successful learning and collaboration experience. However, for some students, the evaluation scores were lower, which is likely reflected in the 'neutral' or 'low score' responses in the survey results.

- **A gap between 'perceived' and 'actual' performance**. While the survey asks for perceptions of 'how much you have improved' or 'how well you think you did', the evaluation measures actual performance. While perception and reality are generally aligned, a small number of students with low scores may indicate that they recognize their limitations, or vice versa: they may think they did well but are rated as needing improvement in the eyes of their instructors. The data in this report suggests that students with lower ratings may have also given lower cognitive responses themselves.

To maintain the overall success of the program, we should focus on students who scored low in the evaluation ratings. By analyzing specific areas of the survey where they felt weak or saw little progress, we can better identify which students need targeted support and intervention. Here are some suggestions for enhancing the program:

- **Increase individualized support:** We should target students with specific weaknesses in areas like "problem-solving" and "collaboration" (e.g., initially approaching a problem, applying systematic steps, and working collaboratively to arrive at a solution) that are commonly identified in survey and evaluation data. To support these students, we should offer them tailored feedback and additional guidance.

- **Assign and train different team roles**: To ensure that all team members are actively involved and understand their roles in team activities, we should clarify role responsibilities and implement teamwork training. This approach will help students who score low on "distributing roles."

- **Increase opportunities for self-reflection**: To address areas where students scored low, such as 'analyzing and reflecting on results' and 'feedback and reflection', we should provide more opportunities for students to analyze their process, results, and interactions with teammates. This practice can help them identify areas for improvement, fostering their holistic development.

4. Conclusion

4.1 Summary of Successful Outcomes

Our partnership with Savoy ES stands out for its distinctive approach and notable success in multiple areas. The key success stories are as follows.

Contributed to expanding access to STEAM education and reducing disparities: We have expanded access to STEAM education and decreased disparities in an underserved community by offering high-quality STEAM programs to public school students at no cost. Our efforts have fostered the development of future science and technology skills in these young learners, effectively addressing the gap in STEAM instruction at schools with limited class time dedicated to these subjects.

Contributed to increasing demand for STEAM: The increased demand for STEAM was clearly demonstrated by the high satisfaction levels and strong willingness of students to participate again, as indicated in the survey. This positive feedback highlights the program's effectiveness in generating interest and enthusiasm for STEAM among students.

Improved STEAM skills and collaboration abilities: The program not only increased students' interest and understanding of STEAM knowledge but also significantly improved their problem-solving and teamwork skills. Both instructor evaluations and student surveys confirmed the

increase in high-level collaboration skills, reassuring us about the program's effectiveness in enhancing STEM skills.

Established an effective cooperation system: Through a strategic partnership with Savoy ES, the organization provided educational content, learning materials, and expert instructors, while the school provided facilities and personnel. This complementary partnership led to significant synergies by effectively combining the resources of both parties, ultimately working towards the shared goal of reducing disparities in STEAM education.

4.2. Lessons Learned and Success Factors

The key lessons learned and factors that contributed significantly to the success of this partnership are as follows.

The effectiveness of hands-on, team-based project learning: Using hands-on educational kits and materials, students collaborate in teams to create a variety of projects. These engaging activities not only enhance student interest but also play a significant role in improving collaboration and problem-solving skills.

Importance of team-based collaborative learning: Team activities greatly enhanced students' communication and collaboration skills. Through problem-solving processes that required teamwork, children acquired knowledge and naturally learned various social and collaborative problem-solving skills. This was reflected in high positive evaluations in both instructor evaluations and student surveys.

Importance of student satisfaction and willingness to participate again: One of the most critical indicators of success was that students expressed high satisfaction with the program and a strong willingness to participate again. This is clear evidence that the program provided students with enjoyable and meaningful experiences, which will have a positive impact on the program's long-term sustainability.

Effective communication and collaboration with schools: The school's active participation, which involved providing classroom space, ensuring student attendance, and allocating one hour for the program, was crucial to the success of the initiative. Continuous communication between the school and the organization was essential to achieving positive outcomes.

Need for customized support: Although the majority of students experienced positive changes, some students struggled to acquire skills or gain confidence. This suggests that individualized support tailored to each student's learning pace and level of understanding is necessary, rather than a one-size-fits-all approach, and that deeper intervention is essential for some students.

4.3. Future Directions and Recommendations

4.3.1. Ways to improve our STEAM program

Strengthen individualized support: As demonstrated in this study, some students experienced difficulties in specific areas of problem-solving and collaboration. In future programs, we need to identify these students more closely and provide in-depth feedback and additional guidance tailored to their specific weaknesses to promote individual growth further.

Strengthen role-sharing in teamwork: We need to improve role-sharing experiences for students who scored low during the program, ensuring that all team members can actively participate in activities and clearly understand their responsibilities.

Increase opportunities for self-reflection: To enhance students' performance in areas such as "analysis and reflection on results" and "feedback and reflection," it is crucial to provide more opportunities for self-reflection. We can encourage students to evaluate their learning processes, outcomes, and interactions with team members.

Bridge the gap between perception and actual performance: By conducting a more in-depth analysis of the subtle differences between survey results and instructor evaluation data, we can help students close the gap between their self-perceived growth and actual performance. This approach is crucial in helping students more accurately identify their strengths and weaknesses and translate them into practical skills.

Conduct pre- and post-data collection: To measure the program's effectiveness more quantitatively and objectively, pre- and post-data collection should be conducted. This data will enable us to set more precise directions for program improvement.

4.3.2. Proposals for expanding partnerships with other schools

Bridge the STEAM education gap: We will address the shortage of STEAM education resources in schools, especially in underserved areas, as well as the limited instructional time available for these subjects during regular school hours. To help overcome this challenge, we are offering schools a free STEAM program during after-school hours.

Secure active participation and support from schools: We propose a partnership model that leverages the strengths of both our organization and the schools. In this collaboration, our organization will provide program content, resources, and instructors, while the schools will contribute space, allocate one hour for the STEAM program, and ensure student participation. When pursuing partnerships with additional schools, it is essential to highlight the value of this cooperative structure and actively encourage their involvement.

Emphasize evidence-based educational outcomes: We will highlight specific educational results through data, such as improvements in students' knowledge of STEAM subjects, problem-solving skills, confidence, and collaboration abilities, to demonstrate the program's effectiveness. Additionally, we will showcase students' high satisfaction rates and their willingness to participate in the program again, as indicated by survey data, to promote our initiative.

Maintain an activity-centered program model: Our hands-on, team-based learning model, which has resulted in high student satisfaction and positive learning outcomes, should be actively implemented in other school partnerships. This approach is the most effective way to uphold the principles of STEAM education and engage students' interest in the subject.

Engage in pre-discussions to build sustainable relationships: For long-term partnerships, it is essential to engage in thorough pre-discussions with schools to establish clear agreements on key issues, such as resource allocation, role distribution, and goal setting for program operations.

5. Appendices

5.1. Appendix 1. Survey questionnaire and results

	Questions	Ratings				
		5	4	3	2	1
Interest in activities	1. How much interest and fun did you have while participating in the program? 1 (not at all likely to participate) to 5 (very likely to participate)	67%	33%	0	0	0
	2. Would you like to participate in the program again? 1 (not at all likely to participate) to 5 (very likely to participate)	83%	17%	0	0	0
	3. How likely would you recommend this activity to a friend? 1 (not at all likely to recommend) to 5 (very likely to recommend)	50%	39%	11%	0	0
	4. How much has your interest in STEAM increased? 1 (not at all increased) to 5 (significantly increased)	56%	33%	11%	0	0
Team Project Engagement	5. How well did you work with your teammates? 1 (not at all well) to 5 (very well)	50%	33%	17%	0	0
	6. How well did the team members communicate and collaborate? 1 (not at all well) to 5 (very well)	56%	39%	5%	0	0
	7. How well did the team work together to solve the problem? 1 (not at all well) to 5 (very well)	44%	44%	11%	0	0
	8. How much has your confidence in working in a team increased? 1 (not at all increased) to 5 (significantly increased)	67%	22%	5%	5%	0
Learning Outcomes/Problem-Solving Skills	10. How much do you think your STEAM-related knowledge increased during this program? 1 (not at all increased) to 5 (significantly increased)	56%	28%	17%	0	0
	11. How much do you think your confidence in learning STEAM subjects has increased? 1 (not at all increased) to 5 (significantly increased)	33%	50%	11%	5%	0
	12. How much do you think your ability to solve problems increased? 1 (not at all increased) to 5 (significantly increased)	50%	28%	11%	11%	0

9. In which topics do you feel the most improvement?	Science	Tech	Engineering	Math
	7	4	7	4

5.2. Appendix 2. Evaluation results

	Questions	Student Name				
		A	B	C	D	E
Problem-Solving Skills						
Problem Approach	How effectively did the student define the problem and gather the necessary information? (1-5 scale)	2	3	3	2	5
Creative Solution	How original was the proposed solution compared to existing alternatives? (1-5 scale)	3	4	4	3	5
Evaluate the step-by-step approach	How effectively did the student apply a structured approach to solving the problem? (1-5 scale)	3	5	5	3	5
Analysis of Results and Reflection	How effectively was the student analyzing the project results and suggesting future improvements? (1-5 scale)	3	4	4	3	5
Collaborative Work						
Role distribution	How well did each team member fulfill their designated role? (1-5 scale)	2	3	4	2	5
Degree of cooperation	How effectively did team members communicate with one another? (1-5 scale)	3	4	4	3	5
Problem-Solving Approach	How well did the team work together to address the problem? (1-5 scale)	3	4	4	2	5
Solution	How well did the team work together to find the solution? (1-5 scale)	3	3	4	2	5
Feedback and Reflection	How effectively did team members provide feedback to one another? (1-5 scale)	3	3	4	3	5

	Questions	Student Name				
		F	G	H	I	J
Problem-Solving Skills						
Problem Approach	How effectively did the student define the problem and gather the necessary information? (1-5 scale)	5	5	5	5	4
Creative Solution	How original was the proposed solution compared to existing alternatives? (1-5 scale)	5	5	5	5	3
Evaluate the step-by-step approach	How effectively did the student apply a structured approach to solving the problem? (1-5 scale)	5	5	5	5	5
Analysis of Results and Reflection	How effectively was the student analyzing the project results and suggesting future improvements? (1-5 scale)	5	5	5	5	3
Collaborative Work						
Role distribution	How well did each team member fulfill their designated role? (1-5 scale)	5	3	5	3	4
Degree of cooperation	How effectively did team members communicate with one another? (1-5 scale)	5	4	5	4	5
Problem-Solving Approach	How well did the team work together to address the problem? (1-5 scale)	5	5	5	5	4
Solution	How well did the team work together to find the solution? (1-5 scale)	5	5	5	5	4
Feedback and Reflection	How effectively did team members provide feedback to one another? (1-5 scale)	5	5	5	5	4

	Questions	Student Name				
		K	L	M	N	
Problem-Solving Skills						
Problem Approach	How effectively did the student define the problem and gather the necessary information? (1-5 scale)	5	5	5	2	
Creative Solution	How original was the proposed solution compared to existing alternatives? (1-5 scale)	5	5	3	2	
Evaluate the step-by-step approach	How effectively did the student apply a structured approach to solving the problem? (1-5 scale)	5	5	3	2	
Analysis of Results and Reflection	How effectively was the student analyzing the project results and suggesting future improvements? (1-5 scale)	5	5	4	2	
Collaborative Work						
Role distribution	How well did each team member fulfill their designated role? (1-5 scale)	5	5	3	4	
Degree of cooperation	How effectively did team members communicate with one another? (1-5 scale)	5	5	3	4	
Problem-Solving Approach	How well did the team work together to address the problem? (1-5 scale)	5	5	4	2	
Solution	How well did the team work together to find the solution? (1-5 scale)	5	5	4	2	
Feedback and Reflection	How effectively did team members provide feedback to one another? (1-5 scale)	5	5	3	2	