# Evaluation of STEAM+H and Design Thinking Interventions for the Circular Economy and Financial Literacy

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***Abstract–*** ***This study evaluates the impact of a pedagogical intervention that integrates the STEAM+H and Design Thinking approaches into the teaching of the circular economy and financial literacy to secondary school students. A mixed-methods approach with a pre-experimental design was applied to a census sample of 180 students. The proposal included an empathetic research phase of the environment, the design of prototypes through the upcycling of PET containers, interdisciplinary integration, and commercial validation within the school community. Qualitative analysis was conducted using ATLAS.ti, while quantitative analysis was performed using SPSS. The results show significant improvements: an 81.7% increase in circular economy knowledge and a 98.1% increase in financial literacy. Furthermore, the reduction in the standard deviation on the post-test reflects greater homogeneity in learning, suggesting group cohesion in the assimilation of content. The business audit reported sales of 840 units, revenue of S/. 2,520, and a net profit margin of 50%. These findings validate the relevance of active methodologies in vulnerable contexts, demonstrating that the combination of technological innovation, environmental responsibility, and youth economic autonomy strengthens key competencies and creates an educational impact that extends beyond the classroom into the community.***

***Keywords--*** ***Design Thinking, circular economy, financial literacy, STEAM+H, upcycling***

## I. Introduction

Contemporary education systems face the pressing challenge of equipping students not only with scientific knowledge but also with practical skills to thrive in a rapidly evolving global economy and in the face of a growing ecological crisis [1], [2]. Traditional teaching models tend to treat disciplines in isolation, separating environmental responsibility from commercial viability and technological design. This compartmentalization limits students' ability to translate theoretical knowledge into sustainable solutions for the real world [3], [4].

At the international level, organizations such as UNESCO emphasize that the transition toward a sustainable global economy requires systemic educational reforms. Modern curricula must integrate environmental responsibility directly into everyday learning environments, shifting from linear consumption paradigms to circular models that prioritize waste reduction, material recovery, and responsible resource management [5], [6].

Despite global policy frameworks that promote education for sustainable development, international school systems often struggle to bridge the gap between theoretical environmental concepts and students' practical skills [7], [8].

Developing countries in Latin America and the Caribbean face serious socio-environmental challenges, characterized by an exponential increase in the generation of municipal solid waste, particularly single-use plastics and polyethylene terephthalate (PET) containers [9], [10].

National education policies often call for cross-cutting competencies in entrepreneurship and environmental stewardship; however, their implementation in the public education sector is severely limited by traditional rote-learning methodologies, inadequate infrastructure, and the lack of practical frameworks that connect classroom theory with economic realities [11], [12].

As a result, students graduate without the critical financial literacy or entrepreneurial skills necessary to actively participate in emerging regional green economies [13], [14].

In national public high schools, these systemic deficiencies manifest as visible, localized environmental degradation such as the accumulation of discarded plastic bottles on the urban periphery along with high vulnerability to the economic instability of students' households. Educational interventions in these public contexts are rarely documented through rigorous empirical research, leaving a fundamental gap in our understanding of how resource-poor schools can transform ecological vulnerabilities into dynamic ecosystems of experiential learning [15], [16].

To bridge this educational gap, integrated frameworks such as STEAM+H (science, technology, engineering, art, mathematics, and the humanities) and design thinking have emerged as powerful catalysts for innovation [17], [18].

Combined with basic financial education, these frameworks empower students to act as active agents of change rather than passive learners, offering a unique pathway to experiential learning [19], [20].

This article evaluates a structured educational intervention implemented with 180 middle school students at a national public school. By involving students in the entire life cycle of

an eco-innovation project from the empathetic identification of the problem and the recycling of PET bottles to create functional objects (flower pots and pencil holders) to commercial validation and financial management this study examines the direct impact of STEAM+H and design thinking on high school students' understanding of the circular economy and their financial skills.

## II. METHODOLOGY

The study adopted a mixed-methods approach, allowing for the integration of quantitative measurements of students' cognitive and financial processes with a qualitative interpretation of their co-creation and problem-solving dynamics [21].

This research was structured from a rigorous perspective that addresses the need to evaluate complex pedagogical interventions in real educational contexts, where strict laboratory control is not feasible [22].

These combinations of analytical approaches ensure a holistic understanding of the phenomenon under study, overcoming the limitations of single-discipline approaches [23].

From a research design perspective, a single-group pre-experimental model with pre- and post-tests was chosen, formally structured as a pre-measurement, an instructional intervention, and a post-measurement [24].

In the field of institutional educational research, this type of design is fully justified when administrative and ethical constraints in public schools prevent the formation of independent control groups or the random assignment of students [25].

The intervention served as the transformative framework against which longitudinal change was measured in the same participants, ensuring that any statistically significant variation in their competencies is closely linked to the implemented program [26].

Regarding the population and sample definition, the study focused on the secondary education level at a national public institution. A census-style, non-probabilistic, purposive sampling method was used, covering the entire cohort of 180 students enrolled in the third year of secondary school [27].

The decision to work with this entire group was based on an inclusive and participatory approach, ensuring that no student was excluded from the circular economy experience. All members of the sample participated actively and collaboratively in the different phases of the project, from the collection of plastic waste to the final sale of the utility products [28].

The operational implementation of the educational program was structured into four sequential phases based on the principles of Design Thinking and the STEAM+H curriculum integration [29]. In the first stage, called empathy and ideation, students critically investigated the problem of pollution caused by polyethylene terephthalate waste in their local environment, designing prototypes aimed at addressing real needs in their community [30].

The second phase integrated scientific, technological, artistic, and humanistic disciplines, addressing volume calculations and product aesthetics [31].

Subsequently, in the third phase, the physical process of transformation and prototyping took place, converting the recycled bottles into functional planters and pencil holders [32].

Finally, the fourth phase introduced modules on applied financial education, in which students calculated production costs, established profit margins, and managed the actual sale of their creations [33].

To collect the empirical data supporting the findings, a system of structured instruments was designed to ensure the reliability and validity of the research [34].

The quantitative component was based on a questionnaire using a five-option multi-item Likert scale, administered at two different time points as a pre-test and a post-test and comprising ten items distributed equally across the dimensions of the circular economy and financial literacy [35].

Likewise, to evaluate the results of the commercial intervention, a team-based financial tracking matrix was implemented, which allowed for the precise quantification of the number of units produced and sold, as well as the net revenue generated [36].

## III. RESULTS

The analysis was structured using a dual methodology: qualitative data was analyzed using ATLAS.ti, and quantitative statistical analysis was performed using SPSS software.

Processing and Qualitative Analysis (ATLAS.ti)

The qualitative analysis made it possible to group the data into three central macro-categories that explain the educational phenomenon:

a) Creative waste management. The constructs in ATLAS.ti showed that students shifted from perceiving PET containers as mere urban waste to recognizing them as raw materials with aesthetic and utilitarian value. The coding highlighted how students solved technical problems related to cutting and packaging through a process of prototyping inspired by basic engineering principles.

b) Empathy and market validation. Through the semantic networks generated by the software, it was found that the process of empathizing with potential buyers in the school setting enhanced the students' resilience and assertive communication when offering the planters and pencil holders.

c) Humanistic socio-environmental awareness. The analyzed excerpts demonstrated that the students engaged in critical reflection on the impact of plastic on their local community, connecting what they learned in science class with their responsibility as active citizens.

From a methodological perspective, the use of coding and semantic networks made it possible to identify the transition from initial perceptions to deeper and more applied understandings, highlighting how the young people went from viewing PET as waste to valuing it as a resource, how they developed communication skills by interacting with real buyers, and how they critically reflected on their role as citizens in light of environmental impact.

Quantitative Statistical Processing and Analysis (SPSS)

TABLE I
DESCRIPTIVE STATISTICS FOR THE DIMENSIONS ASSESSED BEFORE AND AFTER (N=180)

| Variable / Dimension in SPSS | Pre-test Measurement (O1) Mean (μ) ± Standard Deviation (σ) | Post-test Measurement (O2) Mean (μ) ± Standard Deviation (σ) | Percentage Increase in Improvement |
|---|---|---|---|
| Circular Economy (Eco Index) | 2.41 ± 0.82 | 4.38 ± 0.65 | 81.70% |
| Financial Education (Fin Index) | 2.15 ± 0.79 | 4.26 ± 0.71 | 98.10% |

The table shows a substantial increase in the average scores for both assessed dimensions, moving from initial levels close to neutrality toward values clearly associated with conceptual adequacy and mastery, with percentage improvements of +81.7% in Circular Economy and +98.1% in Financial Literacy; furthermore, the reduction in the standard deviation in the post-test indicates greater homogeneity in learning, suggesting that the educational intervention not only strengthened students' level of understanding but also fostered group cohesion in the assimilation of content.

This progress reflects not only a quantitative increase in scores but also a qualitative shift in the way students construct and share knowledge. The reduction in the dispersion of responses shows that the educational experience succeeded in aligning perceptions and consolidating collective learning, creating an environment of greater cognitive equity within the group. In this regard, the educational intervention was not limited to conveying content but served as a catalyst for pedagogical transformation, where collaborative practice and an applied approach fostered the internalization of key competencies for sustainability and financial management, creating an impact that extends beyond the classroom and is directly linked to everyday life.

TABLE II
T-TEST FOR RELATED SAMPLES

| Dimension / Variable | Pre-test Mean (μ) | Post-test Mean (μ) | Difference **(Δ)** | Standard Error (SE) | t | p |
|---|---|---|---|---|---|---|
| Circular Economy (Eco Index) | 2.41 | 4.38 | 1.97 | 0.078 | 25.3 | < 0.001 |
| Financial Education (Fin Index) | 2.15 | 4.26 | 2.11 | 0.079 | 26.7 | < 0.001 |

The t-test for paired samples confirms that the differences between pretest and posttest scores on both dimensions are highly significant ($t = 25.3$ for the Circular Economy and $t = 26.7$ for Financial Literacy, $p < 0.001$); which demonstrates that the educational intervention had a real and consistent impact on the students, substantially increasing their levels of understanding and reducing the variability in their responses, thereby reinforcing the validity of the descriptive findings.

TABLE III
FINANCIAL AND BUSINESS INDICATORS ANALYZED IN SPSS (N=180)

| Financial Indicator (SPSS Variables) | Average per Work Team | Total Sum of the Sample (Cohort) |
|---|---|---|
| Units Produced | 12.00 Units | 960 Units |
| Units Sold | 10.50 Units | 840 Units |
| Total Investment Cost (Inputs) | S/ 1.50 | S/ 120.00 (Shared investment) |
| Total Sales Revenue | S/ 31.50 | S/ 2,520.00 |
| Net Income Generated | S/ 15.75 | S/ 1,260.00 |
| Average Return (%) | 50.00% | 50.0% overall net margin |

The table shows the financial and commercial indicators obtained; these can be interpreted in an integrated manner: the work teams produced an average of 12 units and sold 10.5, which demonstrates a sales capacity close to total production; the investment cost per input was minimal (S/. 1.50 per team, equivalent to S/. 120 for the entire cohort), while sales revenue

averaged S/. 31.50 and totaled S/. 2,520, generating a net profit of S/. 15.75 per team and S/. 1,260 in total. These results reflect an average profitability of 50%, indicating that the practical experience enabled students to understand the direct relationship between investment, production, marketing, and profit, thereby reinforcing applied learning in financial management and entrepreneurship. In summary, the table shows that the initiative was not only economically sustainable but also highly educational in building financial and business skills.

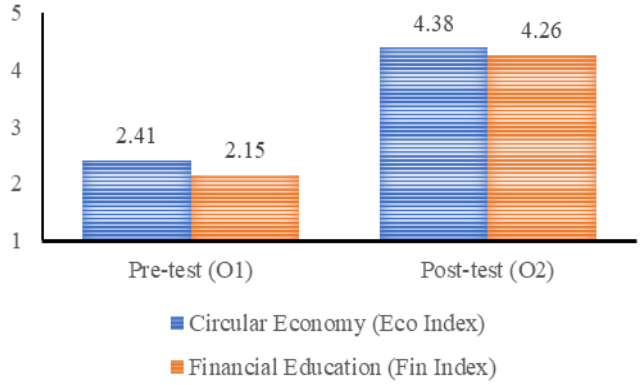



Fig. 1 Implementation of the STEAM+H Strategy and Design Thinking

The comparative chart shows a significant shift in student perceptions following the implementation of the STEAM+H and Design Thinking strategy: in Circular Economy, the average score rose from 2.41 on the pretest to 4.38 on the posttest, reflecting a shift from a lack of understanding toward a grasp of concepts such as upcycling and eco-design; while in Financial Education, the increase from 2.15 to 4.26 validates the effectiveness of the hands-on workshop on cost calculation, pricing, and marketing, overcoming initial conceptual barriers. The magnitude of the differences, confirmed by highly significant inferential tests ($p < 0.001$), demonstrates that the intervention not only consolidated individual learning but also fostered group cohesion in the understanding of key competencies for sustainability and financial management.

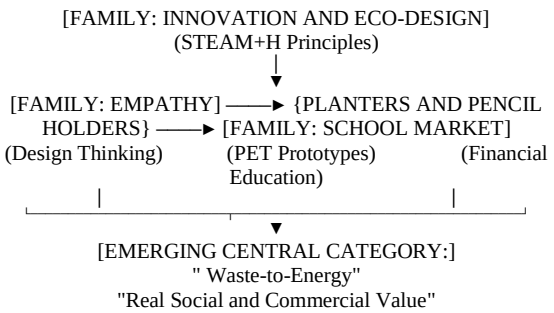



Fig. 2 Eco-Entrepreneurship Semantic Network

Analysis of the semantic network generated in ATLAS.ti reveals a holistic system of eco-entrepreneurship in which the 180 students integrated innovation, eco-design, and financial management. The core of the process focused on creating planters and pencil holders from recycled PET bottles, which was linked to the Design Thinking framework through empathy toward the environment and the iteration of prototypes under the STEAM+H approach. At the same time, this practice was extended to the school market, where students applied concepts of financial education while interacting with real buyers. The emerging category "Transforming Waste into Real Social and Commercial Value" summarizes the experience, demonstrating that the educational intervention went beyond isolated craft activities to form a comprehensive learning process in which environmental theory and commercial practice complemented each other to generate meaningful and sustainable learning.

## IV. Discussion

The study evaluated the impact of a structured pedagogical intervention based on the STEAM+H and Design Thinking frameworks on the circular economy and financial literacy among a census sample of 180 third-year high school students. Through robust methodological triangulation that combined quantitative statistical analysis processed in SPSS and qualitative content analysis assisted by ATLAS.ti, it was possible to examine not only the participants' cognitive development but also their performance in a real-world business validation setting.

When comparing these findings with the specialized literature, there is clear consistency with the approaches of various authors such as [37], [38], [39], [40], [41], who argue that environmental and technological education takes on true meaning when it transcends abstract theory, becomes tangible transformative experiences, and is integrated into the dynamics of upcycling and physical prototyping. The 81.7% increase in the circular economy dimension demonstrates that the transformation of polyethylene terephthalate (PET) containers into functional planters and pencil holders breaks with the inertia of traditional linear consumption. Students stopped perceiving solid waste as urban trash and began to conceptualize it as a valuable raw material, confirming that basic engineering design in high school directly fosters active socio-environmental awareness. This shift in perspective which turns waste into opportunity and intertwines social responsibility generates an impact that transcends the classroom and extends into the community.

Likewise, the quantitative results in the financial education dimension showed a significant increase of 98.1%, supporting the theoretical premises of [42], [43], [44], [45], and [46], who assert that early financial literacy is an indispensable pillar of resilience in vulnerable communities. In this study, the intervention was not limited to an isolated hands-on exercise; the integration of workshops on fixed and variable costs and pricing allowed the student teams to calculate a modest investment in supplementary supplies of S/.

1.50 per team and achieve an overall net profit margin of 50%, resulting in 840 units successfully sold at prices accessible to the school community, generating total revenue of S/. 2,520. This commercial performance empirically validates the proposed hypothesis, confirming that comprehensive pedagogical approaches enhance young people's assertive communication and vocational skills without requiring a budget.

Despite the strength of the results, this study has certain methodological limitations inherent to the context in which it was conducted. Since a single-group pre-experimental design with pre- and post-tests was chosen due to administrative regulations and ethical restrictions on assignment in national public educational institutions the findings should be interpreted as strong evidence of a direct causal association with the pedagogical intervention, without completely ruling out the influence of external variables or natural maturation over time.

## V. Conclusions

It was found that the application of the STEAM+H and Design Thinking frameworks has a significant impact on the development of the circular economy within the school setting. The practical transformation of polyethylene terephthalate (PET) containers into functional planters and pencil holders enabled students to move beyond the traditional view of urban waste, fostering a deep understanding of upcycling and eco-design, as reflected in an 81.7% increase in their environmental competencies.

It was determined that the integration of structured modules on costs, pricing, and marketing substantially increases students' financial literacy. The 98.1% increase in the assessed areas demonstrates that the teaching of economic concepts ceases to be abstract when directly linked to a real-world productive project, equipping young people with analytical tools for managing sustainable microenterprises.

The commercial viability and profitability of the educational model were empirically validated on a realistic and accessible scale, as evidenced by the successful sale of 840 units within the school setting, total revenue of S/. 2,520, and a net profit margin of 50%. This confirms that public educational institutions, despite their financial constraints, can manage sustainable eco-entrepreneurship projects tailored to their specific context.

It is concluded that, despite the limitations inherent in a single-group pre-experimental design, the synchronous integration of science, technology, engineering, art, the humanities, and economics generates a profound cognitive and attitudinal impact. Scaling up these types of methodologies across educational networks in the region represents a solid path toward fostering citizens with critical environmental awareness and economic autonomy.

## VI. Recommendations

Secondary education institutions and ministerial authorities are encouraged to institutionalize and mainstream the STEAM+H and Design Thinking approaches within official curricula. Integrating environmental sustainability and the circular economy as ongoing practical focal points, rather than treating them as isolated topics, enables students to develop genuine critical thinking skills in response to the urban solid waste crisis.

It is recommended that administrative teams and teachers at public schools foster strategic partnerships with the local community and the school market to replicate commercially viable upcycling projects. Linking the production of useful products (such as PET planters and pencil holders) with hands-on workshops on financial literacy and actual cost calculation equips young people to tackle the socioeconomic challenges of their environment with greater autonomy.

Researchers in the field of education are advised to adopt quasi-experimental designs with equivalent control groups and random or balanced assignment in future studies aimed at international scientific dissemination. This will allow for a more rigorous isolation of intervening variables, strengthening statistical rigor and facilitating the generalization of pedagogical models across diverse Latin American contexts.

Education authorities are urged to promote ongoing teacher training programs focused on active methodologies and project-based learning. Equipping teachers with the tools to integrate science, technology, and the humanities is essential for transforming classrooms into true ecosystems of sustainable social innovation.

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