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VISUAL COMMUNICATION OF SUSTAINABILITY AND THE CIRCULAR ECONOMY IN HIGHER EDUCATION: A COMPARISON OF STUDENT PERCEPTIONS AT TWO UNIVERSITIES IN ECUADOR AND HONDURAS

COMUNICACIÓN VISUAL DE LA SOSTENIBILIDAD Y LA ECONOMÍA CIRCULAR EN LA EDUCACIÓN SUPERIOR: PERCEPCIÓN ESTUDIANTIL COMPARADA EN DOS UNIVERSIDADES DE ECUADOR Y HONDURAS

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RESUMEN

Introducción: La comunicación visual de la sostenibilidad constituye un "currículo oculto" clave en el campus universitario para impulsar la economía circular frente a los desafíos climáticos. **Objetivo:** Analizar la percepción estudiantil sobre la comunicación visual de la sostenibilidad y economía circular en instituciones de educación superior de Ecuador y Honduras, comparando por país y género. **Metodología:** Estudio cuantitativo, no experimental y descriptivo-correlacional con 388 estudiantes (Ecuador n=202; Honduras n=186). Se aplicó un cuestionario de 26 ítems estructurado en 7 dimensiones, analizado con pruebas no paramétricas de Friedman y U de Mann-Whitney. **Resultados:** La disposición participativa (D7) registró la mayor media (M=3.90), mientras que la representación de la economía circular (D2, M=3.67) y la alfabetización visual (D6, M=3.70) obtuvieron las puntuaciones más bajas. Ecuador superó significativamente a Honduras en D1-D6, y las mujeres mostraron promedios mayores en D1 y D7. **Discusión:** Existe una tensión entre el alto compromiso participativo estudiantil y un entorno físico semióticamente "mudo". Se propone el Marco de Comunicación Visual Proambiental (MCVPUC) y el programa AVPU para articular la alfabetización visual. **Conclusiones:** La voluntad participativa requiere hacer visible el metabolismo universitario, siendo clave potenciar la señalética pedagógica y la educación gráfica en el campus.

Palabras clave: Alfabetización visual, comunicación visual, currículo oculto, economía circular, educación superior, percepción estudiantil, sostenibilidad.

ABSTRACT

Introduction: Visual communication of sustainability constitutes a key “hidden curriculum” on university campuses for promoting the circular economy in response to climate challenges. **Objective:** To analyze students’ perceptions of visual communication regarding sustainability and the circular economy in higher education institutions in Ecuador and Honduras, comparing findings by country and gender. **Methodology:** A quantitative, non-experimental, descriptive-correlational study was conducted with 388 students (Ecuador, n = 202; Honduras, n = 186). A 26-item questionnaire structured into seven dimensions was administered. Data were analyzed using the non-parametric Friedman and Mann–Whitney U tests. **Results:** Participatory willingness (D7) recorded the highest mean score (M = 3.90), whereas circular economy representation (D2, M = 3.67) and visual literacy (D6, M = 3.70) obtained the lowest scores. Ecuador scored significantly higher than Honduras across D1–D6, while women reported higher mean scores in D1 and D7. **Discussion:** A tension exists between students’ strong participatory commitment and a physical environment that remains semiotically “silent.” The Pro-Environmental Visual Communication Framework for University Campuses (MCVPUC) and the AVPU program are proposed to integrate and strengthen visual literacy. **Conclusions:** Students’ willingness to participate requires making the university’s material flows and resource-use processes more visible. Strengthening educational signage and graphic literacy on campus is therefore essential.

Keywords: Visual literacy, visual communication, hidden curriculum, circular

economy, higher education, student perception, sustainability.

1. Introduction

In the course of the third decade of the twenty-first century, humanity faces environmental challenges of great magnitude, associated with what Earth system scientists call the "Great Acceleration." The imminent collapse of various biophysical systems, manifested through anthropogenic climate change, the accelerated loss of biodiversity, and the systemic degradation of biogeochemical cycles, has forced a critical reassessment of the foundations of modern economic development. The dominant linear model, based on unlimited extraction, mass production, and final disposal, has exceeded safe planetary boundaries, placing us squarely in the era of the Anthropocene. This period is defined as a geological epoch in which human activity has become the predominant and, in many cases, destructive force for the stability of the biosphere (Arevalo et al., 2023; D'Amato, 2021; Deda et al., 2022).

In the face of this systemic crisis of habitability, the United Nations 2030 Agenda and its 17 Sustainable Development Goals (SDGs) provide the normative and ethical framework and the teleological vision for a transition toward global sustainability. Within this complex scheme, SDG 12, focused on Responsible Consumption and Production, and SDG 4, oriented toward Quality Education, converge on the imperative need to transform not only industrial production processes but also the cognitive, cultural, and ethical foundations of global citizenship (Odell et al., 2020; Perrault & Clark, 2017). It is here that the "Circular Economy (CE)" emerges not merely as a technical tool for resource optimization or waste management, but as an ontological and systemic paradigm shift. Circularity proposes a radical transition from a mechanistic, linear view of the economy, which sees nature as a storehouse of raw materials and a dump for waste, to an organic, metabolic, and regenerative view. This model is inspired by biomimicry, observing the closed cycles of nature in which the concept of "waste" does not exist, since the output of one process is always the input of another (Deda et al., 2022; Kirchherr & Piscicelli, 2019; Marzi & Renner, 2024). This transition demands a profound systemic literacy that enables individuals to understand the interconnectedness of flows of materials, energy, and information at the global and local scale (D'Amato, 2021; Khajuria, 2025).

This is where Higher Education Institutions (HEIs) play a catalytic and strategic role in this civilizational transition. As nerve centers of knowledge creation, advanced research, and the education of tomorrow's leaders, universities act as "microcosms" or Living Labs of society (Vergani, 2024). University Social Responsibility (USR) has evolved significantly in recent years to integrate sustainability and circularity into the very core of institutional and operational identity. HEIs have the unique capacity to prototype circular solutions, from closed-loop water systems to servitization models in their laboratories, and to assess their impact before these practices are scaled up to the wider social and economic fabric (Vergani, 2024).

However, the effective implementation of circularity in higher education faces a critical meso-structural challenge that is often ignored: the deep disconnect between

the administrative management of the campus and institutional educational communication (Perrault & Clark, 2017; Whitehill et al., 2022). Many universities have made admirable technical progress in implementing sustainable infrastructure, such as state-of-the-art electronic waste management systems, integrated solar farms, and green public procurement processes. Nevertheless, these technical efforts often remain confined to management reports or administrative databases and are invisible to the vast majority of the student community. As Cotton et al. (2023) astutely point out, there is a powerful "hidden curriculum" embedded in the physical environment of the campus. If sustainability actions are not visually accessible, narrated through clear icons, or integrated into the everyday aesthetics of the university space, the institution is implicitly communicating that sustainability is a secondary administrative function and not a central cultural or educational value. This invisibility creates a perception gap that undermines the foundations of Education for Sustainability (EfS). Management without strategic visual communication is mute, and communication without solid management behind it is perceived as superficial. The truly circular university must be able to project its internal metabolism outward, turning the campus into a legible text, a visually stimulating narrative, and a pedagogical tool that educates through its tangible presence and not only through theoretical instruction in the classroom (Hirst, 2019; Odell et al., 2020; Waite et al., 2025).

At the micro-analytical level, the ultimate success of any institutional transition toward circularity depends on students' perception, semiotic decoding, and behavior. Generation Z, which makes up the majority of the current university population, is highly sensitive to environmental causes, but has also developed an acute and defensive skepticism toward institutional rhetoric that it perceives as superficial, bureaucratic, or purely promotional (*greenwashing*) (Ilić-Kosanović & Ilić, 2021; Mamula Nikolić et al., 2022). The scientific literature suggests that student perception is not a passive response, but is strongly influenced by the visual and narrative coherence of the campus. A student who learns about the metabolic cycles of the circular economy in a technical course but who, on leaving the classroom, encounters overflowing recycling bins, a lack of clear signage in common areas, or architecture that ignores bioclimatic principles experiences severe narrative and cognitive dissonance. This dissonance drastically reduces their motivation to engage in pro-environmental practices and weakens their identity as a circular citizen (Arrieta Díaz, 2017; Ferreira et al., 2023; Ilić-Kosanović & Ilić, 2021).

This problem manifests itself with specific geographic and cultural particularities in the Latin American context. Whereas in European and North American contexts research on the visual perception of sustainability and pro-environmental information design is relatively well established (Cotton et al., 2023; Del Moral Pérez et al., 2022), in our region the production of evidence is still fragmentary and uneven. In the case of Ecuador, academic research has begun to explore successfully the predisposition of young university students toward specific circular behaviors, such as repairing electronic devices or adopting sharing-economy models in cities such as Manta and Guayaquil (Falcone, 2024; Molina-López & Zaldumbide-Peralvo, 2020; Nuela Telenchana et al., 2025). A positive and rational attitude has been identified, but one that is often frustrated by the lack of visual communication infrastructures connecting

individual intention with collective action on campus (Garabiza et al., 2021; Nuela Telenchana et al., 2025).

By contrast, in the case of Honduras, no systematized scientific evidence was identified on how Honduran students interpret the narratives of circularity and sustainability in their institutions. The corpus analyzed shows that, although pro-environmental initiatives exist, they lack scientific evaluation from the perspective of students' visual and semiotic perception. This knowledge gap constitutes a critical barrier to the development of USR policies that are culturally relevant and communicatively powerful in the Central American country. The present research therefore seeks to address this gap through the fundamental question: How do university students in Ecuador and Honduras perceive the visual communication of sustainability and the circular economy in their higher education institutions, and what differences arise according to country and gender?

2. Objectives

2.1. General objective

To analyze the perception of university students in Ecuador and Honduras regarding the visual communication of sustainability and the circular economy in their higher education institutions, identifying differences by country and gender, in order to establish an empirical basis for a proposed visual communication framework aimed at strengthening the visibility and understanding of circularity on the university campus.

2.2. Specific objectives

SO1. To characterize the perception of university students in Ecuador and Honduras regarding the visual communication of sustainability and the circular economy, on the basis of the dimensions that make up the research instrument.

SO2. To compare students' perceptions of the visual communication of sustainability and the circular economy by country and gender, identifying statistically significant differences between the groups studied.

SO3. To establish the components and guiding criteria of a proposed visual communication framework for the circular university, on the basis of the main findings on student perception.

3. Theoretical Framework

3.1. Education for Sustainability versus Institutional Marketing.

The study of the perception of sustainability in higher education requires a distinction to be drawn between Education for Sustainability (EfS) and reputational institutional communication. EfS is not the transmission of technical information, but

a transformative learning process aimed at developing critical awareness and moral agency in the face of the systems that perpetuate unsustainability (Hirst, 2019). EfS must operate as a space of "provocation": the visuality of the campus should not please the eye, but generate dilemmas that oblige students to reassess their assumptions about consumption and ethics, in line with the idea of the physical environment as the "third teacher" (*the environment as the third teacher*).

By contrast, institutional "*Green Marketing*" often falls into the trap of reducing sustainability to a competitive brand advantage for attracting new student profiles. Arrieta Díaz (2017) severely criticizes this tendency, particularly in faculties of economics and business, pointing out that the "marketing of unbridled consumption" clashes head-on with official discourses on sustainable education. Students are bombarded with institutional messages extolling sustainability in admissions brochures, while the internal culture of the faculty continues to reward business models based on infinite linear growth and success measured exclusively in short-term financial terms. This flagrant contradiction creates a perception of institutional hypocrisy that delegitimizes genuine educational efforts. For communication to be effective and transformative, it must abandon its purely promotional function and adopt a pedagogical, semiotic, and ethical one, in which every graphic, sign, and image is a vehicle of systemic knowledge and a tangible commitment by the university to its environment (Maiorescu et al., 2020; Waite et al., 2025; Whitehill et al., 2022).

3.2. Visual Narratives and the Anthropocene

In an era saturated with visual stimuli, technical, statistical, and often catastrophic information about the climate crisis tends to be ignored or to generate an emotional paralysis known as eco-anxiety or a feeling of powerlessness. "Visual narratives" and digital "*storytelling*" are emerging as fundamental pedagogical tools for humanizing the crisis, giving it meaning, and mobilizing civic action. Arevalo et al. (2023) strongly propose that "digital stories" allow students to navigate the overwhelming complexities of the Anthropocene, transforming abstract scientific data into meaningful experiential accounts that foster creativity, engagement, and systems thinking. This approach is corroborated by the experience of Venkatesan et al. (2023), who document how actively involving students in the production of documentary films about the life cycle of everyday products (such as the "*Plastic Linings*" project at *Northeastern University*) is a high-impact experiential learning strategy. Audiovisual production not only educates the audience but profoundly transforms the student producer, reducing their sense of apathy and promoting pro-environmental leadership based on direct knowledge of the material reality of waste.

Visual "*storytelling*" not only conveys information but creates a deep emotional connection that raw data cannot achieve. Del Moral Pérez et al. (2022) find that the "*engagement*" of young university students with pro-environmental narratives depends critically on the capacity of these stories to generate empathy, curiosity, and a sense of collective identity with the ecological cause. Innovative formats such as digital animation and animated infographics, analyzed by authors such as Subandrio (2025) and Waite et al. (2025), make it possible to visualize processes that would

otherwise be invisible to the human eye, such as the regeneration of soil nutrients, the circular flow of materials in a factory, or carbon capture on campus, in a way that is at once educational, transparent, and aesthetically appealing. Visual narrative therefore acts as a cognitive and emotional bridge that translates the technical complexity of sustainability into an experience that is comprehensible and mobilizing for Generation Z students (Del Moral Pérez et al., 2022; Falcone, 2024).

3.3. Visual Literacy and the Hidden Curriculum of the Campus

A central and cross-cutting concept in this theoretical framework is "Pro-Environmental Visual Literacy (PVL)." In a world dominated by the image, it is not enough to expose students to visual stimuli relating to sustainability; it is imperative that they possess the critical tools to decode, evaluate, and question them. Hirst (2019) and Cotton et al. (2023) agree that visuality in higher education often operates at the level of the "hidden curriculum." Cotton et al. (2023) demonstrate through comparative empirical studies that there is an alarming gap: while the official websites of universities are saturated with idyllic images of sustainability (solar panels, students in lush gardens, perfect recycling points), these images rarely match students' physical, everyday experience on the real campus.

This persistent discrepancy creates what is termed "visual institutional blindness," in which students cease to perceive the university's real sustainable actions because these are not integrated into the everyday visual and aesthetic narrative of their immediate environment. For example, if the university's composting system is hidden behind the maintenance buildings and has no educational signage, for the student composting simply does not exist. Visual literacy involves developing in students the capacity to identify these "fractures" in the institutional landscape. When students are trained through participatory methodologies to analyze critically the visual landscape of their own alma mater, they cease to be passive recipients of marketing messages and become active agents of environmental auditing and change. "Digital collage" is used as a powerful instructional design technique that allows students to visualize and narrate their own perceptions and anxieties about the climate crisis, fostering reflective, collaborative, and situated learning that breaks with the traditional passivity of the classroom (Angus-Cole et al., 2023). The circular university must therefore evolve from being a mere one-way transmitter of images to being a facilitator of visual dialogues and spaces of semiotic co-creation (Angus-Cole et al., 2023; Whitehill et al., 2022).

3.4. The Circular Economy as a Visible Metabolic System

The dominant student perception of the "Circular Economy (CE)" tends to be excessively simplistic and reductionist, limited almost exclusively to the act of throwing rubbish into recycling bins. Deda et al. (2022) and Owojori et al. (2022) document with concern a persistent gap between theoretical knowledge of recycling and a deep understanding of the CE as a systemic and metabolic regenerative model. Deda et al. (2022) observe that, even in circularity ideas competitions designed for university students, students rarely consider social and ethical indicators or new

circular business models (such as pay-per-use), focusing mostly on the physical recovery of post-consumer materials.

To correct this perceptual bias, the university must make its "circular metabolism" visible. This involves the strategic use of "circular infographics," real-time data "*dashboards*," and smart signage illustrating not only where to dispose of an object, but where it came from, how much energy it took to produce, and how it will be reintegrated into the biological or technical cycle of the campus (González Quintero & Candela Sanjuán, 2025; Waite et al., 2025). Visual tools should be designed through participatory "*Design Thinking*" processes, ensuring that icons and messages are culturally clear, technically accurate, and visually consistent with the identity of the institution. The ultimate goal is to build a university in which circularity is "readable" and tangible in every corner of the campus: one in which the design of spaces, smart water management, a zero-waste food culture, and renewable energy form a holistic visual narrative that shows students that another economic and social model is not only possible, but is already operating as a living reality beneath their feet (Alazaiza et al., 2025; Vergani, 2024; Whitehill et al., 2022).

3.5. Participatory Visual Methodologies

The expansion of the theoretical framework leads us to consider the methodologies through which visual perception is studied and fostered. Traditionally, research has relied on opinion surveys, but recent authors suggest that capturing the depth of perception requires "visual elicitation methodologies." This involves using images as stimuli in interviews so that students project their values and meanings regarding sustainability (Hirst, 2019; Weder et al., 2019). Weder et al. (2019) propose the use of "*story cubes*" in narrative research in order to understand how individuals perceive sustainability at a personal and emotional level, beyond the ready-made answers of questionnaires.

Likewise, "digital collage" and participatory design are becoming established as pedagogical and research tools. The process of creating a collage allows students to integrate disparate elements of the ecological crisis (technology, nature, waste, hope) into a single coherent image, facilitating the externalization of complex mental models. This practice of aesthetic co-creation is vital for reducing institutional "narrative dissonance," since it allows students to take part in constructing the very image of their university as a circular entity. By giving students the role of designers of the visual narrative, the university fosters a sense of ownership and shared responsibility for the sustainability outcomes of the campus (Angus-Cole et al., 2023; Venkatesan et al., 2023; Whitehill et al., 2022). Visual literacy thus becomes not only a receptive competence, but an expressive and transformative capacity that is fundamental for the professional of the future.

4. Methodology

4.1. Research design

To address the stated objective, the present study was conducted from a quantitative positivist paradigm, which "conceives of science as a description of phenomena based on given facts, which can be observed or measured objectively through systematic processes" (Park et al., 2020); the research was therefore devoted to describing how students perceive universities' visual communication regarding sustainability and the circular economy.

For data collection, the study used a non-experimental design, since the variables under study were observed in their natural context without intervention or manipulation by the researchers and were simply described as they occurred. The research was descriptive-correlational in scope, since it includes the characterization of the variables of interest and the analysis of the relationship between the different groups evaluated without strictly establishing causality (Rezigalla, 2020).

4.2. Participants

The study participants were selected through purposive non-probabilistic sampling (Palella & Martins, 2012), with the following inclusion criteria: that they be university students enrolled in undergraduate programs; that they had completed at least two (2) academic terms at the institution; and that they had access to the universities' digital platforms/networks. Table 1 shows the distribution of the study sample, made up of 388 university students, of whom 52% are from the university in Ecuador (UBE) and 48% from the university in Honduras (CEUTEC/UNITEC). It should be noted that they form part of a training process that corresponds to an action of the research project entitled "Fortalecimiento de Competencias profesionales a través de la Investigación Científica Estudiantil en la Gestión de la Economía Circular - Estudio Comparado" (Strengthening Professional Competencies through Student Scientific Research in Circular Economy Management: A Comparative Study), carried out by the Universidad Bolivariana del Ecuador.

Table 1. Distribution of study participants by country, university, and gender.

Country	University	Gender	Participants	Total
Ecuador	UNIVERSIDAD BOLIVARIANA DEL ECUADOR (UBE)	Female	145	**202**
		Male	57	
Honduras	CEUTEC/UNITEC	Female	105	**186**
		Male	81	
TOTAL PARTICIPANTS				**388**

4.3. Data collection instrument

Data collection was carried out in July 2026 through the administration of a digital questionnaire to the participants. The instrument consisted of 26 items grouped into seven dimensions. Responses were coded on a five-point Likert scale, from 1

(strongly disagree) to 5 (strongly agree). To obtain the score for each dimension, the arithmetic mean of its constituent items was calculated: D1, items Q1–Q4; D2, Q5–Q10; D3, Q11–Q14; D4, Q15–Q17; D5, Q18–Q20; D6, Q21–Q23; and D7, Q24–Q26. In this way, the dimensional scores retained the original range of the scale, between 1 and 5, and higher values represented a greater degree of agreement with the statements corresponding to each dimension.

Before the analysis, the database was reviewed to identify records with no responses and missing values. Records with no responses to any of the 26 items were excluded. For records with partial responses, dimensional scores were calculated using the valid responses available for the items in each dimension. The number of valid observations may therefore vary across dimensions and analyses.

To validate the instrument, it was evaluated by an interdisciplinary panel of five specialists selected according to criteria of academic training, professional experience, and research in the conceptual domains addressed by the instrument. The panel was made up of a specialist in higher education and educational evaluation, a specialist in communication and visual culture, a specialist in sustainability and environmental education, a specialist in circular economy and environmental management, and a specialist in research methodology and psychometrics. The inclusion criteria were postgraduate training in the area of specialization, a minimum of five years of professional or academic experience, and a research record related to the object of study, as indicated by Cabero Almenara and Llorente Cejudo (2013).

The statistical software JAMOVI version 2.6.44 was used for data processing. Internal consistency was estimated using Cronbach's alpha coefficient, both for each of the seven dimensions and for the instrument as a whole. The values obtained were: for D1, $\alpha = .925$; for D2, $\alpha = .957$; for D3, $\alpha = .957$; for D4, $\alpha = .942$; for D5, $\alpha = .908$; for D6, $\alpha = .936$; and for D7, $\alpha = .890$. For the complete 26-item instrument, a coefficient of $\alpha = .986$ was obtained. Some authors (Rodríguez-Rodríguez & Reguant-Álvarez, 2020) regard such results as very high.

Owing to the ordinal nature of the responses and the structure of the dimensional scores, non-parametric statistical procedures were used. The Friedman test was used to compare the scores of the seven dimensions. The magnitude of the concordance between the rankings of the dimensions was estimated using Kendall's W coefficient. The Mann–Whitney U test was used for comparisons between countries and between gender groups. The rank-biserial correlation (r_rb) was used as the measure of effect size. The level of statistical significance was set at $\alpha = .05$. In addition, the Durbin-Conover test was used for pairwise comparisons of the dimension means. In these comparisons, no specific procedure was applied to adjust the p-values for multiple comparisons; the values reported therefore correspond to those obtained directly in the pairwise tests and should be interpreted with this limitation in mind.

Table 2. Diagnostic instrument administered to the participants.

Dimension	Code	Items

D1: Visibility of sustainability	Q1	At my university I can easily identify visual messages related to sustainability.
	Q2	The university uses images, videos, or infographics to communicate its sustainability initiatives.
	Q3	Institutional campaigns clearly show the university's commitment to caring for the environment.
	Q4	The visual messages of my university make visible the importance of caring for natural resources.
D2: Visual representation of the circular economy	Q5	The visual communication of my university shows practices related to the reuse of materials.
	Q6	Institutional images and campaigns show actions aimed at reducing waste generation.
	Q7	My university's communication presents recycling as part of a broader strategy for making use of resources.
	Q8	The university visually communicates actions related to the repair or recovery of materials.
	Q9	Institutional images and messages make it possible to understand what the circular economy means.
	Q10	The university's circular economy initiatives are visible in its institutional communication media.
D3: Student participation and transformative capacity	Q11	The images of my university show students as active participants in sustainability.
	Q12	Institutional campaigns show concrete actions and not only messages about environmental care.
	Q13	Visual content shows how the university contributes to solving environmental problems.
	Q14	Visual content presents the university as a space capable of transforming consumption and production practices.
D4: Identification of the university as an agent of transformation	Q15	Institutional communication presents my university as an institution committed to sustainable transformation.
	Q16	The university communicates sustainability as part of its institutional identity.
	Q17	The university's communication reflects a vision of the future based on sustainability.
D5: Integration of circularity into the university experience	Q18	Circular economy initiatives are related to educational activities in my degree program.
	Q19	The university communicates opportunities for us as students to take part in circular economy initiatives.
	Q20	The university communicates initiatives that link sustainability with businesses or with the community.
D6: Understanding and visual	Q21	The visual content of my university allows me to understand better what sustainability is.
	Q22	Institutional images and campaigns help me to recognize circular economy practices.

literacy for circularity	Q23	I consider that the university uses appropriate visual resources to explain concepts related to sustainability and the circular economy.
D7: Participation and behavior ("Circular Participation")	Q24	Institutional communication encourages me to reuse materials whenever possible.
	Q25	I would like to take part in circular economy projects promoted by my university.
	Q26	I consider it important that we as students participate actively in the transition toward a circular university.

4.4. Ethical considerations

All participants were informed of the details of the study, and their participation was informed, consensual, anonymous, and voluntary. For data protection reasons, the online survey was open only to persons over 18 years of age enrolled in university programs. The procedures of this survey complied with the provisions of the Declaration of Helsinki for research involving human participants and were approved by the ethics committee of the Universidad Bolivariana del Ecuador (CEI-UBE), the institution leading the research project to which this study belongs (The World Medical Association [WMA], 2024).

4.5. Declaration of the use of Artificial Intelligence

The generative artificial intelligence tool ChatGPT was used solely for language assistance, style editing, and review of the coherence of the text. The authors manually validated all content and are responsible for the final version of the manuscript. No data were generated and no analyses were performed using artificial intelligence.

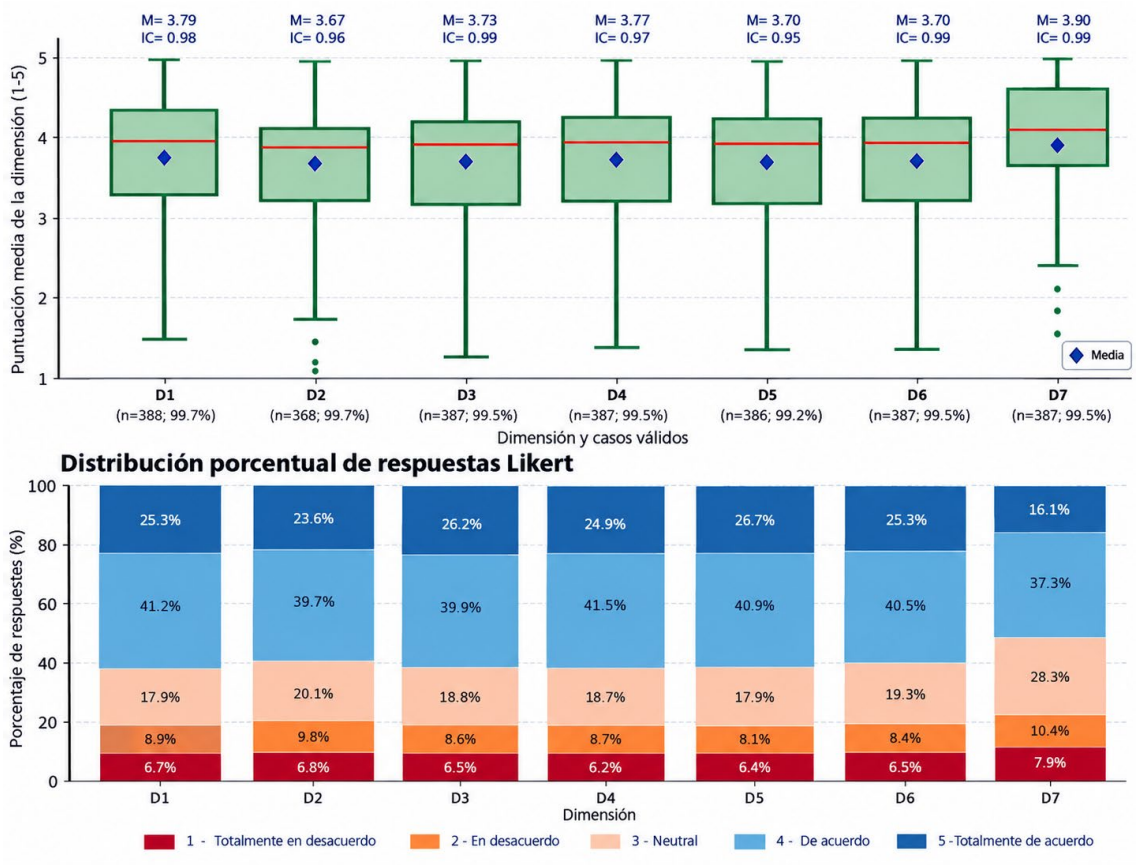
5. Results

5.1. Distribution of student perception of visual narratives of sustainability and the circular economy

The first analysis examined student perception (in terms of means and dispersion) across the seven dimensions of the instrument by means of a box plot (Figure 1). The median (represented by the red horizontal line inside each box) was uniformly located at 4.0 ("Agree") in all dimensions, reflecting a generally favorable consensus and a deep-rooted pro-environmental inclination among the student body. The means ranged from 3.67 (D2) to 3.90 (D7), always within the positive range of the scale. The standard deviation varied narrowly between 0.95 (D5) and 0.99 (D3, D6, and D7), indicating moderate dispersion concentrated toward the upper end of the instrument; the whiskers reached the maximum of 5.0 in all dimensions and extended down to minimum values of between 1.3 and 1.7 (with the exception of D7, whose minimum was close to 2.3). The percentage distribution of responses confirmed this pattern: the categories "agree" (light blue) and "strongly agree" (dark blue) accounted for the majority of responses, with valid-case rates of between 99.2% (D5) and 99.7% (D1 and D2). D7 (Participation and behavior) stood out as the strongest dimension (M = 3.90; SD = 0.99), while D2 (Visual representation of the circular economy) recorded the

lowest mean (M = 3.67; SD = 0.96), with the greatest accumulation of neutral and disagreeing responses in the entire instrument.

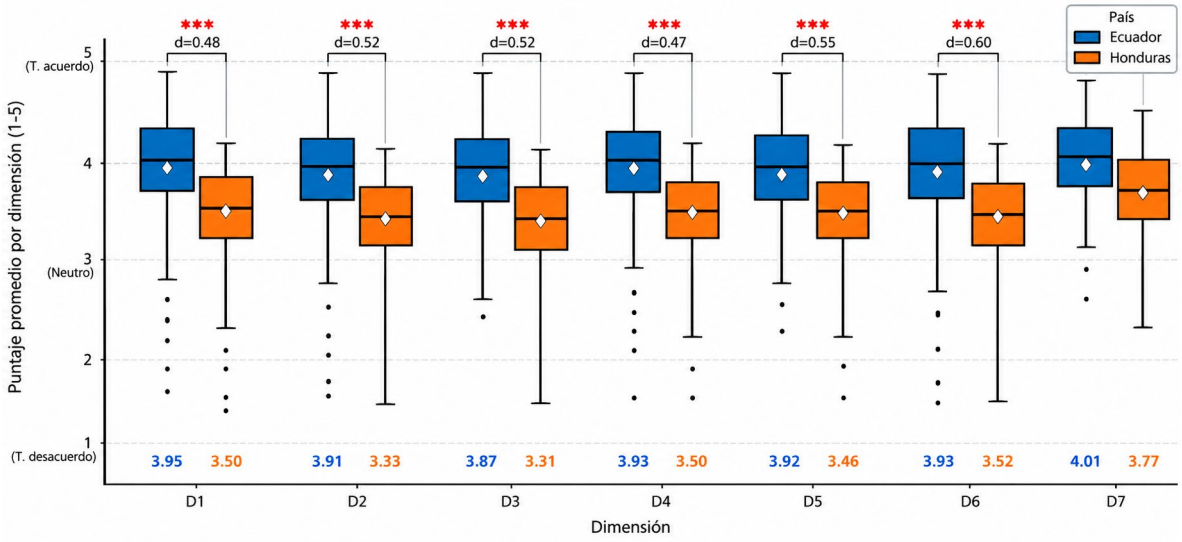
Figure 1. Student perception of visual narratives of sustainability and the circular economy.



5.2. Comparison of student perception by dimension between countries

The comparison between students at the university in Ecuador and the university in Honduras (n = 388) revealed a systematic asymmetry in the way the two groups decode sustainability narratives (Figure 2). In dimensions D1 to D6, Ecuador was consistently above Honduras, with means close to 4.0 compared with values close to 3.5 (D1: 3.95 vs. 3.50; D2: 3.91 vs. 3.33), which suggests a more consolidated visual and communicative environment at the Ecuadorian higher education institution. However, in D7 (Circular participation) the difference between countries was not statistically significant: the means reached their highest and most homogeneous values in the study (Ecuador = 4.01; Honduras = 3.73), indicating that, despite an environment with lower communicative visibility, the attitudinal disposition of Honduran students toward circular participation is comparable to that of their Ecuadorian peers. The overall dispersion of the data, with whiskers extending down to 1.5 and low outliers, especially in Honduras, suggests localized pockets of dissonance and apathy.

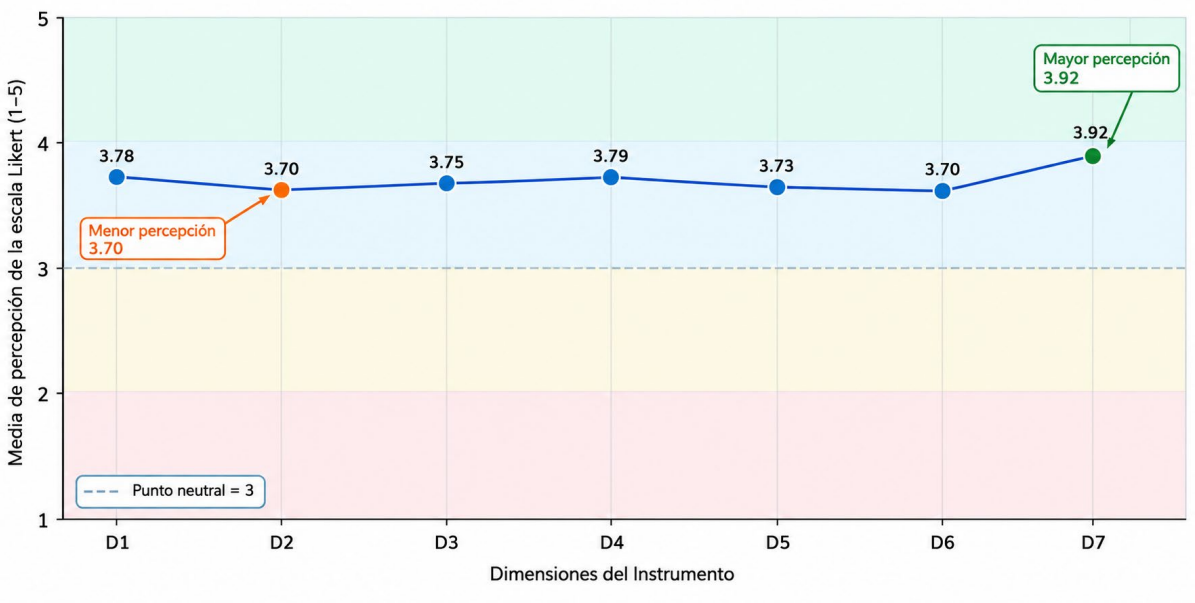
Figure 2. Comparison of student perception by dimension, Ecuador vs. Honduras.



5.3. Trends in student perceptions of the circular university

The trend analysis of the means by dimension shows a trajectory that remains above the neutral point (3.0) across the whole scale (Figure 3). The path begins at D1 (Visibility of sustainability, M = 3.78), falls at D2 (Visual representation of the circular economy, M = 3.70), recovers at D3 (Student participation and transformative capacity, M = 3.75) and D4 (Identification of the university as an agent of transformation, M = 3.79), falls again at D5 (Integration of circularity into the university experience, M = 3.73) and D6 (Understanding and visual literacy, M = 3.70), and culminates in a pronounced rise toward D7 (Participation and behavior, M = 3.92), the strongest dimension in the study, which suggests a favorable attitudinal disposition among the study participants. It should be stressed that D2 and D6 constitute the two lowest troughs, tied at 3.70: in D2, the understanding of the circular economy tends to be reduced to the basic recycling of materials, while in D6 the scarcity of visual resources makes it difficult to translate abstract concepts into everyday learning. The trend chart is therefore consistent with the relevance of proposing a robust visual communication framework that acts as a cognitive bridge connecting the high pro-environmental disposition (D7) with effective visual literacy regarding the metabolism of the campus (D2 and D6).

Figure 3. Trends in student perceptions of the circular university



5.4. Perceptions of sustainability and the circular economy by country and gender

The comparative analysis was structured with reference to the multidimensional model proposed by Bray and Thomas (1995), known as the Bray and Thomas Cube, which makes it possible to organize comparative education studies by considering different geographic levels, demographic groups, and aspects of education and society. In the present study, this model was used as a reference for delimiting two axes of comparison: the geographic level, represented by Ecuador and Honduras, and the demographic group of gender, represented by female and male participants. This use constitutes an analytical adaptation of the original model to the specific object of the research and is not intended to reproduce all its dimensions in full (Bray & Thomas, 1995).

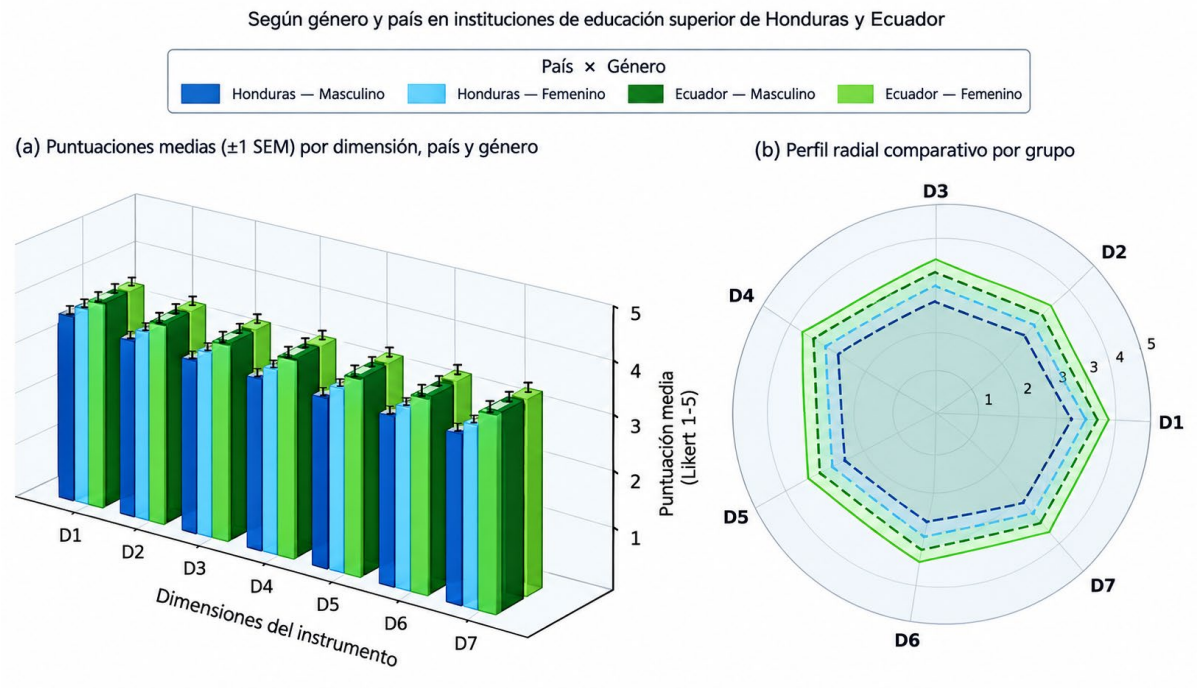
In the comparative radial profile (b) and the three-dimensional bar chart (a), a systematic hierarchy can be identified in the first six dimensions (D1 to D6): Ecuador presented higher scores than Honduras and, in both countries, women showed higher scores than men. The Ecuador-Female group recorded the highest-scoring profile in the dimensions analyzed, while Honduras-Male presented the lowest values, particularly in D2 (M = 3.40). In D7, the differences between the groups narrowed, with scores close to 4.0, which shows greater convergence in the disposition toward participation and behavior related to the circular economy.

These results make it possible to visualize the descriptive differences between the groups defined by country and gender. From this perspective, the graphic representation constitutes an application of the principle of multidimensional comparison put forward by Bray and Thomas (1995), adapted to the analysis of student perceptions of sustainability and the circular economy in higher education institutions in Ecuador and Honduras.

This analysis can be complemented by the comparison of the dimensional scores between Ecuador (n = 202) and Honduras (n = 186) using the Mann–Whitney U test, which revealed statistically significant differences in all seven dimensions. Specifically: in D1, U = 24,891.50, p < .001, r_rb = .325; in D2, U = 25,199.00, p < .001, r_rb = .341; in D3, U = 24,809.50, p < .001, r_rb = .328; in D4, U = 24,831.50, p < .001, r_rb = .329; in D5, U = 24,284.50, p < .001, r_rb = .306; in D6, U = 25,238.00, p < .001, r_rb = .351; and in D7, U = 22,660.50, p < .001, r_rb = .213.

In all cases, the scores were higher among the participants from Ecuador. With regard to gender, the female and male groups were compared, and statistically significant differences were found only in D1 and D7. For D1, U = 17,487.00, p = .038, r_rb = .132, while for D7, U = 18,288.00, p = .002, r_rb = .194. No statistically significant differences were observed in the remaining dimensions: D2, U = 16,954.50, p = .124, r_rb = .098; D3, U = 17,101.00, p = .065, r_rb = .117; D4, U = 16,724.00, p = .142, r_rb = .092; D5, U = 16,507.50, p = .165, r_rb = .088; and D6, U = 16,837.50, p = .114, r_rb = .100.

Figure 4. Bray and Thomas Cube: perceptions of sustainability and the circular economy by country and gender.



Note. Authors' own elaboration based on the study data, taking as a reference the multidimensional model of comparison proposed by Bray and Thomas (1995).

5.5. Inferential analysis by dimension means: Friedman

The Friedman test (non-parametric repeated-measures ANOVA) confirmed statistically significant differences among the seven dimensions ($\chi^2 = 60.4$; df = 6; p < .001), which makes it possible to reject the hypothesis of homogeneity (Table 3), demonstrating empirically that students' pro-environmental perceptions vary systematically according to the semiotic and conceptual nature of each dimension

analyzed. Kendall's W coefficient was .023, indicating a small effect size in the overall differentiation of the rankings of the dimensions. The median remained constant at 4.00 for all dimensions, while the means revealed the differences: the highest value corresponded to PD7 (Participation and behavior, M = 3.93), followed by PD3 (Student participation and transformative capacity, M = 3.80) and PD4 (Identification of the university as an agent of transformation, M = 3.79); the lowest values were recorded for PD2 (Visual representation of the circular economy, M = 3.68) and PD6 (Understanding and visual literacy, M = 3.70).

Table 3. Friedman test and descriptive statistics by dimension.

Dimensions	Mean	Median	χ^2	df	p
PD1	3.78	4			
PD2	3.68	4			
PD3	3.8	4			
PD4	3.79	4	60.4	6	<0.001
PD5	3.76	4			
PD6	3.7	4			
PD7	3.93	4			

Pairwise comparisons using the Durbin-Conover test showed that PD7 differed in a highly significant way from all the other dimensions (p = 0.002 versus PD1; versus PD2, PD4, PD5, and PD6, p remained <0.001; p = 0.004 versus PD3), whereas the difference between PD2 (Visual representation of the circular economy) and PD6 (Visual literacy) was not significant (p = 0.596), which forms a homogeneous plateau of semiotic weakness. PD2 also showed significant differences from the participatory and identity dimensions, such as PD3 and PD4 (p < 0.001 in both cases). Taken together, these results confirm statistically that students express a high level of commitment and willingness to participate (PD7), but find themselves trapped in a physical environment in which the visual representation and pedagogical understanding of the metabolic cycles of the campus (PD2 and PD6) remain at minimal and disconnected levels.

Table 4. Pairwise comparisons (Durbin-Conover) between dimensions.

Dimensions			Statistic	p
PD1	-	**PD2**	3.767	<0.001
PD1	-	**PD3**	0.112	0.911
PD1	-	**PD4**	0.209	0.834
PD1	-	**PD5**	1.367	0.172
PD1	-	**PD6**	3.237	0.001
PD1	-	**PD7**	3.097	0.002
PD2	-	**PD3**	3.879	<0.001

Dimensions			Statistic	p
PD2	**-**	**PD4**	3.558	<0.001
PD2	**-**	**PD5**	2.400	0.016
PD2	**-**	**PD6**	0.530	0.596
PD2	**-**	**PD7**	6.864	<0.001
PD3	**-**	**PD4**	0.321	0.748
PD3	**-**	**PD5**	1.479	0.139
PD3	**-**	**PD6**	3.349	<0.001
PD3	**-**	**PD7**	2.986	0.003
PD4	**-**	**PD5**	1.158	0.247
PD4	**-**	**PD6**	3.028	0.002
PD4	**-**	**PD7**	3.307	<0.001
PD5	**-**	**PD6**	1.870	0.062
PD5	**-**	**PD7**	4.465	<0.001
PD6	**-**	**PD7**	6.334	<0.001

5.6. Pro-Environmental Visual Communication Framework for the Circular University (MCVPUC): From Invisibility to a Regenerative Culture

To complement the interpretation of the findings, the Pro-Environmental Visual Communication Framework for the Circular University (MCVPUC, by its Spanish acronym) is proposed as a theoretical-methodological proposal that brings together principles of the circular economy, visual pedagogy, environmental communication, and information design. Its purpose is to offer a conceptual and operational structure to guide future interventions aimed at strengthening the visual communication of sustainability and circularity in higher education institutions. In this study, the MCVPUC is a proposal derived from the empirical diagnosis carried out and not a model that has been implemented or experimentally validated.

The MCVPUC starts from the premise that the invisibility of the metabolic flows of the campus (water, energy, materials, waste, food, biodiversity) constitutes an epistemological and behavioral barrier to sustainability. Through pedagogical visual architectures, metabolic signage, cycle infographics, traceability narratives, impact *dashboards*, and educational routes, the framework seeks to make the invisible visible, the complex comprehensible, and the systemic participatory. Unlike traditional environmental campaigns centered on prescriptive messages (reduce, reuse, recycle), it adopts a systemic-narrative approach that reveals the interdependencies between individual decisions and collective flows. The framework integrates five operational dimensions: visual diagnosis of the campus metabolism; design of a circular visual identity; implementation of multimodal pedagogical signage; development of visual

literacy capacities; and evaluation of cognitive, perceptual, attitudinal, behavioral, and cultural impact.

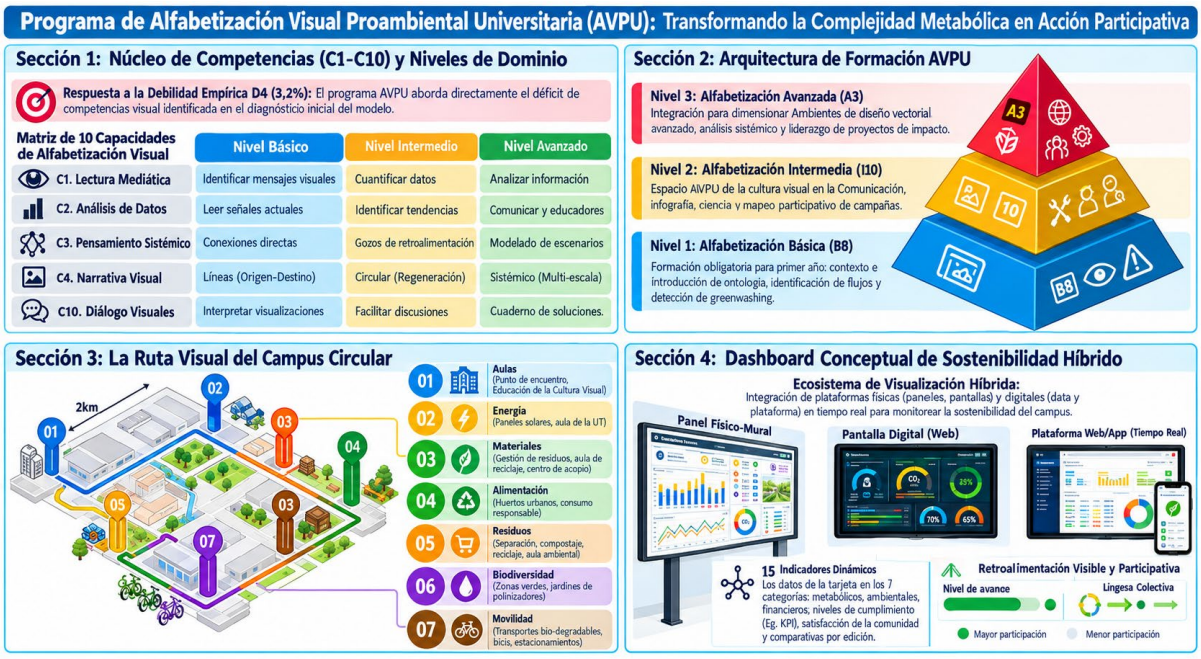
The MCVPUC is also structured as an intervention proposal organized in six conceptual stages: invisibility, visibility, understanding, participation, behavior, and regenerative culture (Figure 5). This sequence represents a hypothetical theoretical-methodological route to guide future pro-environmental visual communication actions that respond to the institutional, cultural, and gender contexts identified between Ecuador and Honduras and between male and female students; the stages should therefore not be interpreted as results of a transformation that has already taken place or as a demonstrated causal relationship. Its effectiveness will need to be determined through subsequent processes of implementation, evaluation, and empirical validation.

Figure 5. Architecture of the Pro-Environmental Visual Communication Framework for the Circular University (MCVPUC).



As its central educational component, the framework incorporates the University Pro-Environmental Visual Literacy Program (AVPU, by its Spanish acronym), aimed at developing ten capacities for interpreting, creating, and using visual representations of environmental systems, in direct response to the weakness identified in D6. The program is implemented at three levels with participatory activities that turn students, teaching staff, and administrative staff into co-creators of the circular visual communication of the campus. In addition, the Circular Campus Visual Route proposes an educational itinerary, self-guided or guided, that connects seven interpretive stations devoted to different metabolic cycles (water, energy, materials, food, waste, biodiversity, and mobility), and functions as an "open-air museum" of institutional circularity. Finally, the Campus Sustainability *Dashboard* presents key environmental performance indicators in an accessible and up-to-date format, in response to the MCVPUC principle of visible feedback (Figure 6).

Figure 6. Circular Campus Visual Route and Campus Sustainability Dashboard.



6. Discussion

6.1. The D7 vs. D2/D6 paradox: an attitudinal engine trapped in a mute semiotic environment

The results reveal a tension between a robust pro-environmental attitudinal disposition and an institutional semiotic infrastructure that has been rendered invisible. D7 (Participation and behavior) is established as the only construct statistically superior to the rest of the instrument ($M = 3.93$; $\chi^2 = 60.4$, $df = 6$, $p < 0.001$; Durbin-Conover: D7 vs. all, $p < 0.001$), which points to a genuine behavioral engine that nevertheless remains trapped in the "plateau of cognitive weakness" formed by D2 (Visual representation of the circular economy) and D6 (Visual literacy), with means of 3.68 and 3.70 and no difference between them ($p = 0.596$). This pattern models the concept of the "hidden curriculum" documented by Cotton et al. (2023), who demonstrate the gap between the image of sustainability projected digitally and the everyday experience of the campus. The weakness of D2 also converges with Deda et al. (2022), who find that students' understanding of the CE rarely goes beyond the recovery of materials. The D7/D2 gap replicates, in the Latin American context, the knowledge-attitude-practice (KAP) model documented by Owojori et al. (2022), according to which the distance between declarative knowledge and circular practice constitutes the most critical systemic failure.

6.2. Ecuador-Honduras asymmetry and the gender dimension

The geographic comparison adds a relevant contextual dimension. Ecuador shows consistent superiority in D1-D6 (D1: 3.95 vs. 3.59; D2: 3.91 vs. 3.53), which confirms its characterization as a territory of emerging evidence in environmental communication (Nuela Telenchana et al., 2025). Honduras, and the male profile in particular, records the deepest trough in the study in D2 ($M = 3.40$), consistent with the differentiated

personal responsibility gap documented by Gavrilova et al. (2020). Nevertheless, the convergence in D7 (Ecuador: M = 4.01; Honduras: M = 3.91; non-significant difference) suggests that circular potential is not exclusive to contexts of greater visibility, a finding in line with Todorova et al. (2024), who attribute the lack of proactivity not to an absence of will, but to the non-existence of channels that convert intention into action. The gender variable adds a strategic layer: the Ecuador-Female group exhibits the greatest visual sensitivity (D3: M = 3.88), while Honduras-Male concentrates the greatest disconnection, a pattern linked by Nikolić et al. (2022) to the differential development of pro-environmental attitudes in Generation Z according to exposure to visual narratives with ecological content.

6.3. Semiotic weaknesses of the campus: D2 and D6 as a deficit in communicative design

The statistical plateau of D2 and D6 has a plausible theoretical correlate: the low perceived score in these dimensions could be associated not with a perceptual limitation on the part of students, but with weaknesses in the communicative design of the institutional environment (Cotton et al., 2023). Waite et al. (2025) demonstrate that circular infographics, designed through collaborative *Design Thinking*, significantly improve the understanding of circular metabolism by making visible the flows that are invisible to the human eye. González Quintero and Candela Sanjuán (2025) propose that graphic design should operate as a systemic language that translates the technical complexity of the CE into culturally accessible representations, while Subandrio (2025) provides evidence from digital animation, where animated narratives about ecological processes raise ecological awareness by making imperceptible cycles perceptible. That D6 ties with D2 at the lowest levels is no coincidence: following Weder et al. (2019), visual literacy cannot develop in a vacuum, but depends on a rich semiotic ecosystem in the immediate environment, without which circularity is reduced to an abstract construct. This contradiction is also noted by Arrieta Díaz (2017) and Maiorescu et al. (2020), who document the gap between the institutional discourse of sustainability and the dominant culture of consumption in faculties.

6.4. The MCVPUC as a device of semiotic justice

The results obtained conceptually support the proposal of the MCVPUC as a possible theoretical-methodological response to the paradox identified between the high willingness to participate (D7) and the lower rating of the visual representation of the circular economy (D2) and visual literacy (D6). Structured in six conceptual stages and six layers of action, the framework integrates elements of visual communication, education for the circular economy, and university participation. Nevertheless, its potential to generate changes in students' engagement, perceptions, attitudes, or behaviors remains an open empirical question. Consequently, the implementation and evaluation of the MCVPUC in different institutional contexts constitutes a necessary line of future research for determining its relevance, feasibility, and effectiveness. It should be noted, however, that the framework responds to the pedagogical principles for CE education of Kirchherr and Piscicelli (2019) and to the vision of Vergani (2024) of HEIs as circular microcosms in which campus management

must become a living pedagogical platform. The digital narratives layer is supported by Venkatesan et al. (2023), who document student documentary filmmaking as a trigger for behavioral change, and by Arevalo et al. (2023), whose digital stories mobilize systems thinking in the face of the complexity of the Anthropocene. The success of the MCVPUC will depend on its capacity to generate the engagement that Del Moral Pérez et al. (2022) identify as a necessary condition (empathy, curiosity, and collective identity), and its differentiated application by geographic context and gender responds to the imperative noted by Khajuria (2025) to develop culturally relevant CE education strategies that do not reproduce the gaps identified.

7. Conclusions

The study achieved its general objective. Through a quantitative diagnosis applied to 388 university students in Ecuador (UBE) and Honduras (UNITEC/CEUTEC), the research characterized student perception of sustainability on their campuses, identifying a structural paradox between a high attitudinal and behavioral disposition toward circularity (D7 = 3.93) and a persistent semiotic weakness in the visual representation of the circular economy (D2 = 3.68) and visual literacy (D6 = 3.70). On the basis of these findings, the Pro-Environmental Visual Communication Framework for the Circular University (MCVPUC) is proposed, together with the University Pro-Environmental Visual Literacy Program (AVPU), as a theoretical-methodological proposal articulated in six layers and six stages. Both components are put forward as conceptual and operational alternatives to guide future strategies of visual communication, literacy, and participation around sustainability and the circular economy in higher education. However, since the MCVPUC was not implemented or subjected to empirical validation in the present study, it cannot be claimed that it produces transformations in pro-environmental culture or in the perceptions or behaviors of university actors. Its relevance, applicability, and effectiveness will need to be examined through subsequent implementation and evaluation studies.

Among the limitations of the study is its quantitative, non-experimental, cross-sectional design, with data collected at a single point in time by means of a self-report instrument, potentially exposed to social desirability bias. In addition, the sample was limited to 388 students from two specific institutions, so the extrapolation of the results to other Latin American HEIs should be undertaken with caution. Likewise, since each country was represented by a single higher education institution (UBE in Ecuador; CEUTEC/UNITEC in Honduras), the results should be interpreted as differences between particular institutions and not as generalizations at the national level. Finally, the evaluation focused exclusively on undergraduate students, without incorporating the perspective of teaching staff or of administrative or maintenance personnel, actors who are equally relevant in the management of university circularity.

A pilot implementation of the MCVPUC and the AVPU program is recommended under the model of campuses as *Living Labs*, using longitudinal studies to evaluate the effectiveness of pedagogical signage, educational routes, and sustainability dashboards on student behavior in the long term. For future research, it is suggested that mixed methodologies be adopted that integrate visual elicitation, participatory

metabolic maps, digital collages, and *eye-tracking* techniques, that the geographic scope be extended to other universities in Latin America, and that inclusive visual narratives be developed that address the gender and identity gaps identified.

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