LEARNING CIRCULAR ECONOMY IN HIGHER EDUCATION: A PEDAGOGICAL MODEL FOCUSED ON SOCIAL IMPACT

APRENDENDO ECONOMIA CIRCULAR NO ENSINO SUPERIOR: UM MODELO PEDAGÓGICO FOCADO NO IMPACTO SOCIAL

APRENDIENDO ECONOMÍA CIRCULAR EN LA EDUCACIÓN SUPERIOR: UN MODELO PEDAGÓGICO CENTRADO EN EL IMPACTO SOCIAL

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Víctor Manuel Molina Morejón[1], Horacio Monsiváis de la Peña[2], Vanessa Espitia Mendoza[3], Eyran Roberto Díaz Gurrola[4], José de Jesús Espinoza Arellano[5]

ABSTRACT

The circular economy (CE) is a key alternative in the face of current environmental and production-related challenges. Its teaching requires pedagogical approaches that integrate theory, practice, and critical reflection. In this study, a course was designed that not only delivered theoretical content, but also strengthened students' ability to apply the CE as a framework for innovation, sustainability, and responsible decision-making. This university course was based on constructive alignment and participatory action research; it included lectures, guided discussions, collaborative work, and practical activities. The methodology was grounded in constructive alignment, ensuring that each activity and assessment corresponded to the established learning objectives. In addition, the methodology incorporated the use of PLS-SEM, a technique suitable for analyzing complex models based on perceptions through latent constructs derived from the empirical data collected, which made it possible to rigorously evaluate the relationships among the model's variables and provide statistical evidence of their consistency. The authors observed that the course enabled students to connect the principles of social entrepreneurship with solutions to real-world problems, while also highlighting the relevance of social and educational variables as driving factors for integrating CE into higher education. Furthermore, education for social entrepreneurship is supported by learning theories and adaptive technologies that facilitate personalized learning experiences. The findings of this investigation align with these methodologies, since they reside within statistically acceptable parameters, hence reinforcing the validity of the suggested model.

[1] Dr. in Technical Sciences. Universidad Tecnológica de La Habana. Cuba e Instituto Politécnico de Odesa. Ucrania URSS. E-mail: victormolina@uadec.edu.mx Orcid: https://orcid.org/0000-0001-9124-0840
[2] Dr. in Administrative Sciences. Universidad Autónoma de Coahuila UAdeC. E-mail: fcactei@uadec.edu.mx Orcid: https://orcid.org/0009-0000-5790-3225
[3] Dr. in Education. Universidad Autónoma de Coahuila UAdeC. E-mail: vespitia@uadec.edu.mx Orcid: https://orcid.org/0000-0003-3788-4498
[4] Dr. in Administration and Senior Management. Universidad Autónoma de Querétaro. E-mail: eyran_diaz@uadec.edu.mx Orcid: https://orcid.org/0000-0002-4702-2376
[5] Dr. in Agricultural Economics. Texas A&M University. College Station. E-mail: jose.espinoza@uadec.edu.mx Orcid: https://orcid.org/0000-0003-0858-3987

Keywords: Innovation and Nature. Circular Design. Circular Services and Resources. Social Impact. PLS-SEM.

RESUMO

A economia circular (EC) constitui uma alternativa fundamental diante dos atuais desafios ambientais e produtivos. Seu ensino requer abordagens pedagógicas que integrem teoria, prática e reflexão crítica. Neste estudo, foi elaborado um curso que não apenas transmitiu conteúdos teóricos, mas também fortaleceu a capacidade dos estudantes de aplicar a EC como um referencial para inovação, sustentabilidade e tomada de decisões responsáveis. Este curso universitário baseou-se no alinhamento construtivo e na pesquisa-ação participativa; incluiu aulas, discussões orientadas, trabalho colaborativo e atividades práticas. A metodologia fundamentou-se no alinhamento construtivo, garantindo que cada atividade e avaliação correspondesse aos objetivos de aprendizagem estabelecidos. Além disso, a metodologia incorporou o uso de PLS-SEM, uma técnica adequada para analisar modelos complexos baseados em percepções por meio de construtos latentes derivados dos dados empíricos coletados, o que possibilitou avaliar de forma rigorosa as relações entre as variáveis do modelo e fornecer evidências estatísticas de sua consistência. Os autores observaram que o curso permitiu aos estudantes relacionar os princípios do empreendedorismo social com soluções para problemas do mundo real, ao mesmo tempo em que destacou a relevância das variáveis sociais e educacionais como fatores impulsionadores para integrar a EC ao ensino superior. Além disso, a educação para o empreendedorismo social é sustentada por teorias da aprendizagem e por tecnologias adaptativas que facilitam experiências de aprendizagem personalizadas. Os achados desta investigação estão alinhados com essas metodologias, uma vez que se situam dentro de parâmetros estatisticamente aceitáveis, reforçando, assim, a validade do modelo proposto.

Palavras-chave: Inovação e Natureza. Design Circular. Serviços e Recursos Circulares. Impacto Social. PLS-SEM.

RESUMEN

La economía circular (EC) constituye una alternativa clave frente a los actuales desafíos ambientales y productivos. Su enseñanza requiere enfoques pedagógicos que integren teoría, práctica y reflexión crítica. En esta investigación, se diseñó un curso que no solo transmitía contenidos teóricos, sino que también fortaleció la capacidad de los estudiantes para aplicar la EC como un marco de innovación, sostenibilidad y toma de decisiones responsables. Este curso universitario se basó en el alineamiento constructivo y la investigación-acción participativa; incluyó clases, discusiones guiadas, trabajo colaborativo y actividades prácticas. La metodología se fundamentó en el alineamiento constructivo, garantizando que cada actividad y evaluación correspondiera a los objetivos de aprendizaje establecidos. Por otra parte, la metodología incorpora el uso de PLS-SEM, una técnica adecuada para analizar modelos complejos basados en percepciones mediante constructos latentes derivados de los datos empíricos recopilados, permitió evaluar de manera rigurosa las relaciones entre las variables del modelo y aportar evidencia estadística sobre su consistencia. Los autores observaron que el curso permitió a los estudiantes relacionar los principios del emprendimiento social con soluciones a problemáticas del mundo real, al tiempo que destacó la relevancia de las variables sociales y educativas como factores impulsores para integrar la EC en la educación superior. Además, la educación para el emprendimiento social se sustenta en teorías del aprendizaje y en tecnologías adaptativas que facilitan experiencias de aprendizaje personalizadas. Los hallazgos de esta investigación se alinean con estas metodologías, ya que se sitúan dentro de parámetros estadísticamente aceptables, reforzando así la validez del modelo propuesto.

Palabras clave: Innovación y Naturaleza. Diseño Circular. Servicios y Recursos Circulares. Impacto Social. PLS-SEM.

1 INTRODUCTION

The circular economy (CE) has become established as an essential approach to addressing current environmental and production challenges. Its interdisciplinary nature makes it an ideal field for university education, as it connects theory with practice and fosters critical reflection. With this purpose in mind, an introductory course was designed for students unfamiliar with the concept, structured in dynamic modules that combined lectures, class discussions, and practical activities. The methodology was based on constructive alignment, ensuring that each activity and assessment responded to the stated learning objectives. The central strategy was participatory action research, which promoted collaborative work and constant feedback, allowing students to develop analytical and practical skills. In this way, the course not only conveyed theoretical content but also strengthened the ability to apply the CE as a strategy for innovation and sustainability.

The purpose of the course was to provide a comprehensive overview of the circular economy (CE). Since most students were unfamiliar with this concept, an approach was designed that combined different perspectives and disciplines. The CE was presented as a system that connects environmental, economic, and innovative aspects, highlighting both its theoretical foundations and its practical applications in reducing impacts and using resources efficiently.

The curriculum was structured in 90-minute modules and aimed to address the diverse interests and backgrounds of the students. It began with an introductory lecture, followed by interactive activities, class discussions, and fieldwork to connect theory with practice. The sessions concluded with group reflections that fostered critical thinking about the topic.

The pedagogical strategy was based on the principle of “constructive alignment,” which allowed teaching and assessment activities to be directly linked to learning objectives. A problem-based learning approach was used, with collaborative work and continuous feedback, so that students could apply concepts and improve their proposals throughout the course. The readings included both classic texts and recent critical literature, ensuring a solid and up-to-date foundation.

Finally, all assessments were conducted in class and focused on presentations that demonstrated how students integrated the knowledge they had acquired. In this way, the course not only conveyed content but also fostered analytical, reflective, and practical skills aligned with the interdisciplinary nature of the circular economy.

Teaching students about the Circular Economy is the starting point for activating more robust cognitive processes, which in turn strengthen the social dimension, understood as the capacity for interaction, commitment, and collective action. This connection extends to a fourth dimension—environmental impact—which allows for the translation of acquired knowledge into tangible circularity practices in academic and community contexts.

2 THEORETICAL FRAMEWORK

2.1 EDUCATIONAL IMPACT

Unlike the study published in 2022, where educational impact was conceived as the result of social and cognitive dimensions, the present model takes educational impact as its central axis. Vallaeys (2016), a recognized international authority on University Social Responsibility (USR), proposed a model structured around organizational, cognitive, social, and educational effects. Based on this framework, our previous research, published in "Dilemas contemporaneos: Educación, Políticas y Valores" (Morejón Molina; Espitia; Montalvo-Morales, 2022), analyzed the relationships between these impacts using the PLS-SEM technique. The results demonstrated that organizational and cognitive impacts influence social effects, which, in turn, has a positive and significant effect on educational impact.

This article takes this finding as a starting point, positioning educational impact, previously considered an outcome, as the initial factor that drives cognitive understanding, social interaction, and the development of skills related to the Circular Economy.

From this perspective, the study seeks to integrate the social dimensions identified by Padilla-Rivera et al. (2020) as an essential, but underexplored component of the circular economy, within an educational framework that links learning outcomes with social and cognitive impacts.

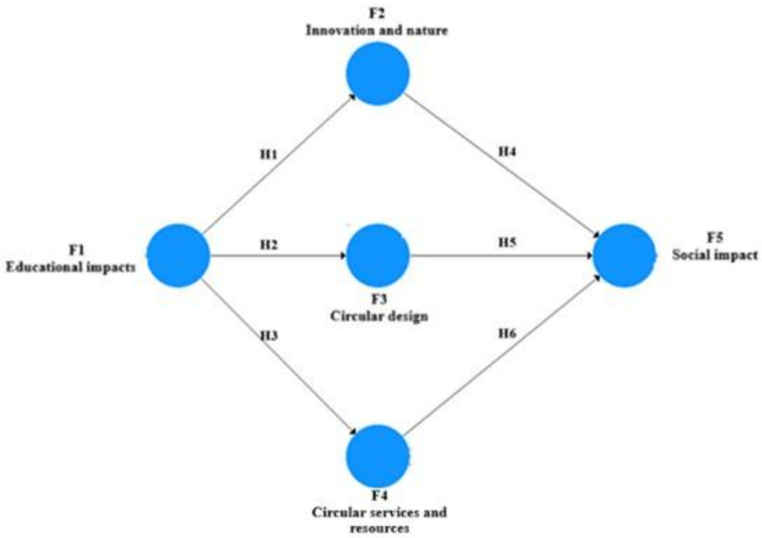
2.2 CONCEPTUAL MODEL/EXPERIMENTAL MODEL

To structure the final conceptual model (Figure 1), the trajectories between the constructs were first defined. Subsequently, the hypothetical relationships between constructs F1, F2, F3, and F4 with F5 were identified, thus formulating the six hypotheses of the study.

Figure 1 shows in greater detail the relationship between the different constructs analyzed, corresponding to the six hypotheses proposed in this research.

Figure 1

Conceptual Model



Source: Prepared by the authors themselves.

2.3 INNOVATION AND NATURE “BIOMÍMESIS”

Several authors have conducted in-depth analyses of different notions of biomimicry and have written extensively on theoretical and philosophical aspects (Riechmann, 2003; Vincent et al., 2006; Benyus, 2012; Dicks, 2015; Blok and Gremmen, 2016). In defining what the word biomimicry designates, current environmental problems tend to be considered the very justification for innovation inspired by natural systems. The natural reference point itself becomes part of the formula for innovating without harming nature. Some of the popular associated definitions are the conscious emulation of the ingenuity of life, or innovation inspired by nature (Benyus, 2012). It is understood as an approach to innovation that seeks sustainable solutions to human challenges by emulating patterns and strategies proven by nature by imitating the functional bases of biological forms, processes and systems to produce sustainable solutions, noted as a rapidly growing discipline that identifies, analyzes, and adapts natural strategies to solve technological problems (Pawlyn, 2011)

The Ellen Machartur Foundation (2022) analyzes various schools of thought, such as cradle-to-cradle design and an economy associated with this research work, which acts with symbiosis and biomimicry and shares different economic ideas.

Benyus (2012) defines biomimicry as the approach that studies nature's best ideas to imitate those designs and processes to solve human problems.

Therefore, considering the information presented, it is possible to propose the following research hypothesis

H1: The educational impact (F1) has a positive influence on innovation and nature (F2).

2.4 CIRCULAR DESIGN

Educational training acts as a lever for the adoption of circular design by equipping students and professionals with the mindset, methods, and tools necessary to consider whole systems rather than mere products. Thus, training processes allow us to transcend the linear ‘produce-use-dispose’ model towards an approach where materials and products maintain their value for as long as possible, and where design assumes a key role in eliminating waste, circulating materials, and regenerating nature (Ellen MacArthur Foundation, 2019; 2023).

Furthermore, the very concept of circular design demonstrates that design decisions determine what happens to products, materials, and systems when they are no longer useful. Therefore, by integrating circular economy principles at the beginning of the design process, we can make the economy work for people, businesses, and nature. With circular design, we can prevent waste and pollution from the outset. Internal circular design guides help transform companies by connecting strategy, supply chain, and circular design practice as an organizational, not just a technical, lever. Ellen MacArthur Foundation (2021) compiles resources for higher education and includes the Circular Design Guide as a toolkit for teachers and students, justifying the educational/pedagogical component of circular economy and design.

The assessment of circularity in organizations includes considering circularity criteria in product design, such as durability, reliability, modularity, standardization, ease of disassembly, upgradability, refurbishment, remanufacturing, reuse, recycling, energy efficiency, and low consumable consumption.

Issues related to the circularity strategies of the product or service offered have been divided into Circular Design (CD) and Circular Services (CS). It is important to highlight this distinction. Circular Services (CS) include issues related to the circular services offered by the company, while Circular Design (CD) includes issues related to considering circularity criteria in the design of the product or service.

The CE diagnosis focuses on the Business category, followed by Design. Business includes issues of Circular Services, Symbiosis, and Stakeholder Engagement. Design focuses on Circular Design, which is the most considered thematic area along with Circular Services. (Valls-Val et al., 2023)

Cattaneo (2022) takes as its context the transformation of education (F1) into design (F3) and focuses on a comprehensive analysis of degree programs, curricula, methodologies, and the intuitive influence of organizations on the shift towards social design education.

Another example of this circular design theme is the IKEA case, where circular economy goals are translated into product design criteria (durability, repairability, reuse, etc.) that can serve to exemplify circular design principles with a specific company (S-Mahalakshmi et al., 2024).

Thus, the link between educational impact (which develops skills, mindsets and knowledge) and circular design (which requires this change of focus to be implemented) justifies hypothesis H2.

Therefore, considering the information presented, it is possible to propose the following research hypothesis:

H2: The educational impact (F1) has a positive influence on circular design (F3).

2.5 PRODUCT SERVICE SYSTEMS (PSS)

Since the 1990s, Product-Service Systems (PSS) have been considered one of the most effective instruments for driving society toward a circular and resource-efficient economy, and for creating a much-needed resource revolution (Tukker, 2015). One definition of PSS is a mix of tangible products and intangible services designed and combined in such a way that they are jointly capable of satisfying the needs of the end customer (Tukker and Tischner, 2006).

Product Service Systems (PSS) have been integrated into a wider range of scientific fields and geographic regions. Recent literature has reaffirmed the definitions and concepts of PSS established since 2006, improving the understanding of their design and their business and environmental benefits, and identifying key success factors and problems to be addressed. Some of these include product availability, the diversity of services offered, and staff skills. Having control over things, objects, and life itself is one of the attributes most valued by consumers. PSS can limit consumers' freedom of behavior and give the impression that the provider dictates their actions, which can result in less intangible value than competing products (Tukker, 2015).

Product service systems. A product service system consists of a mix of tangible products and intangible services, designed and combined in such a way that, together, they can satisfy the consumer's ultimate needs. This concept rests on two pillars: (i) the functionality or satisfaction that the user wants to achieve is taken as the starting point for business development (instead of product ownership as a way to satisfy the need), (ii) the business system that provides such functionality is developed with an "undeveloped terrain" mentality, rather than taking existing structures and routines and the company's own position as given and unchangeable (Tukker and Tischner, 2006).

In a product-service system, a company offers access to the product but retains ownership. This is an alternative to the traditional "buy and own" model. It's a way to reduce customer burden, generate profits, and achieve objectives by offering product-oriented services or advice, usage-oriented services (such as leasing, renting, bundling, and pay-per-service), or results-oriented services (including outsourcing and functional services). (Lewandowski, 2016)

Therefore, considering the information presented, it is possible to propose the following research hypothesis:

H3: The educational impact (F1) has a positive influence on circular services and resources (F4).

2.6 CIRCULAR INNOVATION ECOSYSTEM AS A DRIVER OF SOCIAL IMPACT.

Recent literature on the circular economy recognizes that social impact (F5) does not depend on a single factor, but rather on the simultaneous action of several complementary dimensions. In this model, factors F2 (Innovation and Nature), F3 (Circular Design), and F4 (Circular Services and Resources) contribute in a parallel and convergent manner to generating tangible social benefits, especially in contexts where economic, environmental, or technological constraints prevail.

First, F2—Innovation and Nature—provides the bio-inspired and regenerative vision that enables the creation of adaptive and resilient solutions. The integration of nature-based principles, biomimicry, and circular ecosystems fosters strategies capable of restoring local environments and improving community well-being (Konietzko et al., 2021; Bocken et al., 2016). These innovations not only optimize resources but also generate new opportunities for social collaboration and citizen participation through ecological projects, community actions, and environmental restoration practices (Ellen MacArthur Foundation, 2019, 2023).

Secondly, F3—Circular Design—provides the methodological framework for redesigning products, processes, and systems with criteria of durability, reuse, modularity, and regeneration. Circularity-oriented design fosters the creation of accessible and inclusive solutions, such as repairable products, exchange platforms, and community-based resource management systems (Geissdoerfer et al., 2020). These approaches promote equity in access to resources and strengthen social cohesion through collaborative practices, community repair, and the active participation of citizens in circular initiatives (Millar & Hall, 2021).

Finally, F4—Circular Services and Resources—translates the above principles into practical mechanisms that the community can use directly. These services include preventive maintenance, materials banks, product-as-a-service, and servitization (which refers to the transition from selling physical products to providing integrated product–service solutions, where value is created through use rather than ownership), creative reuse, and local exchange networks (Bocken et al., 2016). The presence of these services generates social benefits by increasing resource availability, reducing household costs, promoting circular economy businesses, and creating green jobs locally (Schröder et al., 2020). Furthermore, educational literature demonstrates that participating in these systems strengthens social skills, a sense of community, and the ability to solve socio-environmental problems (Leal-Filho et al., 2021; Ruiz-Mallén & Heras, 2022; Mendoza et al., 2019).

Taken together, factors F2, F3, and F4 contribute simultaneously to social impact (F5) through distinct but complementary paths:

- F2 provides the regenerative and nature-based vision,
- F3 offers the methodological redesign necessary to transform production systems,
- F4 enables these transformations to materialize into services and resources accessible to the community.

This convergence produces measurable social effects, such as greater well-being, community cohesion, citizen participation, social inclusion, reduced inequalities, and the generation of new sustainable economic opportunities. Therefore, social impact does not arise from a single component, but from the integrated work of innovation, design, and circular services, fully aligned with recent empirical evidence.

F5 Social Impact

The F5 social impact of the circular economy is related to improvements in community well-being, the creation of green jobs, and the promotion of more equitable production models (Schröder et al., 2020). The literature emphasizes that circularity generates benefits in social cohesion, environmental justice, and the strengthening of local communities through collaborative practices, community repair, and exchange networks (Millar & Hall, 2021).

In the educational sphere, the implementation of circular strategies promotes the active participation of students in projects with real impact, which increases social awareness, community engagement, and the capacity to solve socio-environmental problems (Leal-Filho et al., 2021; Ruiz-Mallén & Heras, 2022). Furthermore, educational approaches based on circular economy principles have been shown to strengthen institutional sustainability practices and promote systemic thinking in higher education environments (Mendoza et al., 2019). Taken together, these results show that circular education is not only environmentally relevant but also socially transformative.

Accordingly, the following research hypothesis is stated as follows:

H4: Innovation and nature (F2) have a positive influence on social impact (F5). H5: Circular design (F3) has a positive influence on social impact (F5).

H6: Circular services and resources (F4) have a positive influence on the social impact (F5).

3 METHOTODLOGY

Padilla-Rivera, Russo-Garrido, and Merveille (2020) argue that the social component is insufficiently represented in circular economy research, despite being an essential catalyst for behavioral change and community transformation. This study highlights the importance of social and educational factors as drivers of integrating circularity principles within academia.

Table 1 shows that the composite reliability values and Dijkstra–Henseler's rho coefficient exceed 0.7, supporting the observations (Hair et al., 2017). Hair et al. (2017) recommended utilizing the AVE index and external factor loadings to assess convergent validity. The AVE for each construct exceeds 0.5 and the outer loadings are above 0.7, indicating adequate convergent validity (Hair et al., 2021).

Table 1

Construct, Reliability and Validity

Construct.	**Cronbach´ alpha**	**Dijkstra-Henseler rho**	**CRI**	**AVE**
F1 Educational	0.727	0.849	0.816	0.598
F2 Innovation and nature	0.903	0.910	0.939	0.837
F3 Circular design	0.962	0.963	0.981	0.963
F4 Circular services and resources	0.756	0.755	0.864	0.683
F5 Social impact	0.896	0.896	0.935	0.828

Source: Prepared by the authors themselves.

Discriminant validity analysis, shown in Table 3, assures that a construct does not measure others. The square root of the AVE for each construct must be bigger than its correlation with other constructs, according to Fornell and Larcker (1981). This criterion is met since bold diagonal values are higher than associated values.

Table 2

Discriminant Validity (Fornell-Larcker Criterion)

Construct	F1	F2	F3	F4	F5
F1 Educational	**0.773**				
F2 Innovation and nature	0.765	**0.915**			
F3 Circular design	0.342	0.295	**0.982**		
F4 Circular services and resources	0.603	0.616	0.635	**0.826**	
F5 Social impact	0.470	0.467	0.577	0.778	**0.910**

Source: Prepared by the authors themselves.

The Heterotrait–Monotrait Ratio (HTMT) criterion was used as a robust approach to assess discriminant validity among the constructs (Table 2). According to Henseler et al., (2015), HTMT values should be below 0.85 (strict criterion) or 0.90 (more liberal criterion) to establish discriminant validity. In this study, all values are below these limits, which reaffirms the discriminant validity between the constructs analyzed.

Table 3

Discriminant Validity (Heterotrait-Monotrait Ratio HTMT)

Construct	F1	F2	F3	F4	F5
F1 Educational					
F2 Innovation and nature	0.747				
F3 Circular design	0.360	0.314			
F4 Circular services and resources	0.726	0.742	0.745		
F5 Social impact	0.547	0.519	0.620	0.901	

Source: Prepared by the authors themselves.

4 RESULTS AND DISCUSSIONS

Table 4 shows the results obtained from the structural model estimation. The analysis reveals that five of the six hypotheses were confirmed. Educational impact (F1) has a positive and notable influence on innovation and nature (F2), circular design (F3), and circular services and resources (F4).

Similarly, innovation and nature (F2) exert a positive and significant effect on social impact (F5) ($\beta = 0.464$, $p < 0.001$). In contrast, circular design (F3) does not show a significant influence on social impact (F5), while circular services and resources (F4) have only a marginal effect ($p = 0.038$). In summary, these findings indicate that educational projects indirectly contribute to social outcomes through innovation and circular practices, demonstrating that the educational component is key to the model.

Table 4

Effect of projects and environmental aspects on environmental impact assessment

Hypothesis	(β)path coef	Confidence Interval 95%	Effect Size f²	T Statistics	p value	Hypothesis
H1: The educational impact (F1) has a positive influence on innovation and nature (F2).	0.765	(0.961 - 2.336)	1.412	17.777	0.000	supported
H2: The educational impact (F1) has a positive influence on circular design (F3).	0.342	(0.034 - 0.357)	0.132	3.463	0.000	supported
H3: The educational impact (F1) has a positive influence on circular services and resources (F4).	0.603	(0.375 - 0.968	0.573	11.257	0.000	supported
H4: Innovation and nature (F2) has a positive influence on the social impact (F5).	0.464	(0.000 - 0.049)	0.000	8.266	0.000	supported
H5: Circular design (F3) has a positive influence on the social impact (F5).	0.002	(0.002 - 0.122)	0.030	0.029	0.488	not supported
H6: Circular services and resources (F4) have a positive influence on social impact (F5).	0.140	(0.188 - 0.945)	0.488	1.778	0.038	supported

Source: Prepared by the authors themselves.

Table 5 displays the findings for the endogenous constructs: F2 Innovation and Nature, F3 Circular Design, F4 Circular Services and Resources, and F5 Social Impact. R^2 values span from 0 to 1, where elevated values signify enhanced predictive capability for the endogenous variables. No universal thresholds exist; however, values of 0.75, 0.50, and 0.25 are commonly interpreted as substantial, moderate, and weak, respectively (Hair et al., 2021). The coefficients of determination in this model are moderate, with R^2 values ranging from 0.111 to 0.608.

Q^2 values related to predictive relevance were derived through the blindfolding procedure; Positive Q^2 values suggest that the model possesses predictive capability for a specific construct. Table 6 indicates that all Q^2 values exceed zero, ranging from 0.105 to 0.496, thereby affirming the model's predictive capability for endogenous constructs (Stone, 1974)

Table 5

Constructs

	Q2 (=1-SSE/SSO)	Original sample (**R²**)
F1 Educational		
F2 Innovation and nature	0.473	0.582
F3 Circular design	0.105	0.111
F4 Circular services and resources	0.219	0.360
F5 Social impact	0.496	0.608

Source: Prepared by the authors themselves.

The overall model fit, as presented in Table 6, was evaluated using the SRMR of the saturated model, resulting in a value of 0.144. This value, while surpassing the conservative threshold of 0.08 recommended for simple models, is still deemed acceptable given the model's complexity and the number of parameters estimated.

The discrepancy measures (d_ULS = 2.176 and d_G = 1.112) fall within their 99% bootstrap confidence intervals (HI99 = 0.506 and 0.477, respectively), thereby confirming the model's internal consistency.

Hair et al. (2021) indicate that in complex PLS-SEM models, SRMR values marginally exceeding 0.10 may still be deemed acceptable, contingent upon the corroboration of other discrepancy measures that affirm the model's robustness.

Table 6

Global model fit indices (Saturated model).

	SRMR	**d_ULS**	**d_G**
Saturated model	0.144	2.176	1.112

Source: Prepared by the authors themselves.

Note: SRMR = Standardized Root Mean Square Residual; d_ULS = Squared Euclidean distance; d_G = Geodesic distance. Values were obtained from the saturated model to assess global fit, where lower values indicate a better model fit (Hair et al., 2021).

Within the proposed conceptual model, circular design (F3) cannot be understood as an autonomous determinant of social impact (F5). Its contribution is embedded in a systemic architecture formed by innovation inspired by nature (F2) and by circular services and resources

(F4). Consequently, social impact emerges from the interaction and alignment of these dimensions, which operate simultaneously as an ecosystem rather than as isolated variables.

Although the relationship between innovation and nature (F2) and social impact (F5) was not statistically significant, this finding can be interpreted thru the theoretical framework of Vanaga and Blumberga (2015), who characterize biomimicry as the first steps in developing bio-inspired ideas. This initial creative approach encourages students to observe and imitate nature's functional principles, thereby forming the basis of circular design.

At this formative stage, biomimicry exercises rarely translate into tangible social actions, as they involve processes of individual understanding and creative exploration. This creativity demands advanced cognitive skills, such as abstraction and systems thinking, which are not developed in introductory courses.

The absence of a substantial effect can be ascribed to the temporal and practical divergence between the ideation phase (innovation and nature) and the generation of observable social impacts. In this sense, biomimicry serves as an inspiring starting point, but not yet as a consolidated social practice.

This finding is consistent with Padilla-Rivera et al. (2020), who state that the social dimension of the circular economy represents the greatest challenge to its operationalization, as it requires converting sustainable concepts into collective and institutional behaviors. In conclusion, the absence of validation for H4 signifies a natural stage of maturity in circular learning, wherein nature-inspired creative thinking has yet to be fully realized in the social domain, despite being a crucial prerequisite for its future advancement

5 CONCLUSIONS

From the discussions and results presented, the following conclusions were drawn, with a new approach:

1) The primary feature of the employed technique is that the course not only conveyed academic content but also enabled students to connect the essential principles of social entrepreneurship with the solutions of real-world issues. It emphasized the significance of social and educational variables as catalysts for incorporating circularity ideas into academia, fostering analytical and practical abilities to enhance innovation and sustainability.
2) The suggested methodology employs PLS-SEM, suitable for analyzing intricate models grounded in perceptions, utilizing latent constructs produced from the gathered empirical data.

3) Previous research concluded that education for social entrepreneurship is grounded in learning theories and the implementation of adaptive technologies that facilitate tailored learning experiences. These methodologies consider factors such as learning preferences, feedback mechanisms, cognitive load, and student motivation. The findings of this investigation align with these methodologies, since they reside within statistically acceptable parameters, hence reinforcing the validity of the suggested model.

4)The technique can be enhanced by including surveys of teachers, administrators, business professionals, and the community, as the primary weakness of this research is that it solely involved a very small sample of kids.

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