Bringing Space to Classrooms: A Modified Hands-On CanSat Program for Promoting STEM Education and Career Aspirations

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Chanraksmey (SooAh) Lay is an aspiring mechanical engineer with a passion for hands-on learning and inspiring the next generation of STEM leaders. She recently conducted a summer research project through Bucknell University program titled ”Bringing Space to Classrooms: A Modified Hands-On CanSat Program for Promoting STEM Education and Career Aspirations.” Her work focuses on making space and engineering education more accessible by translating real-world satellite concepts into engaging, classroom-friendly activities for middle school through high school students.

Beyond her research, SooAh is actively involved in engineering outreach, mentorship, and student-led design initiatives. She is driven by a desire to bridge technical innovation with educational impact, particularly in communities where access to STEM opportunities is limited. Through her studies and continued involvement in aerospace-related projects, she hopes to contribute to the advancement of space technology while empowering young students to pursue futures in science and engineering.

Dr. Jude Okolie, Bucknell University

Dr. Jude Okolie is an Assistant Professor in the Department of Chemical Engineering at Bucknell University, USA. He received his M.Sc. degree in Petroleum Engineering from Imperial College London, United Kingdom, in 2015, and his Ph.D. in Chemical Engineering from the University of Saskatchewan, Canada.

Dr. Okolie has several years of experience in teaching, research, and curriculum development at both graduate and undergraduate levels. He has taught courses including Sustainable Energy Systems and Engineering Design at the University of Oklahoma, as well as Materials Science, Data Science for Chemical Engineering, and Heat and Mass Transfer at Bucknell University. At the University of Saskatchewan, he taught Thermodynamics and Process Simulation and Control. His teaching philosophy emphasizes experiential and active learning, encouraging students to integrate critical thinking, teamwork, and problem-solving in addressing real-world engineering challenges.

His research interests include sustainable energy systems, carbon capture and utilization (CCU), circular economy approaches, and the upcycling of spent lithium-ion batteries into lithium orthosilicate (LiSiO) sorbent–catalyst materials for integrated CO capture and syngas production. Dr. Okolie has published more than 70 papers in reputable peer-reviewed journals on topics such as techno-economic modeling of decarbonization pathways, sustainable process design, and advanced materials for CO capture. His research integrates fundamental science, applied engineering, and policy analysis to advance low-carbon technologies.

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Abstract

CanSat is a soda-can-sized model satellite designed to enhance STEM education and inspire students' interest in engineering and space-related fields. Previous studies show that CanSat projects can strengthen students' problem-solving abilities, teamwork skills, and interest in STEM careers. However, many traditional CanSat programs assume prior programming knowledge or technical experience, creating barriers for many middle and high school learners.

This paper presents a modified CanSat program designed to lower these entry barriers by integrating simplified hardware, beginner-friendly software tools, and a structured experiential curriculum. The program features a four-layer PCB system, a web-based learning platform, and a ground station interface that enables students with little or no prior experience to build, program, and launch a functional CanSat.

The program was piloted with 15 middle and high school students in the Lewisburg, Pennsylvania region through a five-day hands-on workshop. Student learning outcomes and perceptions were evaluated using quizzes, hands-on performance observations, and post-program survey responses. Results indicate that 90% of participants reported an improved understanding of engineering work, increased interest in engineering, and greater confidence in engaging with STEM-related activities.

These findings suggest that simplified and scaffolded CanSat experiences can make complex aerospace engineering concepts accessible to novice learners while supporting early STEM interest and career exploration. Future work will focus on expanding the program to additional schools and developing a teacher-ready implementation package to support broader classroom adoption.

I. Introduction

A. Background

Originating from the work of Professor Robert Twiggs at Stanford University, CanSat programs have been adopted internationally to promote hands-on learning and stimulate interest in STEM careers [1]. CanSat projects provide students with a hands-on introduction to aerospace engineering and broader STEM fields by combining the design, assembly, and operation of miniature satellites with practical problem-solving experiences. These programs engage learners in core engineering tasks such as integrating sensors, programming microcontrollers, and analyzing telemetry data, enabling students to develop technical confidence and practical skills [2], [3].

Research indicates that participation in CanSat activities enhances problem-solving abilities, teamwork, and understanding of engineering processes while fostering greater interest in STEM careers [4]. Immersive implementations of CanSat programs within classroom or university curricula further allow students to connect theoretical knowledge with real-world engineering applications, promoting collaboration, data-driven decision-making, and authentic engineering practice [5]. Additionally, international surveys of CanSat initiatives demonstrate that these programs can be delivered in accessible, scalable formats, providing meaningful experiential learning opportunities that introduce students to embedded systems, electronics, and aerospace concepts [6]. Collectively, these studies support the use of CanSat programs as an effective and engaging platform for motivating students to explore engineering pathways and pursue further STEM engagement. Prior research in engineering education highlights the importance of early experiences that help students develop both confidence and interest in STEM fields. Expectancy-value theory suggests that students are more likely to pursue STEM pathways when they believe they are capable of succeeding and perceive value in the activity [7]. Similarly, research on science and engineering identity indicates that hands-on engineering experiences can help students begin to see themselves as capable participants in technical fields, which is a key factor influencing long-term STEM engagement [8]. Programs that provide authentic engineering tasks, such as designing systems, collecting data, and solving real-world problems, can therefore play an important role in shaping students' perceptions of engineering careers. Effective introductory STEM activities are often designed using the principle of 'low-threshold, high-ceiling' learning environments, where beginners can participate with minimal prior knowledge while still allowing deeper exploration as students gain experience. Scaffolded project-based learning activities help novice learners gradually build technical skills while maintaining engagement and reducing frustration. Short-duration outreach programs, such as week-long workshops, typically focus on achievable outcomes including increased STEM awareness, improved confidence with technology, and greater interest in engineering fields rather than deep technical mastery. Designing accessible engineering experiences within these constraints is therefore an important challenge for STEM outreach initiatives.

Despite these demonstrated benefits, many existing CanSat implementations involve complex hardware integration, sensor configuration, and embedded programming tasks that can be challenging for novice learners. Documented CanSat workshops and experimental missions often include multi-sensor systems, communication modules, and custom flight software that require careful configuration and technical guidance [4], [5]. While these implementations provide valuable engineering experience, they may present barriers for middle or high school students with limited prior exposure to electronics or programming. To address these challenges, this paper proposes a modified CanSat program tailored to be inclusive and accessible for middle and high school students with little or no prior technical background. The program incorporates simplified hardware modules, beginner-friendly software tools, and a guided curriculum that supports step-by-step skill development while maintaining the core engineering elements of a CanSat mission. This study contributes to engineering education research by presenting the design, implementation, and preliminary evaluation of a modified CanSat program intended to lower barriers to entry for middle and high school students. The paper describes the system architecture and curriculum structure and evaluates educational outcomes from a pilot workshop, focusing on students' technical confidence, understanding of engineering practices, and interest in STEM careers.

B. Conceptual Framework

This study is guided by research on STEM motivation and engineering identity development. Prior studies suggest that hands-on engineering experiences can influence students' perceptions of their own abilities and their interest in pursuing STEM pathways [7]. In particular, experiential learning environments that allow students to design, build, and test real systems can strengthen technical confidence and help students envision themselves in engineering roles.

Based on this framework, the modified CanSat program was designed to provide authentic engineering tasks, such as sensor integration, programming, data analysis, and mission planning, that mirror real aerospace engineering practices. The evaluation of the program therefore focuses on indicators such as students' confidence with technical tools, understanding of engineering work, and interest in STEM careers, which are commonly used measures in STEM outreach research.

This paper is presented as a Work-in-Progress (WIP) study, describing the design and initial implementation of the modified CanSat program along with preliminary evaluation results from its pilot workshop.

II. Methodology

The methodology is structured into **five sequential phases** to develop, implement, and refine an accessible CanSat program for middle and high school students while promoting STEM engagement and hands-on skill development.

1. Outreach Context: The modified CanSat program was implemented as part of a STEM outreach initiative designed to introduce middle and high school students to aerospace engineering through hands-on learning. Participants were recruited through outreach efforts involving local schools and community organizations. Program announcements were distributed through partner organizations that promote STEM opportunities for students in the region. Interested students completed an online registration form that included several short survey questions regarding their grade level, prior experience with programming or electronics, and interest in STEM or space-related topics. This information helped organizers understand the background of participating students and ensure that the program remained accessible to beginners.

2. Program Objectives and Learning Outcomes through Expert Consultation: "Interviews were conducted with experts in aerospace engineering, CanSat development, and STEM education to inform the program's learning objectives and curriculum design. These consultations provided insights into current aerospace technologies, industry-relevant engineering practices, and effective instructional strategies for introducing complex engineering concepts to middle and high school students.

3. Curriculum and CanSat Tool Development: Drawing on insights from aerospace engineers, CanSat developers, and STEM educators, a structured and accessible curriculum was designed to introduce core engineering and aerospace concepts through CanSat-based activities. The curriculum emphasizes experiential learning, progressive skill development, and practical application, supported by custom-designed CanSat tools that align with the defined learning objectives.

4. Program Implementation and Feedback: The modified CanSat program was delivered through a series of hands-on workshops that guided students through the construction, programming, and testing of their own CanSat. Throughout the implementation, student feedback, performance observations, and informal assessments were collected to evaluate learning gains, student engagement, and areas for program improvement.

5. Assessment and Data Collection: To evaluate the effectiveness of the modified CanSat program, multiple assessment methods were used to capture both learning outcomes and student perceptions. Participants completed short quizzes throughout the workshop to reinforce conceptual understanding of space systems, sensors, and programming fundamentals. In addition, students engaged in hands-on tasks such as building circuits, programming sensors, and assembling the CanSat payload, which allowed instructors to observe practical skill development and teamwork behaviors. At the conclusion of the program, students completed a short survey designed to measure their perceptions of the learning experience. The survey included Likert-scale items (1–5) assessing students' confidence in working with engineering tools, their understanding of engineering work, and their interest in pursuing STEM-related studies or careers. Collected data were analyzed using descriptive statistics to summarize student responses and identify general trends in learning outcomes and program impact.

III. CanSat Program Design and System Architecture

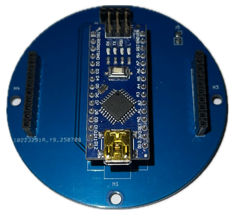
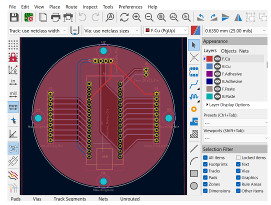
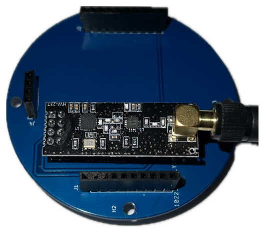
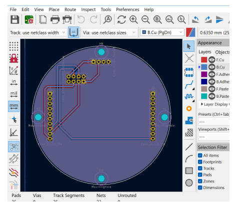
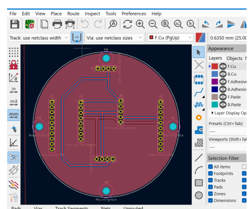
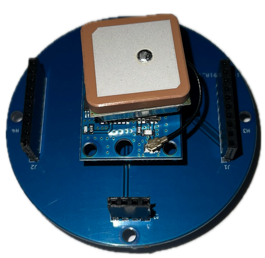
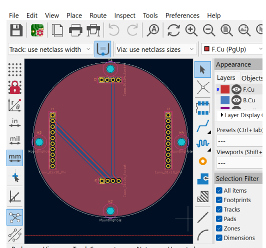
1. CanSat Program Design and Development

The design of the modified CanSat program was driven by a clear set of expected learning outcomes. These outcomes served as the foundation for all components of the program, ensuring that each aspect; hardware, software, and curriculum, contributed directly to student learning and skill development. The key outcomes included understanding and applying basic engineering principles, writing simple programs for embedded systems and sensors, collaborating effectively in teams, designing and building a functional model satellite, conducting tests and analyzing launch data, communicating technical ideas clearly, and gaining confidence and foundational STEM skills in engineering and technology.

2. Hardware System Architecture

The hardware was carefully structured to give students exposure to real-world embedded systems and sensor integration while remaining manageable for beginners. A four-layer PCB system was created using KiCad, with each layer serving a specific function that illustrates how the microcontroller, communication module, sensors, and GPS subsystem work together to simulate core satellite operations (Table 1)..

Table 1: Overview of CanSat Layered Design

Layers	PCBs Design	Description
Layer 1 PCB design & Arduino	 	Microcontroller: Features an Arduino microcontroller, serving as the central processing unit or "brain" of the CanSat, managing data processing and system coordination.
Layer 2 PCB design & nRF24L01	 	Communication: Hosts the nRF24L01 module for radio wave communication, enabling data transmission from the CanSat to a ground station computer for real-time data display.
Layer 3 PCB design & BMP180, MPU6050, VEML7700	 	Sensors: Includes the BMP180 sensor for measuring pressure, altitude, and temperature; the MPU6050 for accelerometer and gyroscope data; and the VEML7700 for light intensity measurements.
Layer 4 PCB design & GPS_GY-neo6 mv2	 	GPS Modulea: Integrates a GPS module for CanSat recovery, logging latitude and longitude data to track its location during mission simulations.

C. Software Tools

Two main software tools were developed to support simulation, coding, and data collection. Together, these tools enhanced student learning by providing both a theoretical learning environment and an interactive coding platform.

- **Web-Based Learning Tool** Created by senior students at PennState Harrisburg, this tool supports learning through:
    - ***Admin*** features for managing accounts, monitoring system activities, and overseeing resources.

- ○ ***Instructor*** tools for training resources, time tracking, and communication to guide students.
- ○ ***Student*** access to learning materials, team chat, a virtual Arduino IDE for coding practice, and instructor communication.

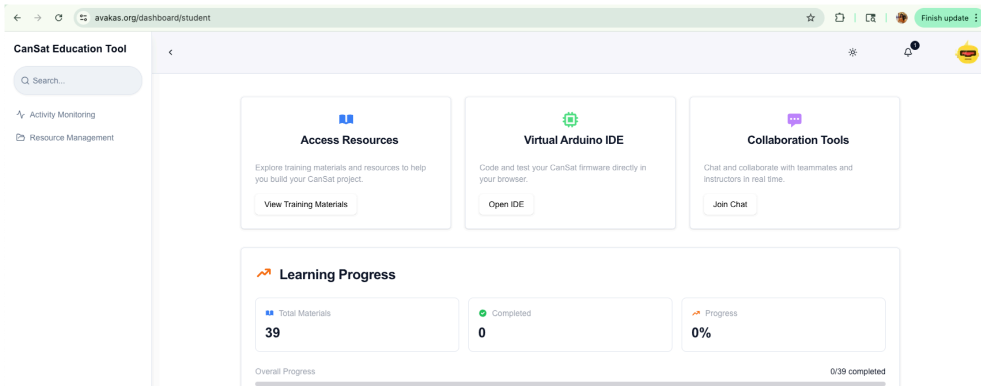


Figure 1: The student dashboard provides access to learning materials, a virtual Arduino IDE for coding practice, and a collaboration tool for team communication all within an integrated web-based environment.

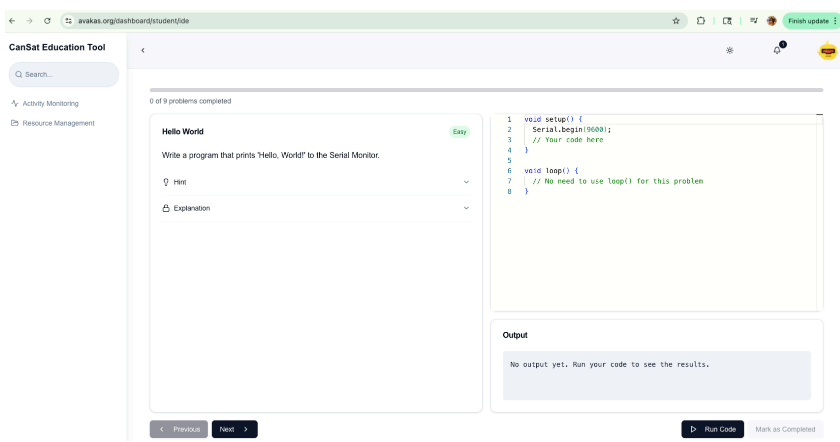


Figure 2: Virtual Arduino IDE - Students can write and run Arduino code to solve a set of problems in a simulated environment.

- **Ground Station Software:** Designed to communicate with the CanSat and log data, mirroring aerospace engineering practices:
  - ○ Features a user interface built with Processing (Java), connected to Arduino code, transmitting data via the nRF24L01 module.

- Visualizes real-time CanSat data (e.g., pressure, altitude, temperature) through plotted graphs.

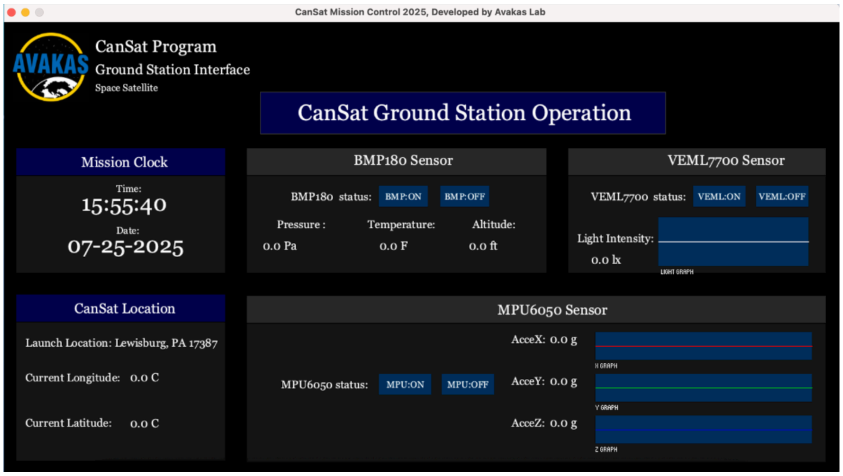


Figure 3: Ground Station GUI (Interface) - Students will be able to view real-time data as the CanSat ascends to higher altitudes.

D. Curriculum Design

The CanSat program is structured as a five-day workshop with four hours of instruction per day. It is designed to engage students in hands-on STEM learning through a project-based satellite mission simulation. Table 2 presents the five-day CanSat workshop structure, outlining the daily focus areas and corresponding learning objectives. (**Table 2**).

Table 2: Program Schedule

Session	Topic	Description	Learning Outcome	Activities	Duration
Day 1: Program Overview & Space Introduction					
1.1	Course Introduction	Overview of the program goals, timeline, and team structure.	Students understand expectations, program goals, and form teams of four.	Ice-breaker activity: Students introduce themselves, share their interests in STEM, and discuss what they'd like to learn.	30 minutes
1.2	Introduction to Space	Introduction to the space environment: vacuum, radiation, microgravity, and temperature.	Students gain a foundational understanding of why studying space is important.	Watch a NASA or ESA video, discuss challenges of space travel, and brainstorm why space matters for Earth.	30 minutes
1.3	What is a Satellite?	Overview of different types of satellites (communication, weather, scientific).	Students understand the importance of satellites in daily life.	Group research activity: Pick a famous satellite and present its function and history.	30 minutes
Break time 15 minutes					
1.4	Quiz & Discussion	Recap the day's topics with an engaging Kahoot quiz.	Reinforce learning and encourage friendly competition.	Top 3 scorers receive small prizes (e.g., stickers, space figures).	30 minutes
1.5	Introduction to Small Satellites	Learn about CubeSats, nano-, and microsatellites.	Students understand the benefits and challenges of small satellites, including space debris concerns.	Discussion on real-world CubeSat missions like NASA's MarCO or Planet Labs.	30 minutes
1.6	What is CanSat?	Overview of the global CanSat program and competitions.	Students understand the purpose and components of a CanSat.	Show past examples of CanSat projects and competitions.	30 minutes
End of the day					
Day 2: CanSat + Engineering + Arduino Basics					

2.1	Review Quiz	A short quiz or worksheet to reinforce previous knowledge.	Students recall and apply concepts learned so far.	Quick quiz, team discussion on answers.	15 minutes
2.2	CanSat Kit Demonstration	Live demo of CanSat layers and their functions.	Students become familiar with the kit's components and sensors.	Interactive demo and Q&A.	30 minutes
2.3	Engineering Disciplines in CanSat	How different engineering fields apply to CanSat (e.g., mechanical, electrical, aerospace, systems).	Students gain insight into interdisciplinary collaboration.	Group matching activity: link CanSat components to engineering roles.	30 minutes
2.4	Introduction to Sensors	Explanation of different sensors used in CanSat and their real-life applications.	Students understand how sensors work and how we use their data.	Show real-life examples (e.g., car sensors, weather stations), analyze a dataset.	30 minutes
Break Time 15 minutes					
2.5	Intro to Microcontrollers	What is a microcontroller? Role in CanSat and everyday devices.	Students understand embedded systems and Arduino's capabilities.	Show examples of Arduino-powered devices.	30 minutes
2.6	Arduino Programming Basics	Learn basic syntax, functions, and logic (e.g., if, loop).	Students write basic code using Arduino IDE.	Practice writing LED blinking, "if" statements, loop function.	30 minutes
2.7	Breadboard & LED Circuit	Hands-on practice with breadboard and LED circuit.	Students understand circuit layout and debugging.	Build an LED circuit and write code to blink it.	30 minutes
End of the day					
Day 3: Sensors, Data Collection & Analysis					
3.1	Review & Quiz	Fun quiz to review Arduino and sensor basics.	Reinforce coding knowledge and encourage reflection.	Prize for highest score.	15 minutes
3.2	Light Intensity & Motion Sensing	Use light sensors and MPU6050 (accelerometer & gyroscope).	Students collect and analyze data related to motion and light.	Compare data under different lighting/motion scenarios.	30 minutes
3.3	Pressure, Altitude & Temperature	Measure pressure and altitude using BMP180 sensor.	Students understand the concept of atmospheric pressure and altitude.	Graph data and discuss how sensors mimic satellite behavior	20 minutes
3.4	GPS Sensor & Location Tracking	Use a GPS sensor to collect location data (lat/lon).	Learn how to read GPS data and apply it to mapping tools.	Use Google Maps to track location.	20 minutes
Break Time 30 minutes					
3.5	Parachute Design & Drop Test	Students design and test parachutes.	Understand the physics of drag and payload protection.	Egg drop competition-bonus for unbroken eggs!	1 hour
End of the day					
Day 4: Building & Mission Planning					
4.1	Reflection & Sensor Review	Review how each sensor connects to mission goals.	Students solidify understanding of sensor roles.	Team discussion and poster-making.	15 minutes
4.2	Radio Communication	Learn how satellites send and receive data.	Understand how CanSat communicates with ground stations.	Test nRF24L01 module.	20 minutes
4.3	Ground Station Interface	Overview of GUI used to read CanSat data.	Students understand how to interpret real-time sensor data.	Simulated data stream reading and interpretation.	30 minutes
4.4	Define Mission Objective	Brainstorm mission goals using available sensors.	Students plan a clear mission with measurable outcomes.	Worksheet and mentor check-ins.	15 minutes
Break Time 15 minutes					
4.5	Build Your CanSat	Assemble CanSat and parachute.	Students apply engineering and teamwork to complete assembly.	Build, test, and troubleshoot with mentors.	1.5 hour
End of the day					
Day 5: Launch & Presentation					
5.1	Pre-Launch Presentation	Present mission design and expected outcomes.	Practice communication and technical storytelling.	Team presentations (5-7 mins each).	1 hour
5.2	CanSat Launch	Launch using a scientific balloon (target: ~70m).	Collect and analyze real-time sensor data.	Launch with parachute, track descent and retrieve payload.	1 hour

5.3	Final Analysis & Celebration	Present actual findings vs. expectations.	Apply scientific methods, analyze outcomes, and celebrate learning.	Final presentations and award of completion certificates.	1 hour
END OF THE PROGRAM					

IV. Program Implementation and Evaluation Results

The modified CanSat program was implemented as a five-day workshop with participating students. Evaluation of the program focused on student learning outcomes, technical engagement, and perceptions of STEM careers. Data were collected through quizzes, hands-on performance observations, team presentations, and post-program survey responses.

- Improved technical confidence: Students with no prior coding experience successfully programmed sensors and microcontrollers.
- Enhanced understanding of real-world data: Learners interpreted telemetry data during the launch and compared predictions with measured results.
- Growth in teamwork: Assembly and mission planning required active collaboration, improving communication and problem-solving.
- Increased STEM interest: Students expressed heightened motivation to explore engineering or space science further.

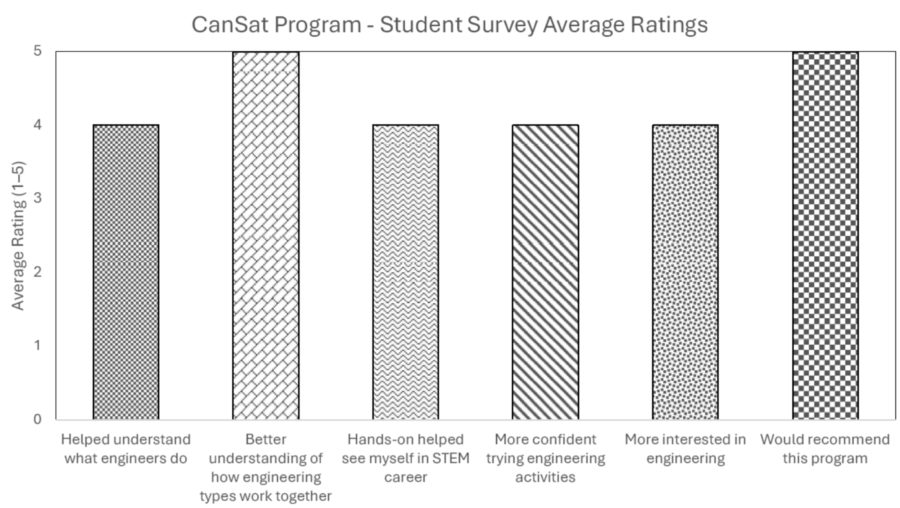


Figure 4: The chart below visualizes average student agreement with key statements (15 responses). Survey responses were summarized using average agreement scores and percentage agreement levels.

Overall, the combination of hands-on success stories (e.g., coding from scratch, successful launches, data analysis) and high survey scores demonstrates that the CanSat program effectively made complex STEM concepts accessible and engaging through structured, scaffolded, team-based activities.

V. Discussion

While the current sensor suite successfully enabled students to collect and analyze environmental and motion data, limitations were observed in sensor performance and robustness during workshop implementation. Some sensors provided adequate functionality for introductory learning objectives but exhibited constraints in accuracy, resolution, or reliability under repeated student handling and launch conditions. These limitations occasionally affected data consistency and required additional troubleshooting time, which can reduce instructional efficiency in short classroom or workshop settings.

Future iterations of the CanSat program will evaluate alternative sensors that offer improved accuracy, durability, and ease of calibration while maintaining affordability and compatibility with beginner-friendly microcontrollers. Selecting more robust sensors would enhance data quality, reduce technical disruptions, and allow students to focus more on engineering analysis rather than hardware debugging.

VI. Conclusion and Future Work

The modified CanSat program lowers the entry barrier to aerospace engineering by combining simplified hardware, user-friendly software, and a structured, experiential curriculum. Its implementation showed measurable gains in student engagement, data literacy, and STEM career interest. Future work will include developing a teacher-ready classroom package that contains:

- Modular lesson plans
- Printable materials and pacing guides
- Instructional videos
- A classroom-optimized CanSat hardware kit

Expanding the program into a scalable model can further democratize space-related STEM learning and support more students in exploring engineering pathways.

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