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The Start Methodology: A Framework for Scientific Project Development and Research Training from Basic Education to Higher Education

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Abstract
Educational projects involving robotics, maker activities, and aerospace challenges can promote scientific engagement, but their construction does not necessarily lead students to conduct structured research or communicate results according to academic conventions. The START methodology—Science, Technology, Aerospace, Research, and Training—was developed to integrate scientific inquiry, technological development, project organization, evidence analysis, and scientific communication within a continuous educational pathway. This study aimed to present the conceptual structure of the START methodology and examine the consistency and potential transferability of its training pathway across different educational contexts. The study combined the conceptual systematization of the framework with a retrospective descriptive multiple-case analysis. Three independent student cohorts mentored during the 2023, 2024, and 2026 editions of the Brazilian Satellite Olympiad (OBSAT) were examined. The documentary corpus included publicly available competition results, institutional publications, certificates, and project records. The cases were compared according to institutional context, educational level, mission theme, technical product, recurring pedagogical procedures, and externally assigned outcomes. Because of the small, non-random sample and the absence of a comparison group, the analysis was limited to descriptive frequencies and cross-case synthesis. All three cohorts achieved first place in their respective regional OBSAT stages (3/3). Among the two cohorts with completed and documented national-stage results, both achieved second place nationally (2/2). Despite differences in institutions, students, missions, and technical requirements, the cases exhibited a recurring pathway comprising problem delimitation, conceptual study, mission planning, prototyping, programming and sensor integration, iterative testing, failure correction, data analysis, technical documentation, and oral defense. Complementary documented awards in projects involving satellite technology and artificial intelligence, space agriculture, and orbital-debris mitigation indicated that the training pathway was applied to different scientific and technological themes. The recurrence of externally evaluated outcomes across independent cohorts supports the consistency and plausibility of START as an integrated framework for scientific project development and research training. However, competition placements are indirect indicators of learning and do not establish a causal relationship between the methodology and student performance. Prospective studies using larger samples, comparison groups, independent evaluators, and validated measures of research competencies are required to assess its educational effectiveness and transferability.

Keywords: Science Education, Project-Based Learning, Inquiry-Based Learning, STEM Education, Scientific Writing, Educational Robotics, Aerospace Education

Introduction

The development of scientific thinking is a central objective of contemporary education, particularly in societies shaped by knowledge production, technological innovation, and the need to address complex scientific and social problems (Cao *et al*., 2025; Chen *et al*., 2026; Halawa *et al*., 2024)[1]. Science education must therefore enable students not only to understand concepts but also to formulate questions, investigate phenomena, evaluate evidence, design projects, and communicate results systematically (Urdanivia Alarcon *et al*., 2023). These competencies are relevant from basic education to higher education because they connect classroom learning with the practices through which scientific knowledge is produced, assessed, and shared.

[1] National Research Council. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press; 2012. https://doi.org/10.17226/13165. OECD. *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*. Paris: OECD Publishing; 2023. https://doi.org/10.1787/53f23881-en.

Despite this broad consensus, science education in many contexts remains strongly centered on content transmission, with limited opportunities for sustained inquiry, project development, and academic writing(Hmelo-Silver *et al*., 2007; Muhamad Dah *et al*., 2024; Strat *et al*., 2024). Consequently, students may understand theoretical content yet encounter difficulties when asked to define a research problem, formulate a hypothesis, select appropriate procedures, analyze evidence, justify methodological decisions, or present their findings with clarity and rigor. This gap is particularly evident in science fairs, student competitions, research-training programs, and school or university projects, where interest and creativity do not necessarily translate into a complete and well-structured investigation.

Several internationally established approaches have sought to reduce the distance between conceptual learning and scientific practice. STEM and STEAM education promote interdisciplinary connections among science, technology, engineering, mathematics, and creative practices (Bell, 2010; Bybee, 2010; Cao *et al*., 2025; Chen *et al*., 2026; Halawa *et al*., 2024; Perignat & Katz-Buonincontro, 2019; Yim *et al*., 2025; Zhang & Ma, 2023). Project-based learning engages students in authentic problems that require planning, decision-making, collaboration, investigation, and the public presentation of outcomes (Kwon & Lee, 2025; Oanh & Dang, 2025; Pérez Torres *et al*., 2024; Perignat & Katz-Buonincontro, 2019; Yim *et al*., 2025). Inquiry-based learning organizes science education around questions, hypotheses, evidence, explanations, and revision of conclusions, particularly when students receive appropriate pedagogical scaffolding (Arifin *et al*., 2025; Hmelo-Silver *et al*., 2007; Muhamad Dah *et al*., 2024; Strat *et al*., 2024; Urdanivia Alarcon *et al*., 2023). Collectively, these approaches have strengthened student agency, contextualized learning, problem-solving, critical thinking, and interdisciplinarity.

Nevertheless, the educational problem addressed in this article is not fully resolved by implementing these approaches separately. Students may participate in an experiment, construct a prototype, or complete a project without progressing through the entire process required to transform an initial idea into a structured scientific investigation and a formal research product. Scientific writing is especially important in this transition because it requires students to organize evidence, articulate reasoning, and communicate knowledge according to disciplinary conventions (Sedlacek & Lomelí, 2024). Robotics and maker-centered activities can also provide motivating and interdisciplinary environments for this development (Davies & Seitamaa-Hakkarainen, 2025; Trapero-González *et al*., 2024), while aerospace challenges offer a contextual theme through which scientific concepts, technological design, teamwork, data analysis, and communication can be integrated.

To address this practical and conceptual gap, this article proposes the START methodology—Science, Technology, Aerospace, Research and Training—as an educational framework for the progressive development of scientific, technological, investigative, and academic communication competencies. START integrates five dimensions within a continuous training pathway: science provides the conceptual basis; technology supports experimentation and problem-solving; aerospace contexts stimulate interdisciplinary engagement; research organizes systematic inquiry; and training develops the skills required to document and communicate results. Rather than treating experimentation, technological construction, research design, and academic writing as separate outcomes, START connects them from the identification of a problem to the production and presentation of scientific knowledge. Its central contribution is therefore an explicit educational pathway that links scientific curiosity, guided inquiry, technological development, project organization, evidence analysis, and formal communication across different educational levels.

The article also introduces a retrospective descriptive multiple-case analysis of three independent student cohorts mentored during the three editions of the Brazilian Satellite Olympiad (OBSAT). The cohorts differed in school, age, educational level, and institutional context, yet all achieved first place in their respective regional stages. Complementary documented outcomes included a national first-place award in a satellite and artificial intelligence challenge, international accreditation at a science fair, and a silver medal in engineering at an international science and technology festival. These observations provide preliminary evidence for examining the consistency and potential transferability of the training pathway across heterogeneous educational contexts, while the small non-random sample, observational design, and absence of a comparison group preclude definitive causal conclusions.

Accordingly, this study aims to present the conceptual foundations and structure of the START methodology and to examine, through documented multiple cases, the consistency and potential transferability of its training pathway from basic to higher education. By formalizing the framework and defining the limits of the available evidence, the article seeks to contribute to scholarly discussion on integrated models of science education and to establish a basis for future studies using larger samples, comparison groups, and validated measures of research competencies.

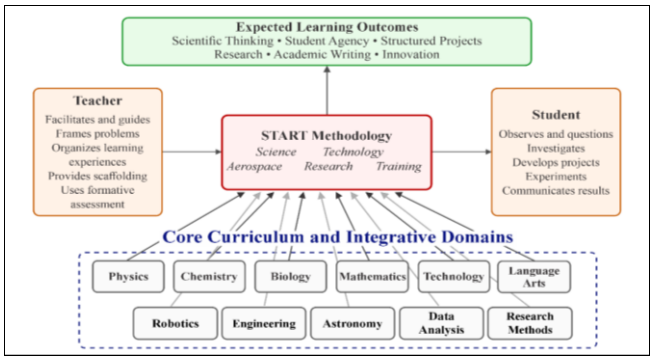


Fig 1: Pedagogical-integrative model of the START methodology, showing its relationship with core curriculum disciplines, teacher mediation, student agency, and expected educational outcomes (**Рис 1:** Педагогико-интегративная модель методологии START, показывающая ее взаимосвязь с дисциплинами основной учебной программы, педагогическое сопровождение, активную роль учащихся и ожидаемые образовательные результаты)

Literature Review

The START methodology is grounded in four complementary theoretical strands: scientific inquiry, project-based learning, research and scientific writing, and interdisciplinary STEM/STEAM education. These strands

share the assumption that science education should extend beyond the transmission of established concepts and involve students in practices such as questioning, investigating, designing, interpreting evidence, and communicating knowledge. However, the literature also indicates that these practices do not automatically produce meaningful learning. Their effectiveness depends on pedagogical guidance, coherent instructional design, teacher preparation, and the explicit integration of conceptual, procedural, technological, and communicative competencies.

Scientific Inquiry and Inquiry-Based Learning

Inquiry-based learning seeks to bring science education closer to authentic scientific practice by involving students in formulating questions, constructing hypotheses, collecting evidence, interpreting data, and developing explanations. Minner *et al*. found that inquiry-oriented science instruction was generally associated with improved conceptual learning, particularly when students actively engaged with scientific ideas and evidence (Minner *et al*., 2010). Hmelo-Silver *et al*., however, emphasized that inquiry should not be confused with minimally guided instruction; complex investigations require scaffolding that supports learners without eliminating their intellectual agency (Hmelo-Silver *et al*., 2007).

Recent systematic reviews reinforce this qualified interpretation. Urdanivia Alarcon *et al*. identified benefits for scientific literacy, reasoning, and problem-solving but also reported substantial variation in how inquiry-based teaching is defined and implemented(Urdanivia Alarcon *et al*., 2023). Strat *et al*. showed that effective inquiry-based science education also depends on teacher preparation, epistemic understanding, and the ability to guide classroom investigations (Strat *et al*., 2024). Dah *et al*. found that open inquiry can strengthen autonomy and higher-order thinking, although its cognitive demands, required instructional time, and dependence on adequate resources can limit its effectiveness (Muhamad Dah *et al*., 2024). Similarly, the meta-analysis by Arifin *et al*. reported positive effects on students' critical-thinking skills while confirming that outcomes vary according to educational level, instructional design, and degree of guidance (Arifin *et al*., 2025).

Together, these studies support inquiry as a central component of science education but reject the idea of a single rigid and universally effective scientific sequence. START responds to this tension by treating problem identification, hypothesis formulation, evidence collection, analysis, and communication as explicit pedagogical reference points rather than as an inflexible representation of how science always proceeds. Its investigative dimension is therefore structured enough to guide novice researchers while remaining adaptable to iterative revision, unexpected results, and different educational contexts.

Project-Based Learning

Project-based learning organizes instruction around meaningful problems, questions, or challenges that require sustained investigation and the production of a concrete outcome. Bell associated PBL with student autonomy, collaboration, communication, and other competencies required for contemporary education (Bell, 2010). Blumenfeld *et al*. similarly argued that projects can sustain motivation by connecting knowledge to purposeful activity, but cautioned that "doing" does not necessarily produce "learning" unless students receive conceptual support and opportunities for reflection (Keys *et al*., 1999).

More recent evidence supports the educational potential of PBL while drawing attention to differences in implementation. The meta-analysis conducted by Zhang and Ma found an overall positive effect on learning outcomes, although the magnitude of the effect varied according to subject area, educational level, group size, and duration(Zhang & Ma, 2023). Pérez Torres *et al*. demonstrated that STEAM project-based learning designs should be evaluated according to the scientific and engineering practices they promote, rather than solely by the attractiveness or functionality of the final product (Pérez Torres *et al*., 2024). Kwon and Lee reported positive effects of STEM PBL on creativity (Kwon & Lee, 2025), while Oanh and Dang identified improvements in collaboration, problem-solving, communication, and other twenty-first-century skills among engineering students (Oanh & Dang, 2025).

These findings indicate that PBL can contextualize learning and connect theory with practice, but a completed prototype or public presentation does not necessarily constitute a structured scientific investigation. Students may successfully build an artifact without clearly defining a research problem, controlling variables, analyzing evidence, or documenting methodological decisions. START supplements conventional PBL by incorporating these research requirements throughout the project cycle. The project is treated not only as a product to be completed but also as a process through which questions are investigated, decisions are justified, results are evaluated, and knowledge is formally communicated.

Research Training and Scientific Writing

Scientific writing occupies a dual role in education: it communicates the results of an investigation and supports the cognitive organization of the investigation itself. The Science Writing Heuristic proposed by Keys *et al*. demonstrated that writing associated with laboratory inquiry can encourage students to connect claims, evidence, procedures, and conceptual explanations (Rivard & Straw, 2000). Rivard and Straw showed that discussion and writing perform complementary functions: talk facilitates the generation and clarification of ideas, whereas writing promotes their organization and consolidation (Bangert-Drowns *et al*., 2004).

The meta-analysis by Bangert-Drowns *et al*. found that writing-to-learn interventions generally produce positive academic effects, although outcomes depend on the nature of the prompts, duration of the activities, and opportunities for metacognitive reflection (Gunel *et al*., 2007). Günel *et al*. further demonstrated that writing for different audiences and in different formats can deepen conceptual learning by requiring students to reformulate scientific meanings rather than merely reproduce information (Blumenfeld *et al*., 1991). More recently, Sedlacek and Lomelí argued that student science writing should have authentic and culturally relevant purposes, allowing learners to communicate evidence in relation to meaningful communities and problems (Sedlacek & Lomelí, 2024).

While these perspectives differ in emphasis, they agree that writing should not be restricted to a final report produced after the intellectual work has already occurred. Nevertheless, many educational projects continue to treat

documentation as a bureaucratic or evaluative requirement. START addresses this limitation by distributing writing across the entire investigative pathway. Research questions, hypotheses, objectives, procedures, observations, failures, data interpretations, and conclusions are progressively recorded and revised. This process prepares students to transform practical experiences into structured reports, posters, oral presentations, and academic manuscripts.

Interdisciplinary STEM/STEAM Education

Bybee characterized STEM education as an effort to integrate science, technology, engineering, and mathematics around relevant problems rather than teaching these disciplines exclusively as isolated domains (Bybee, 2010). Perignat and Katz-Buonincontro showed that STEAM expanded this perspective by incorporating artistic, creative, and design-related dimensions, but their review also identified considerable conceptual ambiguity and diversity among implementations (Perignat & Katz-Buonincontro, 2019). Consequently, labeling an activity as STEM or STEAM does not ensure meaningful interdisciplinary integration.

Recent reviews and meta-analyses have refined this discussion. Halawa *et al*. found that K–12 STEM outcomes are strongly influenced by instructional design, disciplinary integration, problem authenticity, and teacher mediation (Halawa *et al*., 2024). Giang *et al*. highlighted the contribution of STEM education to problem-solving skills while emphasizing the need for explicit strategies and valid assessment instruments (Giang *et al*., 2024). The meta-analyses conducted by Cao *et al*. and Chen *et al*. reported positive effects on learning outcomes and academic achievement but also revealed heterogeneity across educational levels, interventions, disciplines, and research designs (Cao *et al*., 2025; Chen *et al*., 2026). In primary education, Yim *et al*. identified benefits for engagement, creativity, and interdisciplinary learning, alongside persistent challenges involving teacher preparation, curriculum alignment, and conceptual clarity (Yim *et al*., 2025).

The studies on STEAM PBL similarly suggest that interdisciplinary projects are most productive when students genuinely mobilize scientific and engineering practices rather than place several disciplines side by side (Kwon & Lee, 2025; Oanh & Dang, 2025; Pérez Torres *et al*., 2024). START adopts this integrated interpretation. Science provides the conceptual and evidentiary basis; technology enables measurement, construction, and experimentation; and research organizes the production and evaluation of knowledge. The aerospace dimension offers a motivating interdisciplinary context through which physics, astronomy, engineering, mathematics, computing, environmental science, and communication can converge around authentic challenges.

Maker, Robotics, and Aerospace Contexts

Maker education and educational robotics provide practical environments for implementing this integration. Martin described the maker movement as an opportunity to promote learner agency, experimentation, and construction-centered learning (Rosenfeld Halverson *et al*., 2014), while Halverson and Sheridan emphasized participation, creativity, and the development of communities organized around the production of meaningful artifacts (Martin, 2015). Systematic reviews by Rouse *et al*. and Davies and Seitamaa-Hakkarainen nevertheless identified recurring methodological limitations, including small samples, short interventions, inconsistent outcome measures, and insufficient descriptions of pedagogical mediation (Davies & Seitamaa-Hakkarainen, 2025; Rouse & Rouse, 2022). Quintana-Ordorika *et al*. further showed that teacher training is essential if maker activities are to move beyond technical construction and support intentional educational objectives (Quintana-Ordorika *et al*., 2024). In educational robotics, Trapero-González *et al*. reported positive effects on STEM competencies while also noting variability among interventions (Trapero-González *et al*., 2024).

Aerospace projects can intensify this motivational and interdisciplinary potential. Borges de Souza and Montenegro described the use of maker and STEAM approaches in Brazilian educational nanosatellite projects involving electronics, programming, three-dimensional design, bibliographic research, and scientific communication (Kasneci *et al*., 2023). Such experiences illustrate how aerospace challenges can connect technological construction with scientific inquiry. However, motivation and technical complexity alone do not guarantee methodological rigor. The educational value of the aerospace context depends on whether students are guided to formulate researchable questions, generate and analyze data, evaluate limitations, and communicate defensible conclusions.

Synthesis and Unresolved Questions

The literature reveals four persistent challenges. First, inquiry, PBL, writing, and STEM/STEAM are frequently implemented as separate practices rather than as parts of a continuous research-training pathway. Second, their effectiveness depends substantially on scaffolding, teacher preparation, time, infrastructure, and implementation fidelity. Third, many studies prioritize engagement, perceptions, or completed artifacts without directly measuring the quality of students' research competencies. Fourth, relatively few frameworks follow learners from initial scientific curiosity through project development, evidence analysis, documentation, and formal communication across different educational levels.

START addresses these gaps by integrating the four theoretical strands into a progressive pathway from basic to higher education. Its contribution is not the replacement of inquiry-based learning, PBL, scientific writing, or STEM/STEAM, but their systematic articulation within a single framework. The unresolved empirical question is whether this integration produces consistent and transferable improvements in research competencies across populations and institutions. This question requires longitudinal studies, comparison groups, larger samples, implementation measures, and validated instruments capable of assessing inquiry, project design, evidence-based reasoning, and scientific communication.

Materials and Methods

Study Design

This study combined two methodological components: (i) the conceptual systematization of the START methodology and (ii) a retrospective descriptive multiple-case analysis of its educational application. The first component organized the principles, dimensions, and operational sequence of the framework. The second examined documented outcomes

from three independent student cohorts mentored during the three editions of the Brazilian Satellite Olympiad (OBSAT), held in 2023, 2024, and 2026.

A multiple-case design was selected because the educational experiences had already been completed and had occurred in different schools, educational levels, and institutional contexts. This approach enabled the identification of recurring characteristics across heterogeneous cases without treating the study as a controlled experiment. The analysis was descriptive and exploratory; it was intended to examine the consistency and potential transferability of the training pathway rather than establish a causal relationship between the methodology and the outcomes obtained.

Conceptual Development of the START Methodology

The START framework was developed through an integrative synthesis of four educational strands discussed in the literature: inquiry-based science education, project-based learning, scientific writing and research training, and interdisciplinary STEM/STEAM education (Bell, 2010; Davies & Seitamaa-Hakkarainen, 2025; Hmelo-Silver *et al*., 2007; Kasneci *et al*., 2023; Muhamad Dah *et al*., 2024; Perignat & Katz-Buonincontro, 2019; Sedlacek & Lomelí, 2024; Strat *et al*., 2024; Trapero-González *et al*., 2024; Urdanivia Alarcon *et al*., 2023). The synthesis was not conducted as a systematic review or meta-analysis. Instead, the theoretical literature was used to identify complementary practices that could be organized into a continuous research-training pathway.

The resulting acronym represents five interdependent dimensions: Science, Technology, Aerospace, Research, and Training. Science comprises conceptual understanding, observation, questioning, hypothesis formulation, and evidence-based reasoning. Technology includes the critical use of digital tools, programming, sensors, scientific instrumentation, modeling, and prototyping. Aerospace provides an interdisciplinary and motivating context capable of connecting physics, mathematics, engineering, computing, environmental sciences, and technological innovation. Research structures the formulation of problems, selection of methods, collection and analysis of evidence, and interpretation of results. Training encompasses scientific writing, technical documentation, oral presentation, critical revision, and participation in academic or scientific events.

These dimensions were organized as components of a continuous cycle rather than as an inflexible linear sequence. The framework allows students to return to previous stages when tests reveal technical failures, when evidence does not support an initial hypothesis, or when the research problem must be reformulated. This iterative organization was selected because educational scientific projects commonly require repeated cycles of design, testing, analysis, correction, and communication.

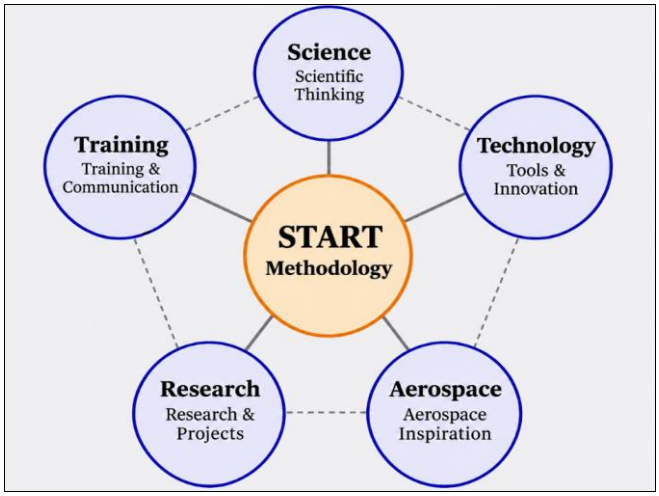


Fig 2: Conceptual model of the START methodology showing the integration of its five formative dimensions: Science, Technology, Aerospace, Research, and Training

(**Рис 2:** Концептуальная модель методологии START, показывающая интеграцию пяти образовательных компонентов: Science, Technology, Aerospace, Research и Training)

Cases and Educational Contexts

The primary units of analysis were three independent student teams mentored by the author, one from each edition of OBSAT. The cases involved the Cidade Olímpica Educacional program, Great International School, and Instituto Dom Barreto. The cohorts differed in age, educational level, school, and institutional context. Because the purpose was to compare the application of a shared training pathway across different educational environments, these differences were treated as relevant characteristics rather than variables to be eliminated.

The exact number and personal characteristics of the students were not used as analytical variables. No individual academic grades, family income, or other sensitive information was collected. The administrative nature of an institution was not treated as a direct measure of the socioeconomic status of its students. The empirical cases primarily involved students in basic education; consequently, although the conceptual framework is designed to be adaptable to higher education, the present case series does not constitute a direct empirical assessment of its implementation at the university level.

OBSAT was selected as the principal analytical setting because its practical modality exposes teams to a common sequence of externally defined activities, including mission planning, prototype construction, testing, technical documentation, presentation, and regional launching[2]. The competition also organizes teams according to educational

[2] Brazilian Satellite Olympiad. OBSAT: practical modality, educational levels, and competition stages. Available at: https://obsat.org.br/. Accessed July 29, 2026.

level and uses external evaluation committees, allowing achievements obtained in different editions to serve as comparable, although indirect, indicators of project performance.

Educational Procedure

Across the three cases, the educational process followed a shared orientation cycle that was subsequently formalized as the START methodology. The process began with the identification and delimitation of a real scientific or technological problem. Students then conducted an introductory literature review and studied the scientific concepts required to understand the proposed mission.

The next stage involved defining the project objectives, formulating research questions or hypotheses when applicable, and preparing a mission plan. The teams subsequently developed their prototypes through the integration of electronics, programming, sensors, structural components, and data-recording systems. The specific hardware and software varied according to the mission, available institutional resources, educational level, and competition requirements. Therefore, the study did not evaluate a fixed equipment package or compare the performance of particular devices. Resources used across the projects included microcontrollers, sensors, embedded electronic components, programming environments, computer-aided design and modeling tools, prototyping materials, and digital resources for data analysis and technical documentation.

Prototype development was followed by iterative testing. Technical failures, inconsistent measurements, programming errors, structural limitations, and communication problems were treated as part of the investigative process. Students were guided to identify the probable causes of each problem, modify the prototype or procedure, repeat the tests, and document the changes made.

During the final stages, the teams organized the collected information, interpreted the results, prepared technical reports, and developed oral and visual presentations. The cycle concluded with the external presentation and evaluation of the projects. This sequence was selected because it connected conceptual learning, technological construction, evidence analysis, and scientific communication within the same educational process.

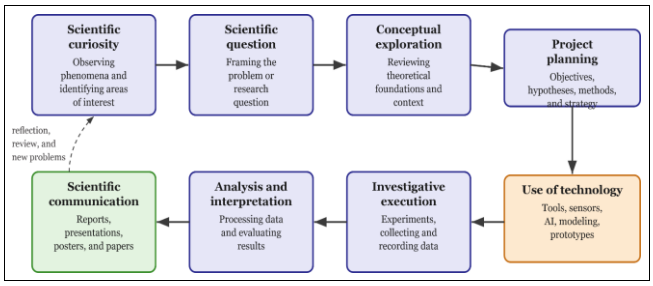


Fig 3: Operational flow of the START methodology, from problem identification and conceptual study to prototype development, evidence analysis, and scientific communication

(**Рис 3:** Рабочая последовательность методологии START: от определения проблемы и изучения теоретических основ до разработки прототипа, анализа данных и научной коммуникации)

It is important to note that not all three experiences were originally presented to the students under the formal name "START." The framework was progressively systematized from the recurring practices used during the mentoring process. The cases should therefore be interpreted as the empirical basis from which the methodology was formalized, rather than as prospectively registered interventions conducted under a previously standardized protocol.

Data Sources and Outcome Measures

The documentary corpus consisted of publicly available competition results, institutional news, school records, public project documentation, certificates, and records of scientific fairs and festivals. Information was organized at the team and project levels. No surveys, interviews, psychological instruments, standardized competency tests, or new experiments involving the students were conducted for this retrospective analysis.

The primary outcome was the placement achieved by each team in its respective regional OBSAT stage. When available, national-stage placements were also recorded. Complementary outcomes included documented awards and accreditations received by projects mentored or co-mentored by the author in other scientific competitions, fairs, and festivals. These complementary cases were included as convergent evidence of application in different project environments, but they were not treated as equivalent to direct measures of student learning.

Competition placements were considered externally assigned project-performance indicators because they resulted from evaluation by committees independent of the present analysis. However, these outcomes may reflect several factors, including prototype quality, technical documentation, oral presentation, competition rules, and the relative performance of other teams. They do not independently measure gains in scientific reasoning, autonomy, conceptual knowledge, or academic writing.

Cross-Case Analysis

A comparative matrix was used to organize the three primary cases according to five categories: (i) institution and educational context; (ii) educational level; (iii) scientific theme or mission problem; (iv) technical product developed; and (v) result assigned through external evaluation. The cases were then compared to determine whether a similar outcome pattern was observed despite differences in institutional and educational context.

The common pedagogical elements examined across the cases were problem delimitation, conceptual study, mission planning, prototyping, programming and sensor integration, iterative testing, failure correction, data analysis, report preparation, and oral defense. The analysis focused on the recurrence of this training sequence and on the convergence of the externally documented results.

Because only three primary cases were available, the analysis was restricted to descriptive comparison. Results were summarized using absolute frequencies, such as the number of regional first-place outcomes among the three cases. No inferential statistical tests, effect-size calculations, or causal models were applied. The small, non-random sample and absence of a control or comparison group made such analyses methodologically inappropriate.

Ethical Considerations

The study involved no new intervention, direct interaction

with participants, or collection of identifiable data for research purposes. The analysis was limited to aggregated results and information previously made public by the participating institutions and scientific events. Student names, individual academic records, family income, and other sensitive personal information were not included.

The author acted as the mentor of the teams and later systematized the educational framework and cases. This dual role may introduce confirmation and selection biases. To reduce overinterpretation, the analysis distinguished documented external outcomes from direct measures of learning and avoided attributing causal effectiveness to the methodology. Future prospective studies should employ predefined protocols, independent evaluators, comparison groups, validated instruments for measuring research competencies, and the ethical procedures required for collecting individual-level data.

Results

Consistency of Outcomes Across the Three OBSAT Editions

Table 1 summarizes the three primary cases included in the retrospective analysis. The cohorts were associated with different institutions and educational contexts and developed independent satellite missions. Despite these differences, all three teams achieved first place in their respective regional stages of the Brazilian Satellite Olympiad (OBSAT).

Table 1: Retrospective summary of the teams mentored during the three OBSAT editions
(**Таблица 1:** Ретроспективная сводка команд, которыми руководил автор, в трёх выпусках OBSAT)

Edition / Выпуск	Team and institution / Команда и учреждение	Context and level / Контекст и уровень	Mission or product / Миссия или продукт	External outcome / Результат внешнего оценивания
1st (2022–2023)	Cidade Olímpica Educacional, SEMEC/Teresina	Municipal program; public-school students; Level 1, lower-secondary education	CanSat designed to investigate ultraviolet radiation and atmospheric ozone	1st place at the regional stage; 2nd place at the national stage[3]
2nd (2023–2025)	GREATERS, Great International School	Private school; Level 1, basic education	Planning, construction, programming, testing, and launching of a CanSat	1st place at the regional stage; 2nd place at the national stage[4]
3rd (2025–2026)	IDBSaT, Instituto Dom Barreto	Private school; Level 1; female students in the 7th and 8th grades	CanSat for the acquisition and transmission of environmental data, with an application to wildfire monitoring	1st place at the regional stage[5]

Source notes / Примечания об источниках:

The descriptive frequency of regional first-place outcomes was therefore 3/3 (100%). Among the two cohorts for which a completed national-stage result was documented, both achieved second place nationally (2/2). No national placement was included for the third cohort because only its regional result had been documented by the data cutoff. Given the small number of cases, these frequencies were not treated as population estimates, and no inferential statistical tests were performed.

The analytical value of this pattern lies in its recurrence after changes in students, institutions, school contexts, missions, and technical requirements. The first cohort was connected to a municipal program serving public-school students; the second belonged to a private school; and the third consisted of 7th- and 8th-grade students from another private institution. Accordingly, the observed pattern did not depend on retaining the same students or operating within a single school.

All placements were assigned by external evaluation committees. This characteristic made them appropriate as exploratory indicators of project performance because the teams were assessed outside the daily relationship between mentor and students. Nevertheless, the placements reflect several components simultaneously, including prototype quality, mission design, technical documentation, oral presentation, competition rules, and the performance of other teams. They should not be interpreted as direct or isolated measurements of scientific reasoning, conceptual learning, autonomy, or writing proficiency.

Across the three cases, the documentary analysis identified a recurring educational sequence: delimitation of a real problem, conceptual study, mission planning, prototype development, programming and sensor integration, iterative testing, correction of failures, analysis of the information obtained, preparation of technical documentation, and oral

[3] Prefeitura Municipal de Teresina. *Alunos da SEMEC se preparam para nova fase da OBSAT*. Available at: https://antigo.pmt.pi.gov.br/2023/01/04/alunos-da-semec-se-preparam-para-nova-fase-da-obsat/. Portal AZ. *Piauí conquista posições de destaque na Olimpíada Brasileira de Satélites*. Available at: https://www.portalaz.com.br/noticia/geral/65901/piaui-conquista-posicoes-de-destaque-na-olimpiada-brasileira-de-satelites/. Accessed July 29, 2026.

[4] Great International School. Equipe GREATERS alcança o segundo lugar no Brasil na Olimpíada Brasileira de Satélites. Institutional publication. Available at: https://www.instagram.com/p/DN3QioaYtZx/. Accessed July 29, 2026.
Cidade Verde. Great International School Wins First Place in Northeast Brazil at the Brazilian Satellite Olympiad. News article. Available at: https://cidadeverde.com/ultimas/398668/great-international-school-conquista-o-1-lugar-do-nordeste-na-olimpiada-de-satelites. Accessed July 29, 2026.

[5] Instituto Dom Barreto. *Alunas do IDB conquistam ouro na etapa regional Norte–Nordeste da OBSAT e avançam para a etapa nacional*. Available at: https://dombarreto.com/portal/noticia/post/601.
Universidade Federal do Maranhão. *Estudantes da UFMA vencem etapa regional da Olimpíada Brasileira de Satélites*. Available at: https://portalpadrao.ufma.br/site/noticias/estudantes-da-ufma-vencem-etapa-regional-da-olimpiada-brasileira-de-satelites. Accessed July 29, 2026.

defense. This recurring sequence later provided the empirical basis for the formal systematization of the START framework.

Complementary Outcomes in Science Fairs and Competitions

The complementary records expanded the descriptive corpus beyond OBSAT. They included a national satellite and artificial-intelligence challenge and projects related to space agriculture and orbital-debris mitigation. These outcomes were selected because they were publicly documented or supported by institutional records and represented applications of the shared training pathway to different scientific and technological problems.

Table 2: Complementary outcomes of student projects mentored or co-mentored by the author
(**Таблица 2:** Дополнительные результаты ученических проектов, выполненных под руководством или совместным руководством автора)

Year / Год	Event / Мероприятие	Project and context / Проект и контекст	Outcome / Результат
2020	17th National Science and Technology Week, SNCT/MCTI	Satellite and Artificial Intelligence Challenge involving lower-secondary students from the Cidade Olímpica Educacional program	1st place nationally in the challenge[6]
2025	6th FeNaDANTE Science and Technology Fair and 1st Great International School Science and Technology Fair (FEICE)	*Agriculture on Mars*, a project focused on developing solutions for growing plants in Martian environments	2nd place in the Engineering category at FeNaDANTE and 2nd place at the 1st FEICE[7]
2026	11th Exhibition of Science, Engineering, Technology and Innovation (EXPOCETI), Pernambuco, and 2nd FEICE	*Clean Orbit*, a project dedicated to developing solutions for monitoring and reducing space debris	2nd place at EXPOCETI and 1st place at the 2nd FEICE[8]

The complementary results indicate that the shared educational pathway was applied to projects involving artificial intelligence, atmospheric monitoring, wildfire monitoring, space agriculture, and orbital-debris mitigation. This thematic diversity suggests that the process was not restricted to a single project or scientific subject. However, awards obtained by the same project at different events are not statistically independent cases and were therefore interpreted as stages of a project trajectory rather than as separate replications.

Taken together, the OBSAT cases and complementary records are compatible with the central proposition of START: educational projects may become more structured when technological construction, scientific inquiry, iterative testing, documentation, and communication are treated as interconnected components of a single pathway. The evidence nevertheless remains concentrated in technological and aerospace projects and cannot, by itself, demonstrate equivalent outcomes in every disciplinary or educational context.

Discussion and Conclusions

The aim of this study was to present the conceptual structure of the START methodology and examine the consistency and potential transferability of its training pathway through documented educational cases. The principal finding was the recurrence of first-place regional outcomes in all three OBSAT editions examined, despite changes in students, institutions, grade ranges, scientific missions, and technical requirements. Two of the three cohorts also achieved second place at the national stage, while complementary awards showed that similar mentoring practices were applied to other scientific and technological themes.

These findings are consistent with studies showing that inquiry-based learning can strengthen conceptual understanding, scientific reasoning, and evidence-based problem-solving when accompanied by appropriate pedagogical scaffolding (Arifin *et al*., 2025; Hmelo-Silver *et al*., 2007; Minner *et al*., 2010; Strat *et al*., 2024; Urdanivia Alarcon *et al*., 2023). They are also compatible with evidence that project-based learning can promote autonomy, collaboration, creativity, communication, and the integration of theoretical and practical knowledge (Bell, 2010; Keys *et al*., 1999; Oanh & Dang, 2025; Pérez Torres *et al*., 2024; Zhang & Ma, 2023). The observed outcomes cannot independently demonstrate that these competencies improved, but they show that the teams were able to complete projects requiring the practical coordination of several competencies emphasized in this literature.

The START framework extends these approaches by organizing inquiry, project development, technology, testing, documentation, and communication within one continuous pathway. Its contribution does not lie in proposing that any of these components is individually new. Rather, it lies in their systematic articulation and in the explicit treatment of scientific writing and communication as processes that develop throughout the investigation instead of being added only after a prototype has been completed. This emphasis is supported by research showing that scientific writing assists students in organizing ideas, connecting claims to evidence, consolidating conceptual understanding, and communicating with different audiences (Blumenfeld *et al*., 1991; Rivard & Straw, 2000; Sedlacek & Lomelí, 2024).

The findings also reinforce the value of interdisciplinary STEM/STEAM environments. Previous reviews and meta-analyses have reported positive effects of integrated STEM

[6] Ministério da Ciência, Tecnologia e Inovações. *MCTI encerra a 17ª Semana Nacional de Ciência e Tecnologia*. Available at: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/noticias/2020/10/mcti-encerra-a-17a-semana-nacional-de-ciencia-e-tecnologia. Prefeitura Municipal de Teresina. *Programa educacional da Prefeitura de Teresina vence Olimpíada Brasileira de Satélites*. Available at: https://antigo.pmt.pi.gov.br/2020/10/24/programa-educacional-da-prefeitura-de-teresina-vence-olimpiada-brasileira-de-satelites/. Accessed July 29, 2026.

[7] Outcomes documented in project certificates and institutional records from the 6th FeNaDANTE and the 1st FEICE, consulted on July 29, 2026.

[8] Great International School. *Registros da 11ª EXPOCETI e da 2ª FEICE: projeto Clean Orbit*. Institutional publication. Available at: https://www.instagram.com/p/DZs95COFs0w/. Accessed July 29, 2026.

and STEAM interventions, while also identifying substantial heterogeneity related to educational level, instructional design, teacher preparation, disciplinary integration, and assessment methods (Bybee, 2010; Cao *et al*., 2025; Chen *et al*., 2026; Giang *et al*., 2024; Halawa *et al*., 2024; Perignat & Katz-Buonincontro, 2019; Yim *et al*., 2025). The present cases support the view that interdisciplinary projects require more than the juxtaposition of science, engineering, and technology. Their educational coherence depends on a defined problem, systematic investigation, evidence analysis, pedagogical mediation, and formal communication.

Maker and robotics research similarly emphasizes learner agency, experimentation, and the creation of meaningful artifacts, but also identifies limitations involving short interventions, small samples, inconsistent assessment instruments, and insufficient descriptions of teacher mediation (Davies & Seitamaa-Hakkarainen, 2025; Martin, 2015; Minner *et al*., 2010; Quintana-Ordorika *et al*., 2024; Rosenfeld Halverson *et al*., 2014; Rouse & Rouse, 2022). START responds to these challenges by positioning the teacher as a methodological mentor and by treating technical failures, redesign, repeated testing, and documentation as legitimate components of scientific formation.

The current analysis also extends the authors' previous work on maker- and STEAM-oriented educational nanosatellite projects (Kasneci *et al*., 2023). That earlier study documented how electronics, programming, three-dimensional design, bibliographic research, and scientific communication could be integrated into aerospace education. The present study advances this line of work by formally defining the START framework, comparing three independent OBSAT cohorts, and distinguishing external project outcomes from direct measurements of student learning.

From a practical perspective, the results indicate that the framework may be adapted to different institutional settings. Nevertheless, the presence of a municipal program, public-school students, and private schools should not be interpreted as evidence of socioeconomic equivalence. School administrative status is not a valid individual measure of social class, income, access to resources, or family educational background. The findings support institutional diversity only at the descriptive level.

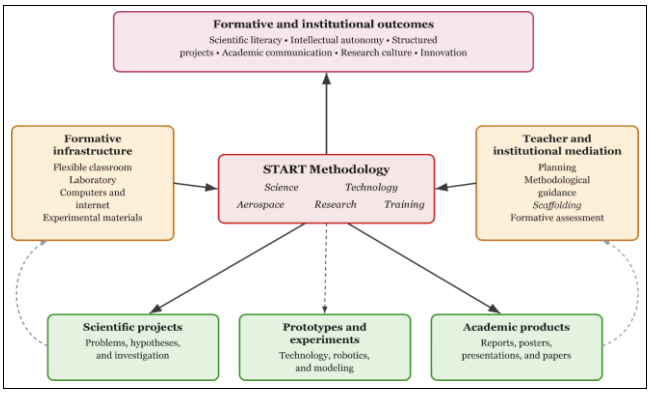


Fig 4: Institutional architecture for the implementation of the START methodology across basic education, higher education, research groups, and scientific and technological events
(**Рис 4:** Институциональная архитектура внедрения методологии START в системе общего и высшего образования, исследовательских группах и научно-технологических мероприятиях)

The evidence must also be interpreted in light of several limitations. The study used a small, non-random and retrospectively selected sample, without a comparison group, pre- and post-intervention measures, or statistical control of previous experience, preparation time, available resources, family support, and institutional support. The same person formulated the methodology, mentored the teams, and systematized the cases, creating a risk of confirmation and selection bias. Furthermore, competition placements are indirect indicators of learning and depend on the rules, evaluators, competitiveness, and assessment criteria of each event.

The empirical cases were also concentrated in basic education. Consequently, although START was designed as a framework extending from basic to higher education, this study does not directly demonstrate its effectiveness at the university level. The claim of applicability to higher education remains conceptual and must be examined through specific empirical studies.

Future research should employ prospective protocols, larger and more diverse samples, comparison groups, independent evaluators, and validated instruments for measuring scientific reasoning, project design, autonomy, evidence-based argumentation, and academic writing. Studies should also record unsuccessful or non-awarded projects, assess implementation fidelity, and examine how teacher preparation, infrastructure, mentoring time, and institutional support affect outcomes. Longitudinal research could determine whether participation influences later engagement in STEM education, scientific production, or academic and professional trajectories.

In conclusion, the available evidence supports the consistency and plausibility of the START methodology as an integrated pathway for scientific project development and research training. The recurrence of externally evaluated outcomes across independent cohorts suggests potential transferability, but it does not constitute definitive causal proof of effectiveness. START should therefore be understood as a theoretically grounded and empirically informed framework that now requires prospective and controlled validation. Its practical significance lies in offering educators a coherent structure for connecting scientific curiosity, interdisciplinary project development, technological experimentation, evidence analysis, and formal communication. As digital laboratories, scientific simulations, embedded systems, and artificial-intelligence-supported analytical tools become more accessible, the framework may support increasingly complex investigations, provided that technological expansion remains accompanied by methodological rigor, ethical oversight, and qualified teacher mediation.

Author Contributions

The sole author was responsible for conceptualization; methodology; investigation; data collection and curation; formal analysis; visualization; project administration; supervision; writing—original draft; writing—review and editing. The author has read and approved the final version of the manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

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