Developing Computational Thinking and an Entrepreneurial Mindset in Regular Basic Education Students through Agile Methodologies

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Abstract*— This article proposes and evaluates the integration of agile frameworks—Scrum and Design Thinking—within a Project-Based Learning (PBL) environment in Regular Basic Education (RBE) classrooms. The study examines how this methodological integration supports students' transition from technology users to solution developers while fostering computational thinking and an early entrepreneurial mindset. The intervention used iterative cycles, defined roles, prototyping, and structured feedback in projects involving heating systems, hydroponic crops, and hygiene products. The findings indicate improvements in algorithmic thinking, abstraction, pattern recognition, problem decomposition, and the organization of sequential procedures. Students also demonstrated autonomy, collaboration, communication, and responsibility during project development. Iterative work cycles and explicit assessment criteria supported knowledge retention, technical validation, and the refinement of solutions based on evidence. The results suggest that the combined use of PBL, Scrum, and Design Thinking provides a viable pedagogical framework for promoting computational, collaborative, and entrepreneurial competencies in public secondary education.

Keywords*—Computational Thinking, Regular Basic Education, Scrum, Design Thinking, School Entrepreneurship, Agile Methodologies.

I. Introduction

Twenty-first-century education requires students to develop higher-order thinking skills in response to continuously evolving technological environments. These cognitive and practical competencies support adaptation to complex contexts shaped by technical innovation, where mathematical and creative problem solving intersect [1]. Preparing Regular Basic Education (RBE) students for a digital environment characterized by social, economic, and environmental challenges requires teaching and learning settings that promote innovation and sustainability [2].

Rigorous assessment of cognitive skills at early ages has therefore become relevant for educators, requiring systematic and reliable instruments to measure emerging abilities and support long-term educational quality [3]. The combined use of flipped classrooms and active methodologies has been associated with stronger analytical skills and participation among adolescents [4]. Continuous evaluation of educational programs and the structured use of experiential methods in technical and theoretical disciplines also contribute to professional preparation [5].

Traditional teaching approaches in RBE often remain centered on the teacher as the main source of knowledge and provide limited opportunities to develop these competencies. They frequently emphasize memorization and rigid procedural approaches to problem solving. When learning is not contextualized, students may have difficulty connecting theory with practice and transferring classroom knowledge to real settings. A predominantly observational role also limits opportunities to develop independent judgment, algorithmic reasoning, and empathy toward the needs of the surrounding community.

This article proposes, describes, and evaluates the integration of frameworks from software engineering and product design in school project environments within RBE classrooms. The iterative framework supports organization, teamwork, active participation, ownership, and transparent assessment [6]. The human-centered framework emphasizes empathy, open ideation, and continuous refinement in response to real problems [7].

The study examines, through classroom evidence, how this methodological integration changes the role of students in public institutions. Students move from passive technology use and reception of static content toward the active development of functional solutions. The integrated structure is intended to foster systematic computational thinking and an entrepreneurial mindset oriented toward purposeful and ethical technology development.

II. Literature Review and Theoretical Framework

A. Computational Thinking (CT) and Technological Literacy

Computational thinking was initially defined as a fundamental process that involves solving problems, modeling complex systems, and understanding human behavior through the analytical and logical concepts underlying computer science [8]. This perspective extended the scope of these cognitive skills beyond software development and positioned them as applicable across academic disciplines.

Internationally, particularly in K-12 education, there is broad support for integrating algorithmic reasoning and abstraction into school curricula to prepare students for future work contexts [9]. The expansion of these cross-cutting competencies has also encouraged the design and validation of concept inventories for assessing artificial intelligence and computing literacy, particularly among middle and secondary school students [10].

Academic organizations and researchers have developed national guidelines and conceptual frameworks to help students understand artificial intelligence and its influence on everyday

life [11]. These efforts have defined core competencies and instructional design considerations for effective, inclusive technology literacy programs aligned with children's cognitive development [12]. The main dimensions of computational thinking include decomposition, pattern recognition, abstraction, and the formulation of step-by-step solutions that can be interpreted by humans and machines.

B. Project-Based Learning (PBL) and the Flipped Classroom

Project-Based Learning (PBL) is recognized for engaging students in action-oriented, sustained, and collaborative inquiry that supports deeper and more durable learning [13]. This experiential approach promotes direct and guided engagement with problems, reinforcing theoretical understanding through practice and discovery [14]. The literature indicates that students retain information more effectively when they take an active role in structuring their inquiry processes.

The flipped classroom complements this approach by moving initial theoretical study to multimedia environments outside the classroom and using face-to-face time for guided practice and reflection [15]. This arrangement allows teachers to support complex projects, facilitate discussion, and address individual technical questions during class [16].

Integrating PBL with the flipped classroom supports students' ability to abstract complex concepts and apply them in real contexts. It may also reduce disengagement and low information retention associated with conventional instruction.

C. Agile Methodologies and Scrum in Education

The Agile Manifesto, originally developed for software development, changed product development by prioritizing individuals, interactions, and responsiveness to change over rigid processes, tools, and extensive documentation [17]. These principles were later operationalized in the Scrum Guide, which provides a lightweight and disciplined framework for addressing complex adaptive problems and delivering value [18].

Adapting agile practices to engineering curricula has been associated with improved learning experiences, stronger participant engagement, and transparent collaborative work [19]. Systematic assessments support the use of agile approaches in higher and technical secondary education to strengthen self-regulation and time management [20].

In PBL environments, hybrid models that incorporate Scrum events and artifacts support the management of teaching and learning processes and provide teachers with frequent information on group progress [21]. Their effectiveness is linked to clearly assigned responsibilities and students' positive perceptions of incremental progress [22]. Iterative agile methods have also supported the conception and design of robotic products in mechatronics education [23].

D. Design Thinking and Engineering Approaches

Design Thinking, developed within design ecosystems such as Stanford, provides a human-centered heuristic approach based on collaborative tools and iterative mindsets that encourage the revision of initial ideas [24]. Its emphasis on empathy and structured innovation has contributed to its adoption in industry and education [25].

Integrating iterative evaluation and design thinking into students' scientific research projects supports the development of solutions that are conceptually innovative and practically feasible [26]. The CDIO framework (Conceive, Design, Implement, Operate) complements these methods by providing systemic and institutional guidelines for technical education [27]. Current discussions on educational structures also identify adaptive thinking as a curricular priority.

E. Gender Gaps and Educational Synergies

Demographic variables should be considered when these methodologies are introduced in RBE. Documented gender differences in the development of computing skills among primary and secondary students indicate the need for targeted pedagogical support to promote equitable participation. Collaborative methods and socially oriented solution design can provide participation contexts that support female students, especially where instruction would otherwise focus on isolated syntax practice [9].

F. xSTEAM and Interdisciplinary Learning under Resource Constraints

The interdisciplinary projects examined in this study can also be interpreted in relation to xSTEAM (eXtreme STEAM), an extension of STEAM developed for educational contexts characterized by severe technological and resource constraints. Romero and López De Luise [29] describe xSTEAM as an approach that considers technological adaptability, organizational conditions, pedagogical strategies, sociocultural context, and resource availability when designing integrative learning experiences. This perspective is relevant to the present study because the projects combine science, technology, engineering, mathematical reasoning, human-centered design, and entrepreneurial problem solving in a public-school environment with limited infrastructure. The convergence of computational thinking and

entrepreneurial thinking therefore supports interdisciplinary problem solving under contextual constraints.

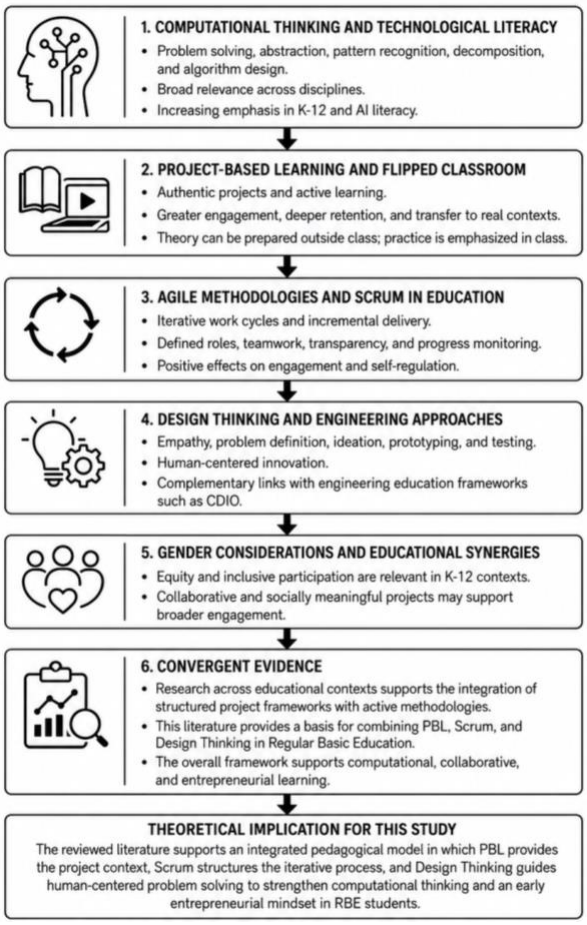


Fig. 1 Theoretical foundations supporting the study

Evidence from higher education provides a complementary perspective on the integration of structured project management frameworks with active learning. The experience associated the project life-cycle phases with progressive deliverables and documented the development of competencies related to planning, scope management, collaboration, communication, and value delivery [28]. Several student projects also demonstrated potential for technological entrepreneurship. These findings indicate that professional project management frameworks can be adapted to educational settings and combined with iterative, user-centered methods to structure authentic projects and support technical, collaborative, and entrepreneurial learning.

III. Methodology

To evaluate the effect of formally integrating Design Thinking and Scrum on the development of computational thinking, the study adopted an action-research approach within the natural setting of an RBE classroom. This participatory design allowed the researcher to intervene, adjust implementation parameters, and iteratively refine teaching practices as the learning sessions progressed across the school terms.

A. Participants, Context, and Didactic Transposition

The intervention was implemented throughout the school year at Elvira García y García Public Educational Institution, a secondary-level RBE school. Its student population represents diverse socioeconomic and cultural backgrounds within an urban context. This setting enabled the study to examine the feasibility and effects of agile methodologies in a public institution with common limitations in technological infrastructure. The context also provided evidence on the applicability of pedagogical innovation outside highly resourced environments.

The implementation involved complete student cohorts. Following principles of equity and collaborative learning, students were organized into interdisciplinary teams of four to five members. Teams were formed using a structured heterogeneity criterion that considered gender distribution and differences in prior cognitive and technical skills. This configuration was intended to reflect engineering and professional development teams while supporting peer learning, mutual assistance, and conflict resolution from multiple perspectives.

Because agile methodologies and heuristic innovation frameworks were originally developed for corporate and industrial settings, they required didactic adaptation. The ceremonies, technical terminology, and delivery expectations were adjusted to the psychosocial and cognitive characteristics of adolescents. Performance metrics were simplified, and work rhythms were established to fit the available instructional time [10], [11].

The institutional records used for this action-research report documented complete cohorts and team composition, but did not preserve a consolidated dataset with the exact sample size (N), number of participating sections, or full demographic breakdown in a form suitable for retrospective reporting. These figures are therefore not reconstructed or estimated in this manuscript. Accordingly, the study does not infer population-level estimates or demographic subgroup effects. Future replications should prospectively register N, section counts, age, gender, prior technical experience, and other relevant demographic variables to improve reproducibility and external validity.

The intervention was implemented by the classroom teaching staff responsible for the subject. The source documentation did not contain a standardized record of the teachers' professional profiles, prior certification, or formal training hours in Scrum and Design Thinking. Teacher preparation therefore cannot be analyzed as an independent implementation variable in this study. Replication protocols should report disciplinary background, teaching experience, agile-method training, and facilitation workload.

The evaluation relied on classroom evidence, student deliverables, process records, and functional observations of the prototypes. No standardized pre/post computational-thinking instrument or validated entrepreneurial-intention scale was administered. The reported improvements should therefore be interpreted as qualitative and functional evidence within an

action-research design rather than as standardized effect estimates.

B. Roles, Sprints, and Heuristic Phases

In this adaptation, the classroom teacher assumed the role of Product Owner, presenting broad challenges related to the Sustainable Development Goals, resolving ambiguities in project requirements, and periodically validating functional acceptance criteria. Within each team, responsibility for internal coordination and the removal of operational obstacles rotated among students, allowing different participants to perform Scrum Master functions. This structure provided supervised autonomy.

Technical development and project conceptualization were organized into school sprints lasting one to two weeks. At the end of each iteration, teams presented a public demonstration to their peers and showed a tangible increment, such as a component diagram, preliminary code structure, or documented field test.

The innovation and conceptual design stage followed the five iterative phases of Design Thinking: empathize with community needs, define an actionable problem statement, generate multiple alternatives, produce low-cost rapid prototypes, and test them to collect empirical feedback [24]. Returning to an earlier phase was presented as a normal part of refinement and quality improvement [25].

IV. Implementation and Documentation of Case Studies

During the academic year, student teams applied the adapted agile framework to conceive, design, build, and validate technological solutions and scientific applications. The projects addressed local needs related to thermal infrastructure, household resources, sustainability, health, and biotechnology. Scrum review and improvement cycles guided the iterative development of deliverables. The following cases are organized into three areas of pedagogical innovation and practical application.

A. Hardware and Applied Electronics Innovation

In this area, students applied abstract principles of algorithms and computational thinking to the physical use of electromechanical components and microcontrollers. The projects addressed household comfort and preparedness for natural or human-caused disruptions.

1) Homemade flashlight: A group of students designed and assembled emergency flashlights for use during unplanned power outages. The project applied basic electronics through series and parallel circuits built with conductive wires, switches, and light-emitting diodes (LEDs), housed in structures made from recycled polymers. Through the documented process, participants developed an empirical understanding of resistance, voltage, and current flow while incorporating environmental criteria through the reuse of materials.

2) Smart heating system: Low temperatures and high humidity during the Lima winter led another team to design an automated thermal chamber. Using an open-source Arduino board, the students connected digital temperature and humidity sensors (DHT11), electromagnetic relays, and small exhaust fans in a real-time closed-loop system. Conditional If-Else routines enabled the prototype to maintain 24 °C inside the test chamber and achieve higher readings than the control environment. The code documentation and experimental results reflected the use of algorithmic structures and analog variable readings.

B. Sustainability and Urban Agriculture Innovation

Given the shortage of agricultural space in densely populated metropolitan areas and food-security risks associated with climate change, students developed ecological and scalable solutions.

1) Mini-greenhouse (fitotoldo): Several teams used parametric design and natural science research to plan, build, and monitor small-scale household greenhouses. The structures were intended to protect vegetables from adverse weather and endemic biological pests. Students collected and analyzed daily data on internal temperature, condensation, germination rate, and optimal planting depth. The project required a systems approach to understand the greenhouse effect and its influence on photosynthesis.

2) Hydroponics—hydroponic vegetable cultivation with substrates: Another group prototyped functional hydroponic systems to optimize water use, three-dimensional space, and reliance on chemical pesticides. The project compared the performance of organic and inorganic substrates, including perlite and coconut fiber. Daily spreadsheet records and data visualizations indicated faster growth and lower water consumption than soil-based agriculture.

C. Biotechnology, Health, and Pharmacognosy Innovation

This area applied computational thinking principles related to sequencing and systematic procedures to chemical synthesis, native plant preservation, and the study of biological effects on human physiology.

1) Liquid soap production: A student team documented and standardized a biochemical process for small-scale artisanal liquid soap production, linking entrepreneurial activity with community hygiene. Students prepared detailed flowcharts for the stages of saponification and measured purified water, saline solutions, and aromatic extracts. Continuous pH monitoring was used to assess compliance with dermatological safety parameters.

2) Homemade yogurt production: Students conducted a food biotechnology project focused on yogurt enriched with live probiotic cultures. They used algorithmic monitoring to record time, viscosity changes, and temperature ranges required for safe lactic fermentation. The project also included a review of the reported effects of beneficial microorganisms on the human immune system.

3) Eureka Project—matico infusion: A team conducted an experimental study of the antibacterial and wound-healing activity reported for leaves of Piper aduncum, a native plant commonly known in Peru as matico. Controlled chemical extraction, specifically continuous steam distillation, was used

to establish a repeatable laboratory protocol for consistently obtaining pure essential oils.

4) Cat's claw tea preparation: The extraction of active metabolites from Uncaria tomentosa bark was planned and documented. Students designed a parametric study of boiling times, solute concentrations, and reported prophylactic effects of continued consumption on common infectious and viral conditions. The study required an extensive review of sources to support the hypotheses.

TABLE I
SUMMARY OF IMPLEMENTED CASE STUDIES

Innovation area	Project	Development and resources used	Documented technical and learning outcome
Hardware and applied electronics	Homemade flashlight	Series and parallel circuit design using wires, switches, and LEDs integrated into structures made from recycled polymers.	The project produced a lighting solution for power outages and supported an empirical understanding of resistance, voltage, and current flow while incorporating environmental awareness.
Hardware and applied electronics	Smart heating system	Arduino board, DHT11 sensor, relay, and fans configured as a feedback circuit; programming through If-Else conditional routines.	The prototype maintained 24 °C in the test chamber and demonstrated the use of algorithmic structures, variable readings, and an automated thermal response.
Sustainability and urban agriculture	Mini-greenhouse (fitotoldo)	Small-scale design and construction; daily records of temperature, condensation, germination, and planting depth to protect vegetables from weather and pests.	Students applied a systems approach to understand the greenhouse effect, its relationship with photosynthesis, and the monitoring of environmental variables.
Sustainability and urban agriculture	Hydroponic crops with substrates	Comparison of organic and inorganic substrates; daily spreadsheet records and visualization of growth and water-consumption data.	Records indicated faster growth and lower water use than soil-based agriculture.
Biotechnology, health, and pharmacognosy	Liquid soap	Flowcharts to standardize saponification; measurement of water, saline solutions, and aromatic extracts; continuous pH control.	The production sequence was systematized, and the product was assessed against dermatological safety parameters, linking algorithmic thinking, entrepreneurship, and community health.
Biotechnology, health, and pharmacognosy	Homemade yogurt	Production with probiotic cultures and monitoring of time, viscosity, and temperature during lactic fermentation.	A procedure for safe and effective fermentation was structured and complemented by a review of the reported effects of beneficial microorganisms on the immune system.
Biotechnology, health, and pharmacognosy	Eureka Project: matico infusion	Experimental study of Piper aduncum using chemical extraction and continuous steam distillation to evaluate reported antibacterial and wound-healing activity.	A repeatable laboratory protocol was systematized for consistent essential-oil extraction and scientific analysis of a native medicinal plant.
Biotechnology, health, and pharmacognosy	Cat's claw tea	Parametric study of Uncaria tomentosa: boiling times, solute concentrations, and a literature review of its active metabolites.	Students formulated and supported hypotheses about the extraction process and reported prophylactic effects on common infectious and viral conditions.

V. DISCUSSION AND RESULTS

A. Qualitative and Quantitative Evaluation of Results

Implementing agile methodologies throughout the school year produced observable changes in the physical and functional quality of the deliverables and in students' cognitive performance. Review of the cohorts' progress indicated changes in how students organized problems and responded to technical setbacks. The resulting competencies extended beyond computational tasks to collaborative and reflective participation.

1) Development of algorithmic thinking: Students showed greater ability to plan solutions through logical sequences. The methodology required flowcharts and pseudocode before materials were manipulated. In the conditional routines used with the DHT11 sensor and the time and temperature parameters for lactic fermentation, students identified the relationship between instruction order and process outcomes.

This reduced reliance on unstructured trial and error and supported a systematic procedural approach.

2) Decomposition of complex systems: Scrum supported the decomposition of complex projects into manageable components. Students initially experienced planning difficulties in projects such as the controlled-microclimate greenhouse. They later divided the work into specific tasks (e.g., "build the base," "install the plastic covering," "seal the edges," and "install the thermometer") and managed them through the Sprint Backlog and Kanban boards. This organization supported a more balanced distribution of responsibilities and reduced cognitive load during implementation.

3) Abstraction and pattern recognition: The iterative phases of Design Thinking supported students in filtering secondary information and focusing on relevant variables. In the hydroponics projects, they prioritized nutrient levels, water flow, and light exposure. In the studies of medicinal phytochemicals from matico and cat's claw, teams identified empirical relationships among extraction methods, processing time, and the purity of the resulting active compound.

4) Technical validation of prototypes: Quantitative observations supported the functional feasibility of the prototypes. Data from the thermal test chambers showed that the student-built hardware maintained environmental stability under external variation. In the biochemical projects, protocol optimization and documentation supported consistent essential-oil extraction and demonstrated procedural precision and experimental rigor.

B. Pedagogical and Methodological Discussion

The integration of Project-Based Learning (PBL), Scrum management principles, and iterative Design Thinking established a methodological environment in which early errors were treated as part of the learning process and entrepreneurial competencies could develop. Cognitive literature describes early closure as the tendency to retain an initial idea in order to protect an academic grade. The instructional design addressed this tendency by organizing work into sprints and incorporating low-cost prototyping from the initial stages of each project. These practices enabled students to test their proposals, observe the effects of their decisions, identify design problems, and collect evidence before completing the final product.

The iterative structure allowed students to revise their solutions without receiving an academic penalty for modifying an initial proposal. Each cycle of planning, implementation, testing, and revision provided opportunities to incorporate evidence obtained through experimentation. Sprint reviews and prototype demonstrations also made progress visible and supported timely feedback from teachers and peers. This improvement cycle contributed to the development of systematic problem-solving processes, particularly in projects that required students to coordinate technical tasks, manage variables, and respond to unexpected results.

The feasibility of the intervention also depended on adapting the teacher's role. Teachers acted as learning facilitators and performed functions analogous to those of a Product Owner or Scrum Master by guiding teams, clarifying project requirements, and focusing attention on local needs. Student autonomy was supported through methodological controls, including clear acceptance criteria, systematic hypothesis formulation and testing, and the identification and control of dependent and independent variables. These measures supported the technical and scientific validity of the experimentation. The findings indicate that supervised autonomy can coexist with academic discipline, strengthen responsibility for the learning process, and enable students in public education to conceptualize, model, and implement tangible solutions within structured technical standards.

Although gender distribution was considered when teams were formed, the study did not collect standardized pre/post measures disaggregated by gender. The available evidence therefore does not support a claim that the intervention reduced a gender gap in computational thinking. This issue remains relevant because collaborative and socially meaningful projects may create more inclusive participation conditions [9]. Future studies should examine this possibility using gender-disaggregated computational-thinking, participation, and learning measures.

Entrepreneurial outcomes were inferred from observable classroom behaviors such as opportunity identification, solution ownership, resource optimization, prototype communication, and alignment with local needs. The study did not administer a validated entrepreneurial-intention or entrepreneurial-mindset instrument, nor did it systematically measure market feasibility, cost-benefit relationships, or end-user perceived value. The entrepreneurial findings should therefore be interpreted as developmental classroom evidence rather than as direct measures of venture readiness.

These methodological characteristics also limit external validity. The intervention was conducted in one public educational institution during one school year, without a control group and without standardized pre/post measures. Causal attribution of observed changes to the integrated framework cannot therefore be established. The findings support feasibility and pedagogical plausibility, while comparative and mixed-method designs are required to estimate effect magnitude and generalizability.

TABLE II
SUMMARY OF RESULTS AND PEDAGOGICAL DISCUSSION

Dimension analyzed	Documented evidence	Consolidated result	Pedagogical discussion and implication
Algorithmic thinking	Flowcharts and pseudocode before construction; If-Else conditionals for the DHT11 sensor; time and temperature parameters in yogurt production.	Students organized problems through logical sequences and reduced reliance on unstructured trial and error.	PBL situated algorithmic logic in applied contexts. Iterative tests linked instruction order to physical or biochemical outcomes.

Decomposition of complex systems	Division of the fitotoldo and other prototypes into specific tasks; use of the Sprint Backlog and Kanban boards; responsibilities assigned in teams of four to five members.	Projects were organized into manageable units, with a more balanced workload and lower cognitive load during implementation.	Scrum converted complex goals into verifiable increments, made progress visible, and supported self-regulation, coordination, and shared responsibility.
Abstraction and pattern recognition	In hydroponics, students prioritized nutrients, water flow, and light exposure; the matico and cat's claw projects examined relationships among extraction method, time, and purity.	Students filtered secondary information, identified relevant variables, and recognized recurring relationships between conditions and results.	The define, prototype, and test phases of Design Thinking supported the selection of critical variables and progressive refinement of working hypotheses.
Technical validation of prototypes	The thermal chamber maintained 24 °C; consistent essential-oil extraction was documented; greenhouses and hydroponic systems incorporated daily records.	The prototypes showed functional feasibility, and the protocols demonstrated procedural precision and repeatability.	Acceptance criteria, public demonstrations, and end-of-sprint feedback integrated technical rigor, formative assessment, and continuous improvement.
Entrepreneurial and collaborative competencies	Development of socially and environmentally useful solutions; rotating roles; peer demonstrations; recycled materials; optimization of water, energy, and space.	Autonomy, communication, resilience to failure, ownership, and alignment of technology with local needs were strengthened.	PBL, Scrum, and Design Thinking connected computational thinking with early entrepreneurship and supported students' role as solution developers.
Overall synthesis and scope	Action research conducted during the school year in a public RBE institution, with complete cohorts and documentation of processes, products, and prototype performance.	The integrated framework was pedagogically feasible in a resource-constrained context and generated qualitative and functional evidence of learning.	The findings support the model's applicability. Broader comparative studies and standardized computational-thinking measures are required to strengthen external validity.

VI. Conclusions and Future Work

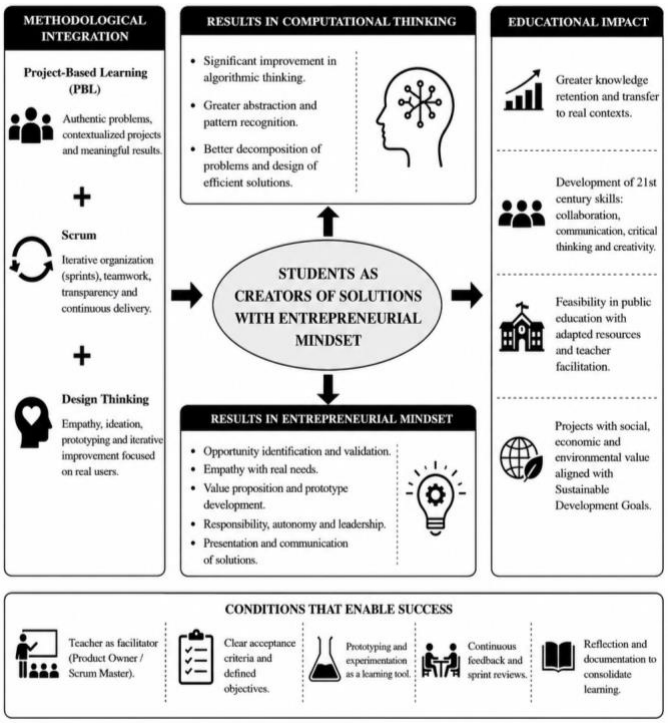


Fig. 2 Synthesis of conclusions derived from integration of PBL, Scrum and Design Thinking in EBR classrooms

The structured integration of Design Thinking, Scrum, and PBL in RBE provided a viable strategy for the early development of computational thinking. In a public education setting with limited technological infrastructure, secondary students were able to apply cognitive and procedural tools associated with systems engineering. The methodology supported a shift from passive technology use to the active development of functional solutions. Students addressed social, environmental, and community problems and applied technical knowledge to practical needs.

The didactic adaptation of agile frameworks originally developed for corporate project management also supported cross-cutting competencies relevant to future professional performance. Participants practiced collaborative work, resilience in response to technical failure, and assertive communication with peers and teachers. Their technical and analytical skills were reflected in the abstraction of complex systems, the representation of algorithmic processes through flowcharts without prior programming-language knowledge, and the construction of functional physical prototypes. Evidence included electronic circuits for thermal control and biotechnology protocols for crop management and the extraction of active compounds from botanical species.

These findings contribute to the field of education for entrepreneurship and innovation by showing how PBL, Scrum, and Design Thinking can support the development of computational, collaborative, and entrepreneurial competencies in Regular Basic Education. The results also indicate that authentic projects, iterative experimentation, and value-oriented problem solving can provide an appropriate basis for

introducing innovation and entrepreneurship at an early educational stage.

Future research should extend the implementation and comparative evaluation of this pedagogical model to a broader group of educational institutions. Studies should include students from more diverse socioeconomic, linguistic, and demographic contexts to strengthen external validity. The research line can also progress from unplugged programming and basic microcontroller automation toward formal instruction in more advanced textual and visual programming languages. Curricular integration of object-oriented programming and introductory artificial intelligence, connected to open-hardware platforms and educational robotics, could expand students' technological competencies, increase the technical rigor of school projects, and support technology entrepreneurship in basic education.

Future studies should employ mixed or quasi-experimental designs, including standardized pre/post measures such as a validated Computational Thinking Test, validated scales of entrepreneurial mindset or intention, gender-disaggregated analyses, and comparison groups using conventional PBL or traditional instruction. Multi-school samples would allow analysis across broader socioeconomic and demographic contexts. Entrepreneurial assessment should also incorporate opportunity recognition, value proposition quality, user-perceived value, basic cost-benefit analysis, and market or social feasibility.

Future implementations should examine teacher preparation as a key design variable. Acting as Product Owner and agile facilitator requires training in sprint planning, acceptance criteria, iterative feedback, and Design Thinking. Evaluating staged professional development, supported by templates and shared planning resources, together with teacher workload and self-efficacy, would help determine whether the model can scale sustainably.

ACKNOWLEDGMENT

The authors acknowledge the participation of the students involved in the educational intervention and the support provided by the teaching staff and school administration during the implementation of the classroom projects. Their collaboration facilitated the development, documentation, and evaluation of the activities reported in this study.

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