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Article

High School Teacher Training in the Context of Aerospace Education Through the use of Educational Space Kits CubeSats with a Focus on Computational Thinking – CVT-E Augusto Severo

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Abstract: Computational thinking, a core competency in Brazil's Base Nacional Comum Curricular (BNCC) for high school education, is explored as a tool for aerospace education with public school teachers in Rio Grande do Norte (RN), Brazil. This project, a partnership between IFRN and the Brazilian Space Agency (AEB), developed an educational CubeSat kit—a 1U picosatellite—to train teachers in programming and using CubeSats as a multidisciplinary STEAM (Science, Technology, Engineering, Arts, and Mathematics) resource. The CubeSat comprises five subsystems: Diagnostics, Payload, Control and Telemetry, Power, and Connections. The diagnostics subsystem detects module failures using LEDs and a buzzer, with accessibility features for students with visual or hearing impairments. The payload subsystem performs nine types of environmental and physical measurements, enabling interdisciplinary STEAM activities. The control and telemetry subsystem is based on the ESP32 microcontroller, powered by a rechargeable battery, while the connections subsystem integrates all modules. Programming is done via BIPES, a free block-based and textual platform that supports computational thinking and accessibility. The project unfolds in two phases: an initial six-month teacher training with weekly 3-hour sessions and remote mentoring on CubeSat programming and use, followed by a four-month application phase where teachers guide students in practical activities using the kits. Weekly meetings track progress and provide both pedagogical and technical support, while a concluding workshop synthesizes experiences and outcomes. Preliminary reports suggest that CubeSat-based activities have enhanced student engagement, reinforced experiential learning by connecting theory with practice, and improved teachers' integration of educational technologies.

Keywords: Space Education; Computational Thinking; CubeSats; Teacher Training; Educational Technologies; Active Learning

1. Introduction

The popularization of space technologies and the growing number of missions involving small satellites, such as CubeSats, have sparked interest across various educational sectors in incorporating these technologies as teaching tools. This trend aligns with a global movement toward democratizing access to space and leveraging technological resources to support learning at different educational levels. (Heidt et al. 2000, Batschauer, Zuchi e Fischer 2021)

In a context where basic education faces challenges in fostering student interest in science and technology, the pedagogical use of embedded systems and experimentation with sensors can serve as a catalyst for active learning (Valente 1999). The practical application of these resources in the classroom promotes student agency, stimulates scientific curiosity, and connects school content with real-world situations. (Papert 1980)

Within this framework, the development of computational thinking—understood as the ability to formulate problems and solutions logically, systematically, and based on computer science concepts—becomes an essential component (Wing 2006). This article presents partial results of a joint initiative between the Federal Institute of Rio Grande do Norte (IFRN) and the Brazilian Space Agency (AEB), which aims to train public high school teachers in the educational use of CubeSats, using a nationally manufactured educational kit and a methodology centered on the development of computational thinking.

The teachers participating in this training come from a wide range of subject areas, including biology, mathematics, general science, as well as from technical and vocational schools. The goal is for these educators to incorporate the knowledge acquired into their respective disciplines, promoting interdisciplinary connections and enhancing the relevance of scientific and technological concepts within their curriculum.

The strategy of training teachers as knowledge multipliers significantly expands the reach of the initiative. As these educators bring their learning into the classroom, the results propagate in a kind of geometric progression, reaching hundreds of students indirectly and strengthening a scientific and technological culture in schools in a structured and sustainable way. (Freire 1996)

2. Methodology

The project was structured in two sequential phases, with the overarching goal of fostering computational thinking through the practical use of embedded systems and sensor-based experimentation in educational settings. In the initial phase, 20 teachers from public high schools and technical institutes in the metropolitan area of Natal, RN, participated in a six-month training program. Conducted through weekly workshops totaling approximately 72 hours, the training combined foundational theoretical content with hands-on practice. The curriculum introduced basic principles of astronautics, environmental data acquisition, embedded programming, and the interpretation of sensor data. The approach emphasized the development of logical reasoning, problem decomposition, and structured thinking—all essential skills for computational thinking.

A key resource used throughout the training was an educational CubeSat kit developed and patented by (IFRN 2025) (see Figure 1). This modular system was designed to be accessible and safe for student use, with five functional boards—sensors, control, power, diagnostics, and connections—produced using 3D-printed ABS. Its design allows for easy, tool-free assembly in any order, supporting classroom adaptability and hands-on learning.

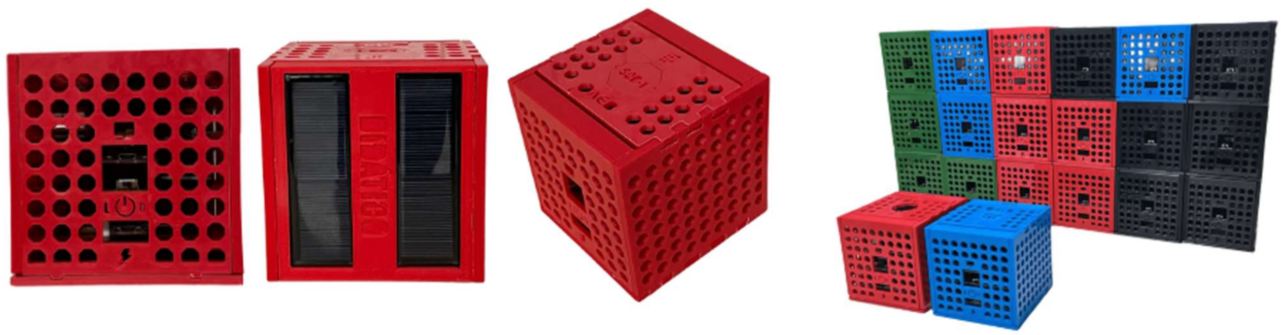

Figure 1. CubeSat kit developed by IFRN.

The sensor board integrates different devices that enable the collection of environmental and motion data, Figure 2:

- the DHT22 sensor, responsible for measuring air temperature and humidity;
- the MPU9250 sensor, which acts as a digital compass by detecting acceleration, rotation, and orientation;
- the BMP280 sensor, used to measure atmospheric pressure and estimate altitude;
- the LDR, a light-dependent resistor that detects ambient light intensity;

- and the CCS811 sensor, which evaluates air quality by monitoring gases such as carbon dioxide (CO2) and volatile organic compounds (VOCs).

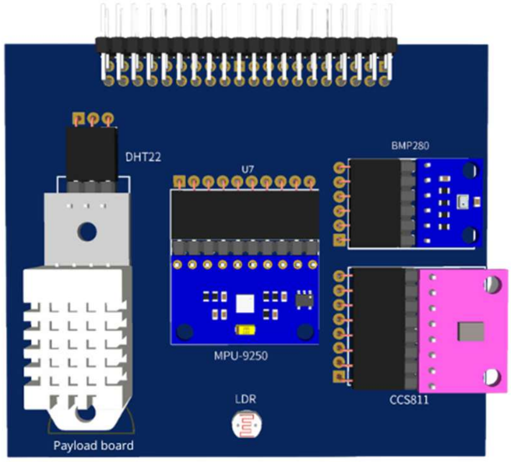

Figure 2. The payload subsystem performs nine measurements: pressure, humidity, temperature, air quality, acceleration, gyroscope, magnetometer, luminosity, and battery level.

The control board houses an ESP32-WROOM microcontroller along with an SD card module, allowing for data acquisition and storage, Figure 3.

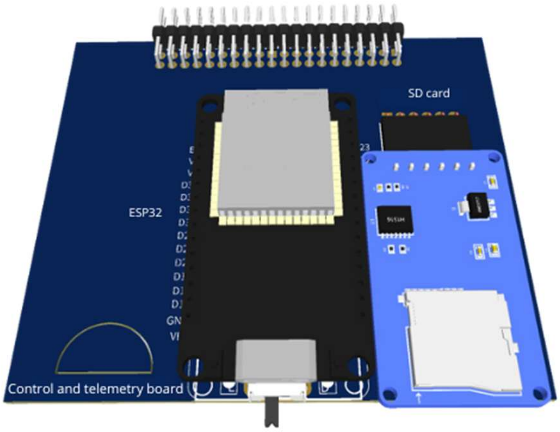

Figure 3. The control and telemetry subsystem uses an ESP32 and an SD card module for data storage.

The power board includes a 3.7V Li-Po battery and a TP4056 charge controller, which can be recharged using solar panels (375 mW, 5V) connected via the interface board, Figure 4.

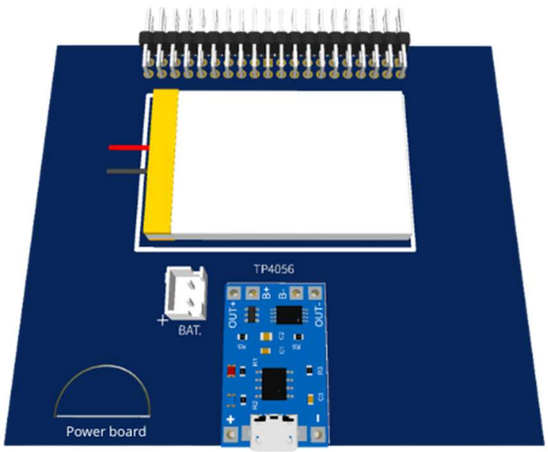

Figure 4. The power subsystem provides electrical energy to all other subsystems.

Meanwhile, the diagnostics board is equipped with RGB LEDs and a buzzer to provide visual and auditory feedback, enhancing accessibility for students with sensory impairments, Figure 5.

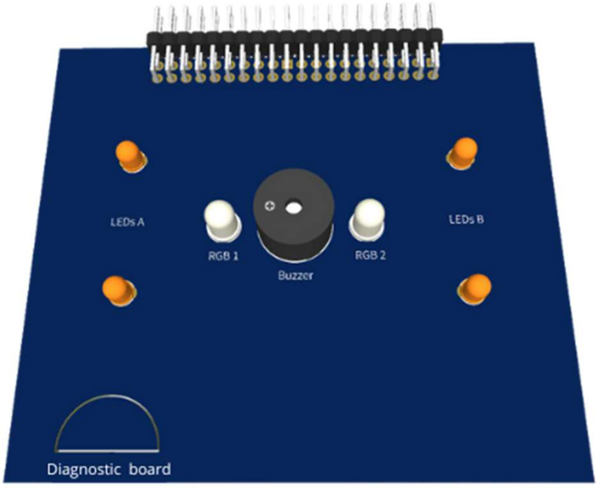

Figure 5. The diagnostic subsystem helps identify problems in other CubeSat modules.

Programming and data monitoring were carried out using BIPES (Block-based Integrated Plat form for Embedded Systems), a user-friendly environment that supports block-based programming and real-time data visualization (see Figure 6). This platform lowered the barrier to entry, allowing teachers to focus on computational logic, system behavior, and iterative problem-solving.

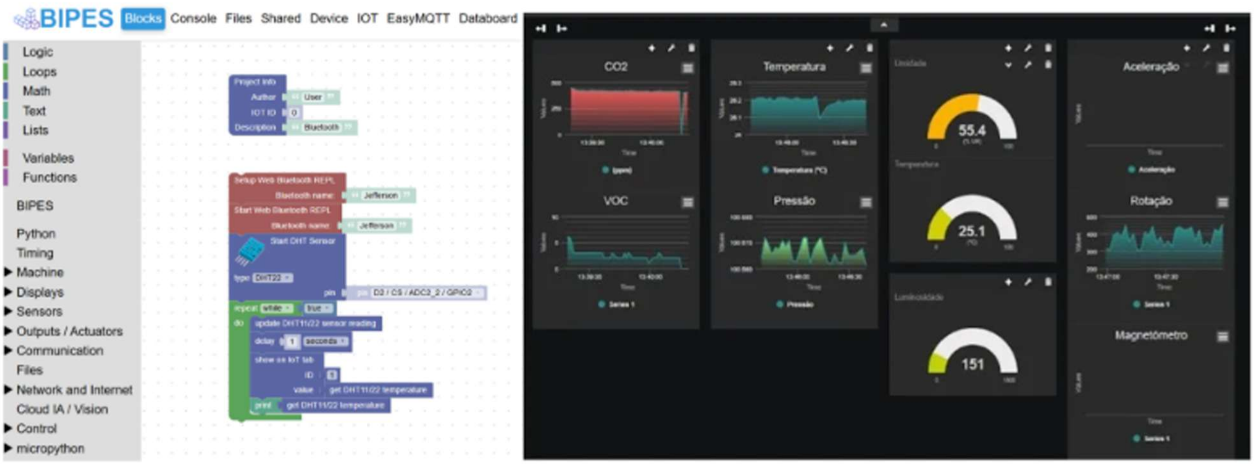

Figure 6. BIPES Project example.

In the second phase, the teachers transferred the knowledge gained to their own classrooms. Each educator organized student teams to carry out experiments using the CubeSat kits, applying the tools in subjects such as biology, mathematics, general sciences, or technical education. These interdisciplinary activities encouraged students to investigate real-world phenomena through data collection and programming, deepening their engagement and strengthening computational thinking skills.

Teachers were supported throughout the implementation with guidance from technical and pedagogical mentors. Weekly check-ins helped address challenges, exchange experiences, and ensure consistency with the project's educational goals.

At the conclusion of the school-based activities, all participants convened for a final collaborative session. During this event, they shared results, reflected on their classroom experiences, and contributed feedback for the continued refinement of both the training model and the CubeSat kit. This iterative process contributed to enhancing the project's scalability and impact in the broader context of public education.

3. Results and Discussion

The implementation of the training and school-based activities yielded a range of qualitative and quantitative results that illustrate the effectiveness of the approach in promoting computational thinking and interdisciplinary learning. The cost of the kits provided to schools was fully funded through a subdecentralization of budgetary credits from the Ministry of Science, Technology and Innovation (MCTI). The resources are being managed in partnership with the Federal Institute of Education, Science and Technology of Rio Grande do Norte (IFRN) and the Foundation for Educational and Technological Development of Rio Grande do Norte (FUNCERN), with implementation scheduled through 2025.

One of the most significant outcomes was the level of engagement demonstrated by participating teachers, many of whom came from diverse disciplinary backgrounds—including biology, mathematics, general sciences, and vocational education. Despite prior limited experience with embedded systems or programming, participants quickly adapted to the tools provided, particularly the CubeSat kit and the BIPES platform. This adaptability was attributed to the intuitive design of the hardware and the visual programming environment, which together lowered entry barriers and fostered experimentation and problem-solving.

The Teacher training is conducted at the Augusto Severo Vocational Space Center (CVT-E) through a public call for applications, with selected participants receiving scholarships as incentives. All training sessions take place in the CVT-E laboratories.

Throughout the classroom implementation phase, teachers developed activities with sensors and projects related to their respective fields of expertise, such as monitoring environmental conditions, measuring air quality, and simulating satellite telemetry. These practices not only enabled the application of scientific concepts but also provided a concrete context for understanding logical structures, data processing, and iterative testing — all of which are central elements of computational thinking. Teachers reported an increase in students' interest in science and technology, as well as greater participation in classroom discussions and group activities.

Another notable observation was the versatility of the CubeSat kit across different subject areas. For instance, biology teachers used temperature and air quality data to discuss environmental health; mathematics teachers explored numerical data analysis; and technical education instructors integrated electronics and programming into their curricula. This cross-disciplinary adaptability demonstrated the potential of the kit to serve as a unifying educational tool across multiple areas of knowledge. The inclusive design of the kit also contributed positively to the learning environment. Teachers highlighted how the visual (LEDs) and auditory (buzzer) outputs allowed students with sensory impairments to participate more fully in the experiments, aligning with inclusive education principles. Weekly follow-up meetings with pedagogical and technical mentors played a crucial role in ad dressing challenges such as hardware handling, data interpretation, and project documentation. These sessions fostered a community of practice among educators, enabling the exchange of ideas and collaborative problem-solving. Taken together, these findings suggest that initiatives centered on accessible technological kits and structured teacher support can substantially enhance the teaching of computational thinking in public education. Furthermore, the scalability of the solution opens possibilities for broader adoption across regional and national educational programs.

4. Conclusions

The initiative demonstrated the potential of combining accessible technological tools with tar geted teacher training to foster computational thinking in public education. By focusing on the use of embedded systems and sensor-based experimentation, the project enabled teachers from diverse subject areas to integrate real-world problem-solving and logical reasoning into their regular classroom activities. The modular CubeSat kit, along with the visual programming environment provided by the BIPES platform, proved to be effective in demystifying technology and encouraging hands-on learning. These resources supported the development of key skills such as abstraction, decomposition, algorithmic thinking, and data interpretation—core components of computational thinking.

Moreover, the strategy of training teachers who, in turn, reach dozens or hundreds of students within their schools, created a multiplier effect that significantly expanded the impact of the project. This geometric progression of knowledge dissemination highlights the importance of investing in educators as central agents of innovation in education.

The success of the initiative also underscores the importance of inclusive and interdisciplinary approaches. The CubeSat kit's design allowed meaningful participation of students with sensory impairments and supported pedagogical applications in subjects ranging from biology to mathematics and vocational disciplines.

As a result, the project not only contributed to advancing technological fluency among teachers and students but also offered a replicable model for other regions and educational systems seeking to incorporate computational thinking into their curricula in a practical, accessible, and scalable way.

6. Patents

The authors declare that the following patent resulted from the work reported in this manuscript: Educational Teaching Kit for Practices with Picosatellites. 2025. Patent BR102025002765-8.

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Conflicts of Interest: The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results

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