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Optimizing efficiency and sustainability in higher education: development and validation of a lean thinking adoption instrument

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Introduction: Lean Thinking has been applied across various sectors to optimize processes and improve efficiency; however, its implementation in higher education still faces methodological and structural challenges.

Methods: This study developed and validated an instrument to measure the application of Lean Thinking in Ecuadorian higher education institutions. A cross-sectional empirical design was used, involving 315 university students who responded to a 42-item questionnaire. Data were analyzed through exploratory and confirmatory factor analyses.

Results: The results revealed an eight-dimensional factorial structure addressing leadership, long-term thinking, continuous improvement, waste elimination, student value, teaching, research, and community engagement. The instrument showed high reliability (Cronbach's $\alpha = 0.94$; factor loadings > 0.40), convergent validity (AVE > 0.40), and discriminant validity (HTMT < 0.85). Model fit indices confirmed its robustness (CFI = 1.000, TLI = 1.008, RMSEA = 0.000). Leadership was the highest-rated factor ($M = 7.53$, SD = 1.09), while research scored the lowest ($M = 7.25$, SD = 1.13).

Discussion: This validated tool provides a reliable means to assess Lean adoption in higher education. Findings suggest that Lean implementation enhances institutional efficiency and student experience, though sustained impact requires long-term strategies.

KEYWORDS

lean thinking, leadership in education, waste reduction, higher education, instrument validation

1 Introduction

The concept of Lean Thinking has evolved from its origins in the manufacturing sector, where it was developed by Toyota to optimize processes, reduce waste, and improve organizational efficiency (Charron et al., 2014). Over the decades, Lean principles have been adopted by multiple sectors, including services, healthcare, and, more recently, education (Muraliraj et al., 2018). In this context, Lean has become a key strategy for enhancing administrative and academic management in Higher Education Institutions (HEIs), facilitating resource optimization and the development of agile and efficient processes.

However, the application of Lean in the educational sector presents unique challenges. Unlike manufacturing, where processes are repetitive and highly standardized, HEIs operate in dynamic and multifaceted environments where teaching, research, and community engagement require flexible and adaptive approaches (Ahlstrom, 2004). Additionally, the organizational structure of universities is often fragmented into departments and faculties with diverse objectives, making it difficult to implement Lean methodologies uniformly (Mohamed Rafi, 2020). These characteristics make the adoption of Lean in higher education require specific models that integrate continuous improvement tools with principles of educational innovation and institutional sustainability.

In recent years, various Lean tools, such as 5S, Value Stream Mapping (VSM), and Kaizen, have been implemented in HEIs to enhance administrative and academic efficiency (Kakouris et al., 2022). These strategies have contributed to reducing waiting times in administrative processes, optimizing enrollment management, and improving student experience through better resource allocation (Martínez León, 2019). However, rapid technological advancements and the evolution of educational models demand that universities continuously adapt their management methods, incorporating more integrated and systematic approaches for Lean application (Seidel et al., 2017).

In this regard, Lean Thinking not only impacts university administration but also connects with the development of leadership and strategic planning competencies within educational institutions (Delago et al., 2016). Its application in teaching can result in more efficient, student-centered teaching methodologies, while in the research domain, Lean facilitates resource optimization and reduces bureaucratic burdens in project management (Socconini, 2019). Moreover, its integration into community engagement processes enhances the execution of impactful outreach programs with a more efficient and results oriented structure (Bell and Orzen, 2016).

At the level of educational policies, it has been argued that the implementation of Lean in HEIs should be approached systematically, ensuring that principles of efficiency and continuous improvement are applied at all levels of the educational system, from primary education to higher education (Mayr et al., 2018). Some studies suggest that governments should promote Lean training programs within universities, fostering a culture of innovation and process optimization that benefits both academia and the productive (Mrugalska and Wyrwicka, 2017). However, in practice, the implementation of Lean in higher education remains an emerging phenomenon, with few studies evaluating its impact on academic quality and institutional sustainability (Neves-Silva et al., 2016; Sassanelli et al., 2015).

While Lean Thinking has proven to be an effective methodology for improving operational efficiency across various sectors, its adoption in Ecuadorian HEIs still faces significant challenges. The lack of validated tools to measure its implementation limits the ability of institutions to assess its effectiveness and develop evidence-based strategies. Therefore, this study aims to develop and validate an instrument that measures the application of Lean in Ecuadorian HEIs, providing a practical framework for its implementation and optimization in the educational sector. Through this instrument, the study seeks to facilitate decision-making in academic and administrative management, promoting a structured approach to Lean adoption in higher education.

2 Literature review

Lean Thinking originated in the manufacturing sector as a process optimization approach aimed at waste reduction, continuous improvement, and value creation (Liker and Meier, 2006). Its application in the educational sector is relatively recent, with studies exploring its potential to enhance both academic and administrative quality in Higher Education Institutions (HEIs) (Helmold, 2020).

Although Lean has been extensively implemented in the industrial and service sectors, the literature indicates that its adoption in higher education presents multiple methodological and structural challenges. Identified barriers include resistance to change, lack of training, and the need to adapt Lean principles to the specific dynamics of educational environments (Vinodh and Ben, 2015).

Nevertheless, various studies highlight that Lean can significantly contribute to both operational and academic efficiency in HEIs by reducing non-value-adding activities, improving time management, and optimizing curriculum planning (Gómez-Molina and Moyano-Fuentes, 2022).

2.1 Key forms of waste in HEIs

One of the primary objectives of Lean in education is the identification and elimination of waste that negatively impacts institutional efficiency and performance. According to Douglas et al. (2015), the main sources of waste in universities include:

- Unnecessarily complex administrative processes.
- Excessive time spent on bureaucratic activities.
- Inefficient use of academic and technological resources.
- Overloaded curricula with redundant content.
- Lack of synchronization in course scheduling and assessment planning.

These factors result in a loss of time and effort for students, faculty, and administrative staff, reducing the effectiveness of both teaching and institutional management. To address these issues, various Lean tools have been successfully implemented in higher education, with notable applications including 5S for organizing academic spaces, Kanban for optimizing record management and enrollment processes, Value Stream Mapping (VSM) for identifying inefficient processes, Kaizen for continuous improvement in educational programs, and Just-In-Time (JIT) for planning and delivering academic resources (Narayanamurthy et al., 2017; De La Vega et al., 2020).

2.2 Impact of lean on academic and administrative management

The impact of Lean on academic and administrative management has been documented in studies highlighting its potential to optimize bureaucratic processes, improve course efficiency, and enhance the quality of educational services. From an administrative perspective, research has shown that reducing waiting times in enrollment processes and eliminating unnecessary procedures allows institutions to focus on strategic activities that add value to the student experience (Gento et al., 2021).

In the academic domain, restructuring curricula under a Lean approach facilitates the elimination of redundant content, leading to a more efficient learning progression (Ávalos et al., 2019). Additionally, the integration of information technologies in teaching and

TABLE 1 Lean instrument constructs for HEIs.

Lean factors	Defining lean factors	Author(s)
Leadership (LD)	It involves the actions, attitudes, and behaviors of managers and their influence on employees.	Ingelsson and Mårtensson (2014)
Long-term thinking (LtT)	Long-term vision that involves lasting commitments to Lean implementation.	Ingelsson and Mårtensson (2014) and Salhieh and Abdallah (2019)
Waste elimination (WE)	Any effort that does not create value from the customer's point of view.	Sfakianaki and Kakouris (2019), Ohno (1988), and Shingo and Dillon (1989)
Continuous improvement (CI)	Constant implementation of slight changes that result in cumulative improvements.	Sfakianaki and Kakouris (2019), Piercy and Rich (2015), and Salhieh and Abdallah (2019)
Student value (SV)	Student-centricity as the primary client of higher education.	Sfakianaki and Kakouris (2019) and Sajan et al. (2017)
Teaching (TCH)	Knowledge building and capacity building through teacher-student interaction.	CES República del Ecuador Consejo De Educación Superior (2022) and Jama (2019)
Research (RCH)	A creative and systematic process that enhances scientific knowledge and its application in the local context.	CES República del Ecuador Consejo De Educación Superior (2022) and Jama (2019)
Linkage with society (LS)	Capacity building and knowledge in response to community needs.	CES República del Ecuador Consejo De Educación Superior (2022) and De Aparicio et al. (2017)

institutional management has improved access to study materials, reduced operational costs, and fostered more flexible and autonomous learning environments (Yoshino et al., 2020).

However, ensuring the sustainability of Lean in higher education remains a challenge. Most existing studies have focused on short-term impacts, without fully addressing their long-term scalability or its effects on student academic performance. Further research is needed to explore how Lean methodologies can be institutionalized to ensure continuous improvement and lasting benefits in higher education (Tortorella et al., 2021).

2.3 Lean model adapted to higher education

Despite its benefits, literature highlights significant barriers to the implementation of Lean in education. Resistance to change is one of the primary obstacles, as HEIs are often structured within traditional hierarchical frameworks that hinder the adoption of agile and flexible methodologies (Koromyslova et al., 2019). Additionally, the lack of specialized Lean training for the academic sector limits its effective application, as most training programs are designed for the industrial sector and do not consider the unique characteristics of educational environments (Sfakianaki and Kakouris, 2019). Another challenge is the scarcity of empirical evidence on Lean's impact in higher education, as many existing studies focus on pilot projects or specific case studies without providing longitudinal analyses that assess its long-term effectiveness (Tortorella et al., 2021). This underscores the need for more robust research to validate Lean's implementation in education and develop models adapted to the specific characteristics of HEIs.

To overcome these limitations, several studies have proposed Lean models tailored to higher education, based on key dimensions such as those presented in Table 1. The literature emphasizes that leadership plays a fundamental role in Lean implementation, as the commitment of institutional leaders is essential for facilitating organizational change and ensuring the sustainability of improvements (Ingelsson and Mårtensson, 2014). Waste elimination has been identified as a priority in educational management, as it enhances operational efficiency and reallocates resources to higher-impact academic activities (Sfakianaki and Kakouris, 2019; Ohno, 1988). Likewise, continuous improvement is a key component in the transformation of HEIs, as it promotes gradual refinement in teaching and administrative processes without causing unnecessary disruptions (Piercy and Rich, 2015). Finally, value creation for students has become a central focus of Lean models in education, as it enables academic programs to align with labor market needs while enhancing the overall learning experience (Sajan et al., 2017).

A critical element in adapting Lean to higher education is long-term thinking, which involves the strategic planning of improvements in the educational system to ensure their sustainability. Unlike other sectors where Lean is implemented to achieve immediate results, in HEIs it is essential to consider the evolution of academic programs, the modernization of infrastructure, and alignment with national and international educational policies (Höfer and Naeve, 2017).

Teaching is another fundamental dimension in the application of Lean, as it enhances the effectiveness of teaching methods and optimizes teacher-student interaction. The reduction of administrative tasks and the simplification of curricular processes allow faculty to focus on innovative pedagogical strategies, such as project-based learning and adaptive teaching (Tortorella et al., 2021).

In the research domain, Lean facilitates resource optimization, the reduction of bureaucratic barriers in project management, and the strengthening of collaborative networks among researchers. Previous studies have demonstrated that Lean can accelerate the peer review and publication process of scientific articles, as well as improve efficiency in research fund administration (Vinodh and Ben, 2015).

Finally, community engagement is a key pillar in Lean implementation in higher education, as it fosters the development of social impact programs that address community needs. The optimization of outreach project management and the application of Lean strategies in social responsibility initiatives have proven to be effective in strengthening the relationship between universities and their external environment (Koromyslova et al., 2019).

While literature has made significant progress in exploring Lean in higher education, a major gap remains in the validation of measurement

TABLE 2 Sample distribution.

Category	Factor	Frequency	Proportion
Gender	Male	237	75.2
	Female	78	24.8
Age	17–24 years old	253	80.3
	25–30 years old	53	16.8
	31–35 years old	6	1.9
	More than 40 years old	3	1
Work	Yes	198	62.9
	No	117	37.1
Workday	Morning	154	48.9
	Afternoon	5	1.6
	Evening	156	49.5
Level	Fourth semester	4	1.3
	Fifth semester	82	26
	Sixth semester	35	11.1
	Seventh semester	147	46.7
	Eighth semester	47	14.9
Level of knowledge about lean thinking	None	50	15.9
	Basic	190	60.3
	Intermediate	72	22.9
	Advanced	3	1

instruments to assess its impact in these settings. Most studies have adopted qualitative or descriptive approaches, but more precise tools are needed to evaluate Lean's effectiveness in education, considering variables such as student satisfaction, administrative efficiency, and learning outcomes. In this regard, the present study seeks to contribute to the field by developing and validating a specific instrument to assess Lean implementation in Higher Education Institutions in Ecuador, addressing the limitations identified in the literature and providing a methodological framework to facilitate its application in this context.

3 Materials and methods

3.1 Design, sample participants, and measurement

The present study was designed following an iterative approach that integrated a systematic literature review and expert validation to assess the implementation of Lean practices in Higher Education Institutions (HEIs) in Ecuador, particularly in relation to teaching, research, and community engagement. This research adopts an empirical and cross-sectional descriptive approach, allowing for the analysis of Lean practices at a specific point in time while generating findings of practical relevance (Cohen et al., 2000). This approach was selected for its capacity to provide reliable and timely insights into the educational context.

The study involved 315 students enrolled in the Industrial Engineering program at an Ecuadorian university, selected from the fourth semester onward using a non-probabilistic purposive sampling strategy. This technique, widely used in qualitative and applied educational research, enabled the selection of participants with relevant academic exposure to organizational and production processes—key aspects for understanding Lean practices in the academic setting (Palinkas et al., 2015).

Although the inclusion criteria ensured that students had been introduced to process management concepts, this did not imply advanced knowledge of Lean Thinking. Rather, the objective was to capture students' perceptions based on their academic experiences, not to assess technical mastery of Lean methodologies. As shown in Table 2, participants reported varying levels of familiarity with Lean, ranging from no knowledge to advanced. This diversity was considered an asset for the study, as it allowed the evaluation of perceptions across a broad spectrum of awareness.

Data collection was conducted through an online survey, which facilitated participant access and minimized data entry errors. Participants were fully informed about the purpose of the study and were assured of anonymity and confidentiality, helping to reduce the risk of social desirability bias.

The sample size was determined based on the methodological guidance proposed by Cohen et al. (2000), who recommend between 5 and 10 participants per item in instrument validation studies (The R Foundation, 2023). Given the 42-item structure of the questionnaire, the recommended sample range was 210 to 420 participants. The final sample of 315 respondents thus met these parameters, ensuring adequate statistical power for the subsequent analyses.

3.2 Lean thinking in the industrial engineering curriculum

In the context of Ecuadorian higher education, Lean Thinking is introduced in the Industrial Engineering curriculum through subjects such as operations management, production systems, and process optimization. These courses provide a foundation in key Lean principles—including value creation, waste elimination, and continuous improvement and often contextualize their application beyond manufacturing, addressing service and administrative environments.

As students advance in their academic journey, particularly from the fourth semester onward, they participate in case studies, academic projects, and applied coursework where Lean is addressed both conceptually and practically. These experiences foster the development of process-oriented thinking and enable students to identify organizational practices aligned with Lean principles within academic institutions.

While the depth of Lean-related knowledge may vary among students, the curricular structure ensures a baseline understanding that supports their ability to assess how educational environments reflect Lean values. This context justifies the selection of Industrial Engineering students as an appropriate population for investigating perceptions of Lean implementation in Higher Education Institutions.

3.3 Instrument

The measurement instrument was designed based on a preliminary theoretical model grounded in a literature review on the application of Lean in higher education. Since no standardized questionnaire exists in Ecuador to evaluate the implementation of this approach in Higher Education Institutions (HEIs), an original instrument was developed, ensuring its theoretical foundation in previous studies and its relevance to the Ecuadorian academic context. To establish a robust conceptual framework, foundational works such as those by Papadopoulou and Özbayrak (2005) and Shah and Ward (2007) were used as key references. These studies helped focus the literature review on Lean as a holistic management system, highlighting its evolution beyond a traditional industrial tool and its applicability in the academic environment.

The final questionnaire consisted of 42 items, formulated to assess various strategic dimensions of Lean application in the university environment. A 10-point Likert scale was used, where 1 represented the lowest perception and 10 the highest perception of each analyzed aspect. The decision to use a 10-point Likert scale was based on the need to capture more nuanced perceptions from students regarding the application of Lean practices in their academic environment. This type of scale is also commonly used and easily understood by students in the Ecuadorian university context. Compared to traditional 5- or 7-point scales, extended scales such as the 10-point format allow for a wider range of responses and help reduce central tendency bias. Prior research has highlighted that broader response options increase the sensitivity of measurements, especially when dealing with complex constructs. Classic studies, such as Ferguson (1941), have shown that increasing the number of response categories enhances an instrument's ability to detect subtle differences in respondents' evaluations. This feature is particularly relevant in studies assessing multifaceted dimensions such as leadership, continuous improvement, and student value.

In its design, the questionnaire incorporated key elements related to curriculum planning, optimization of teaching time, development of research competencies, and the impact of community engagement. Each item was developed to capture participants' perceptions regarding Lean integration into academic and administrative processes. The instrument was structured around the following dimensions:

1. Leadership: Examines the role of university administrators in the adoption and management of Lean practices in higher education (Lu et al., 2017).
2. Long-term thinking: Assesses institutional strategic orientation and its focus on continuous improvement (Mårtensson et al., 2023).
3. Continuous improvement: Explores the institution's ability to adapt and optimize its processes (Singh and Singh, 2012).
4. Student Value: Measures Lean's impact on academic experience and learning outcomes (Balzer et al., 2016).
5. Teaching: Evaluates the integration of Lean principles into pedagogical methods and the optimization of the teaching-learning process (Yalçin Tilfarlioğlu, 2017; Khandan and Shannon, 2021).
6. Research: Analyzes Lean's influence on scientific production and the efficiency of research processes (Staedele et al., 2019).
7. Linkage with Society: Examines Lean's impact on university-society interactions and its role in strengthening social commitment (Moscardini et al., 2022).
8. Waste elimination: Analyzes the efficiency of resource utilization within educational and administrative processes (Szabó et al., 2024).

The complete instrument, including the 42 items grouped by factor, is presented in the Appendix. For example, one item states, *"The university offers clear and timely information about academic processes,"* which reflects a Lean principle (transparency and flow of information) while remaining accessible to students regardless of their technical background. This approach ensured that responses were based on lived academic experiences, not technical expertise.

3.4 Validation of the instrument

The validation process of the instrument was carried out using a rigorous approach, encompassing the evaluation of content validity, internal consistency, construct validity, convergent validity, and discriminant validity within the Ecuadorian context. To ensure the relevance and clarity of the items, a content analysis was conducted with the participation of a panel of experts selected based on specific criteria, including experience in university teaching, academic training at the master's or doctoral level in Process Engineering, and research expertise in innovation and process design in higher education. Content validity was determined using Aiken's V coefficient, obtaining an average value of 0.89, indicating a high level of agreement among experts and confirming the adequacy of the instrument in terms of coherence and theoretical relevance (Pastor, 2018).

Regarding construct validity, an exploratory factor analysis (EFA) was performed, followed by a confirmatory factor analysis (CFA) to evaluate the underlying structure of the questionnaire. The EFA identified eight latent dimensions using the minimum residual method and Varimax rotation, determining the number of factors based on the eigenvalue greater than 1 criterion. To estimate the internal consistency of each identified factor, Cronbach's alpha coefficient was calculated, yielding adequate reliability levels.

Convergent validity was assessed through the calculation of average variance extracted (AVE), where values above 0.4 indicated that the items adequately represented the underlying theoretical constructs. While Fornell and Larcker (1981) suggest that an AVE value of 0.5 or higher is ideal, they also note that if AVE is below 0.5 but the composite reliability (CR) exceeds 0.6, the construct's convergent validity can still be considered acceptable. Additionally, discriminant validity was determined using the Heterotrait Monotrait (HTMT) criterion, a method introduced by Henseler, Ringle, and Sarstedt (Roemer et al., 2021) as a more reliable approach for variance-based structural equation modeling. This criterion ensures that each dimension is conceptually distinguishable from the others, recommending that HTMT values remain below 0.90 to confirm adequate discriminant validity.

Finally, to confirm the factorial structure obtained, a confirmatory factor analysis (CFA) was conducted using the unweighted least squares (ULS) estimator applied to the covariance matrix (Shi and Maydeu-Olivares, 2020). Moreover, composite reliability was calculated as a complementary measure of internal consistency. The results obtained throughout the different phases of the validation process support the methodological robustness of the instrument, confirming its validity and reliability for measuring the evaluated constructs in the context of higher education in Ecuador, where, to date, no similar vali-dated instrument has been available.

3.5 Data analysis

The descriptive analyses and exploratory factor analysis (EFA) were conducted using JASP version 0.17.2.1 for Windows. Meanwhile, the confirmatory factor analysis (CFA) and figure generation were performed using R version 4.3.2 within the R statistical environment, utilizing specific packages (The R Foundation, 2023).

3.6 Ethical considerations

From an ethical perspective, the research adhered to the guidelines of Winter and Gundur (2024), ensuring confidentiality, anonymity, and voluntary participation. Participants first completed an informed consent form, authorizing their participation and the use of data for academic purposes, ensuring the ethical integrity of the research process (Creswell and Creswell, 2017). Additionally, institutional approval was obtained for the implementation of the instrument, ensuring compliance with internal regulations and established ethical principles. Participants were informed about the study's objectives, and their informed consent was obtained prior to data collection. Furthermore, a brief explanation of the importance of Lean Thinking in higher education was provided to ensure participants' proper understanding.

4 Results

4.1 Description of a study sample

The sample consisted of 315 participants, of whom 75.2% were men and 24.8% were women. The majority (80.3%) were between 17 and 24 years old, while only 2.9% were over 30 years old. 62.9% combined their studies with work. Regarding academic schedules, 48.9% attended morning sessions, 49.5% attended evening sessions, and 1.6% attended afternoon sessions.

Academically, 46.7% were in their seventh semester, followed by 26% in the fifth semester, 14.9% in the eighth, 11.1% in the sixth, and 1.3% in the fourth. In terms of Lean Thinking knowledge, 60.3% had basic knowledge, 22.9% had intermediate knowledge, 15.9% had no knowledge, and only 1% had advanced knowledge.

4.2 Assessment of data adequacy

To assess the suitability of the data before applying exploratory factor analysis (EFA), three fundamental tests were conducted: internal reliability of the instrument using Cronbach's Alpha, sampling adequacy through the Kaiser-Meyer-Olkin (KMO) index, and sphericity testing using Bartlett's test.

First, the internal reliability of the questionnaire was determined using Cronbach's Alpha coefficient, as shown in Table 3, yielding a value of 0.943, which indicates excellent internal consistency among the instrument's items (Mallery and Mallery, 2003).

This coefficient is widely used in psychometric research to assess the homogeneity of the items within a scale, and values above 0.9 suggest high reliability of the measured construct (Thorndike, 1995). Nevertheless, all other constructs obtained scores above 0.7, which is generally considered acceptable for internally consistent scales (Tavakol and Dennick, 2011).

Secondly, sampling adequacy was verified through the Kaiser-Meyer-Olkin (KMO) index, which reached an overall value of 0.92. This result indicates that the data exhibits an adequate factorial structure, as values above 0.80 are considered meritorious, while those

TABLE 3 Alfa coefficient (α) for the eight factors.

Factor	Number of items	α
Leadership (LD)	5	0.842
Long-term thinking (LtT)	5	0.781
Continuous improvement (CI)	5	0.774
Student value (SV)	5	0.819
Teaching (TCH)	5	0.814
Research (RCH)	4	0.757
Linkage with society (LS)	5	0.865
Waste elimination (WE)	8	0.801
Total scale	42	0.942

exceeding 0.90 are interpreted as excellent (Kaiser, 1974). Furthermore, individual KMO values for each item ranged between 0.85 and 0.95, suggesting that none of the items exhibit sampling adequacy issues, and therefore, they can be included in the factor analysis.

Finally, Bartlett's test of sphericity yielded a statistically significant result ($\chi^2 = 5981.92$, df = 861, $p < 0.001$), confirming that the correlation matrix is not an identity matrix and that there are sufficient correlations among the items to justify the application of factor analysis (Bartlett, 1950). The significance of this test supports the feasibility of exploratory factor analysis (EFA), as it suggests that the items are adequately interrelated for identifying latent factors (Field, 2018).

In summary, the results obtained from these preliminary tests support the viability of exploratory factor analysis, indicating that the data exhibits a suitable structure for dimensional reduction and the identification of underlying constructs.

4.3 Exploratory factorial analysis

To identify the underlying structure of the instrument, an Exploratory Factor Analysis (EFA) was conducted using the minimum residuals (minres) method with Varimax rotation. This procedure maximizes the variance of the factors, facilitating the interpretation of factor loadings.

The number of constructs to retain was determined based on the recommendations of Hair et al. (2010), using a minimum factor loading threshold of 0.40. In total, the eight identified constructs explained 43% of the variance in the data, which is considered adequate for this study.

During the analysis, it was observed that one research-related item exhibited a significant factor loading on a different factor than theoretically expected. This behavior suggests that the item did not adequately measure the intended dimension, leading to its removal from the analysis to improve the factorial validity of the instrument.

The following section presents the factor loadings of the retained items in the exploratory factor analysis, demonstrating satisfactory convergence within their respective constructs (Costello and Osborne, 2005).

To facilitate the interpretation of Table 4, it is important to understand how each item corresponds to a specific latent factor through its factor loading. These loadings represent the strength of association between each item and a given dimension, with values above 0.40 considered acceptable for retaining items in the model. This ensures that the instrument captures coherent and interpretable structures across all dimensions.

For example, Item 1 showed a loading of 0.65 on the Leadership (LD) factor, indicating a strong alignment with this construct. Similarly, Item 21 loaded at 0.64 on the Teaching (TCH) dimension, while Item 36 presented a loading of 0.42 on Waste Elimination (WE), all of which demonstrate that the items are well anchored in their respective dimensions. Importantly, each item retained in the analysis loaded significantly on only one factor, supporting the internal consistency and clarity of the questionnaire's structure.

4.4 Convergent and discriminant analysis

Convergent validity was assessed through the calculation of the average variance extracted (AVE), a criterion that estimates the proportion of variance captured by each construct relative to the total variance. Values above 0.5 are considered indicative of an adequate explanatory capacity of the latent construct, although in exploratory studies, thresholds close to 0.4 are acceptable, as they reflect a factorial structure with reasonable variance levels in applied contexts. Additionally, convergent validity is further supported by the high composite reliability coefficients, all of which exceed 0.6, indicating strong internal consistency and reinforcing the robustness of the measured constructs. The AVE matrix obtained is presented in Table 5.

The results indicate that most dimensions achieve acceptable AVE values, suggesting that the variance explained by the constructs exceeds the variance attributed to measurement error. This finding implies that the items within each dimension exhibit a high degree of internal correlation and accurately represent the underlying latent variable, further corroborating the presence of convergent validity through both AVE and composite reliability.

On the other hand, discriminant validity was assessed using the Heterotrait Monotrait (HTMT) matrix, a recommended technique for evaluating construct differentiation based on the heterogeneity of their correlations. Values below 0.85 are considered empirical evidence of adequate separation between latent dimensions, indicating that each construct measures a theoretically distinct aspect within the model. The HTMT matrix obtained is presented in Table 6.

The coefficients obtained confirm that the evaluated dimensions exhibit adequate differentiation, as none of the values exceed the critical threshold of 0.85. This indicates that the underlying dimensions of the Lean methodology in HEIs maintain an independent conceptual identity, without excessive overlap that could compromise the interpretation of the constructs.

4.5 Confirmatory factor analyses

To verify the exploratory factorial structure of eight factors, a Confirmatory Factor Analysis (CFA) was conducted using the Unweighted Least Squares (ULS) estimator to assess model fit. The model was tested with a total of 315 observations and 438 estimated parameters. The global fit indices of the model are presented in Table 7, along with the standardized scores (Figure 1).

4.6 Item analysis

Table 8 presents a summary of the descriptive statistics for each of the eight dimensions assessed in the instrument, offering insight into their psychometric performance. The data are based on participant responses to a 10-point Likert scale, where 1 represents low implementation and 10 represents high implementation of Lean-related practices within the university context.

Among the results, the Teaching dimension obtained the highest average score ($M = 7.88$, SD = 0.99), followed by Leadership ($M = 7.53$, SD = 1.09) and Long-Term Thinking ($M = 7.41$, SD = 1.14), suggesting a favorable perception of these constructs. In contrast, Waste Elimination recorded the lowest average ($M = 6.57$, SD = 1.69), accompanied by the highest standard deviation, indicating greater variability in participants' views regarding the implementation of this dimension. Likewise, the Research dimension ($M = 7.25$, SD = 1.13)

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TABLE 4 Exploratory factor analysis (EFA) results.

	LD	LtT	CI	SV	TCH	RCH	LS	WE
Item 1	0.65							
Item 2	0.55							
Item 3	0.68							
Item 4	0.54							
Item 5	0.56							
Item 6		0.63						
Item 7		0.52						
Item 8		0.55						
Item 9		0.58						
Item 10		0.52						
Item 11			0.50					
Item 12			0.53					
Item 13			0.64					
Item 14			0.57					
Item 15			0.40					
Item 16				0.61				
Item 17				0.64				
Item 18				0.53				
Item 19				0.50				
Item 20				0.45				
Item 21					0.64			
Item 22					0.66			
Item 23					0.66			
Item 24					0.60			
Item 25					0.53			
Item 26						0.54		
Item 27						0.52		
Item 28						0.58		
Item 29						0.62		
Item 30							0.57	
Item 31							0.64	
Item 32							0.63	
Item 33							0.61	
Item 34							0.58	
Item 35								0.59
Item 36								0.42
Item 37								0.43
Item 38								0.44
Item 39								0.41
Item 40								0.40
Item 41								0.59
Item 42								0.67

The rotation method applied is Varimax.

TABLE 5 Convergent validity through AVE.

Dimension	AVE	Composite reliability
Leadership (LD)	0.549	0.858
Long-term thinking (LtT)	0.451	0.801
Continuous improvement (CI)	0.446	0.800
Student Value (SV)	0.488	0.826
Teaching (TCH)	0.508	0.837
Research (RCH)	0.471	0.780
Linkage with society (LS)	0.580	0.873
Waste elimination (WE)	0.467	0.820

TABLE 6 HTMT based discriminant validity.

Dimension	LD	LtT	CI	SV	TCH	RCH	LS	WE
LD		0.669	0.580	0.726	0.515	0.633	0.608	0.613
LtT			0.657	0.609	0.477	0.583	0.545	0.615
CI				0.637	0.596	0.602	0.602	0.694
SV					0.593	0.593	0.668	0.648
TCH						0.602	0.616	0.567
RCH							0.699	0.660
LS								0.721
WE								

LD: Leadership; LtT: Long-term Thinking; CI: Continuous Improvement; SV: Student Value; TCH: Teaching; RCH: Research; LS: Linkage with Society; WE: Waste Elimination.

TABLE 7 Expected values of the fit indices for a structural equation model and values obtained in the confirmatory factor analysis (CFA).

Adjustment index	Indexes	Value	Recommended values
Discrepancy measurement	CMIN/DF	0.760	(<2)
	Root Mean Square Error of Approximation (RMSEA)	0.000	(0–0.1)
Incremental adjustment	Comparative fit index (CFI)	1.000	[0.9-1]
	Normalized fit index (NFI)	0.979	[0.9-1]
	Non-normed fit index (NNFI)	1.008	[0.9-1]
	Tucker-Lewis index (TLI)	1.008	[0.9-1]
Parsimony-adjusted and related measures	Parsimony-adjusted measures (PNFI)	0.899	(0.5-1)
	Goodness of fit index (GFI)	0.997	(0.9-1)
	Relative fit index (RFI)	0.977	(0.9-0.1)

CMIN/DF: discrepancy between chi-square and degrees of freedom; RMSEA: root mean square error of approximation; CFI: comparative fit index; NFI: normed fit index; NNFI: non-normed fit index; TLI: Tucker-Lewis index; PNFI: parsimonious normed fit index; GFI: goodness-of-fit index; RFI: relative fit index.

showed relatively moderate values, reflecting potential areas where Lean application is perceived as less consistent.

The standard deviation values are particularly useful for identifying heterogeneity in perception across participants. Dimensions with higher variability, such as Waste Elimination and Continuous Improvement, may suggest context-specific differences or the presence of subgroups with divergent experiences—potentially linked to variables such as department, gender, or level of Lean knowledge.

The unidimensionality coefficients included in the table indicate the internal coherence of each factor, derived from the confirmatory factor analysis. Values close to 1.00 reflect a strong tendency for items within each construct to measure a single underlying dimension, supporting the structural validity and internal consistency of the instrument.

5 Discussion

This section interprets the main findings of the study, integrating statistical evidence and theoretical implications to strengthen the understanding of Lean implementation in Higher Education Institutions (HEIs).

Leadership obtained the highest score ($M = 7.53$, $SD = 1.09$), reaffirming its central role in Lean implementation. This finding reflects the strategic importance of top-level management in driving

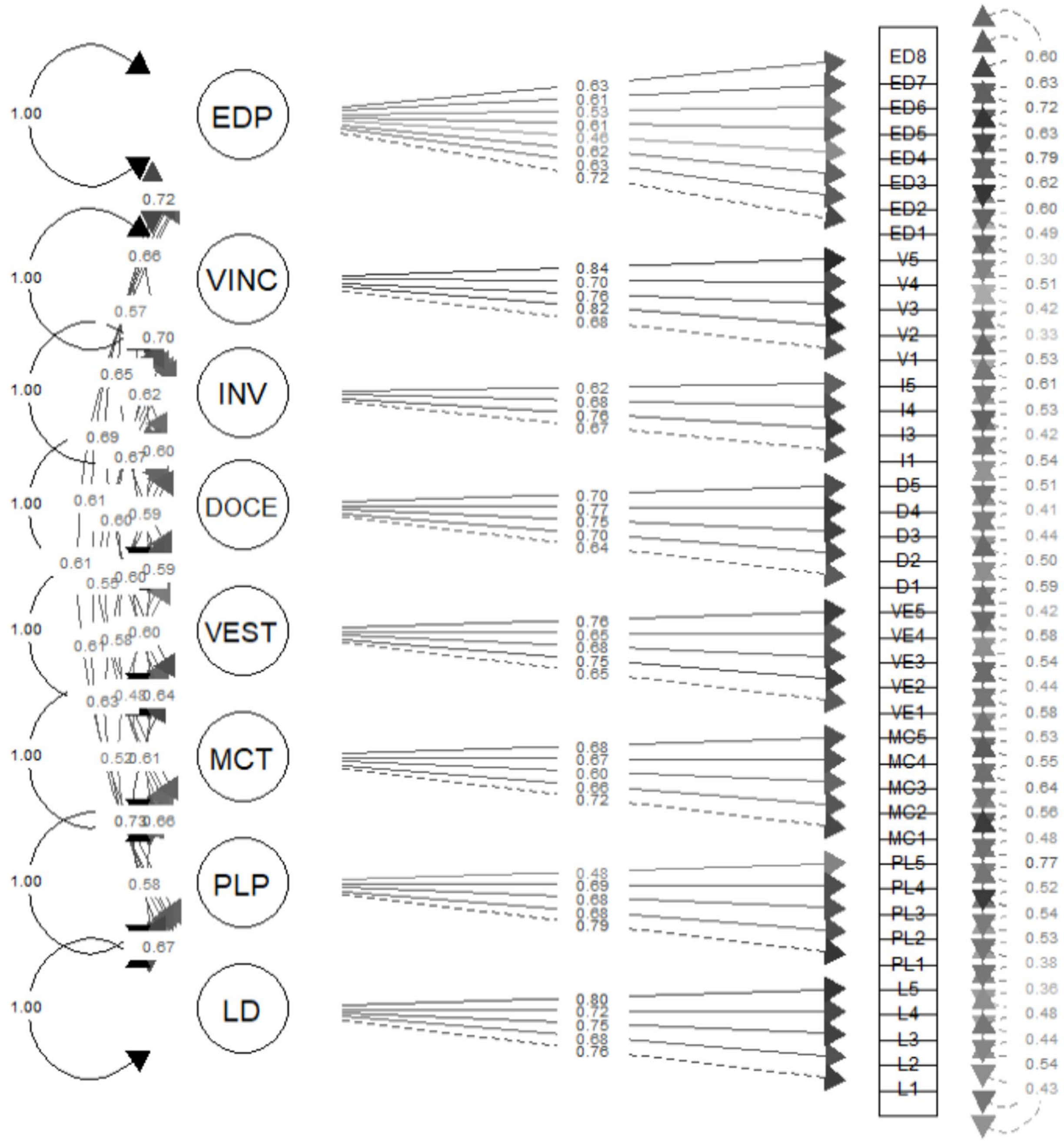

FIGURE 1
Confirmatory factor analysis of the eight-factor model, with standardized weights and measurement errors associated with each of the items included.

Lean initiatives and possibly points to a cultural alignment or institutional maturity in applying Lean principles within the Ecuadorian context. It is consistent with studies that identify leadership as a key enabler of successful organizational change and continuous improvement (Ingelsson and Mårtensson, 2014). The high composite reliability values observed in the Leadership, Long-Term Thinking, and Engagement dimensions further support the robustness of this construct as a pillar of Lean in academia. These results echo the findings of prior research that highlight the critical role of leadership and student-centered approaches in promoting institutional transformation (Klein et al., 2023a; Klein et al., 2023c; Klein et al., 2023e; Klein et al., 2023b; Klein et al., 2023d; Sila and Ebrahimpour, 2005).

Conversely, the Research dimension yielded the lowest average score ($M = 7.25$, SD = 1.13), suggesting that Lean implementation in this area remains underdeveloped. This outcome may stem from a combination of factors, including a general unfamiliarity with Lean principles among research staff and the complexity involved in applying standardized practices to activities that are often nonlinear, exploratory, and externally conditioned. The limited

TABLE 8 Descriptive statistics, unidimensionality and reliability of the instrument.

Factor	Mean	SD	Unidimensionality
LD	7.53	1.09	0.995
LtT	7.41	1.14	0.997
CI	6.98	1.40	0.994
SV	6.83	1.38	0.995
TCH	7.88	0.99	0.999
RCH	7.25	1.13	0.994
LS	7.18	1.09	0.997
WE	6.57	1.69	0.987

LD: Leadership; LtT: Long-term Thinking; CI: Continuous Improvement; SV: Student Value; TCH: Teaching; RCH: Research; LS: Linkage with Society; WE: Waste Elimination. The values shown are based on participant responses to a 10-point Likert scale, where 1 = low implementation and 10 = high implementation.

integration of Lean tools in research processes may also reflect institutional priorities that traditionally emphasize teaching and administration over innovation in research management. Previous studies (Vinodh and Ben, 2015) have highlighted the potential benefits of Lean in optimizing research workflows, but these findings indicate persistent challenges. Further studies should examine whether this low score reflects implementation gaps, lack of training, or deeper resistance to process-oriented models in academic research culture.

Additionally, these results may be shaped by specific characteristics of the Ecuadorian higher education system. The system operates under centralized regulation by national entities such as the *Consejo de Aseguramiento de la Calidad de la Educación Superior (CACES)* and the *Secretaría de Educación Superior, Ciencia, Tecnología e Innovación (SENESCYT)*, which impose performance-based evaluation frameworks and strict accreditation processes. While these mechanisms aim to improve academic quality and accountability, they can also foster a compliance-oriented institutional culture. This may contribute to a stronger focus on administrative and teaching efficiency, as reflected in the higher scores for Leadership and Long-Term Thinking, while leaving less flexibility for research innovation and experimental approaches aligned with Lean principles.

Although the differences between the dimensions are not statistically tested in this study, the moderate standard deviation values suggest a relatively consistent perception among participants. Nonetheless, the wider dispersion in dimensions such as Waste Elimination (SD = 1.69) points to variations in how students experience resource efficiency practices. This heterogeneity may indicate differences across academic units or student cohorts, and future studies could apply *t*-tests or ANOVA to compare responses by gender, semester, or prior exposure to Lean, as reported in Table 2. These subgroup analyses could provide deeper insight into patterns of perception, particularly considering that responses came from students ranging from those with no Lean knowledge to those with advanced familiarity.

Among these subgroup considerations, gender differences merit particular attention. Although the present study did not perform inferential analysis by gender, the sample included both male and female respondents in relatively balanced proportions (see Table 2). Gender may influence how students perceive institutional leadership, engagement, and academic processes, given the potential variation in experiences, expectations, and levels of participation in Lean-related initiatives. Future research should examine whether such gender-based differences exist, particularly in dimensions like Student Value or Engagement, which may be perceived differently based on institutional roles or sociocultural factors.

The findings of this study support the applicability of the Lean model in HEIs, demonstrating its positive effects on academic management, administrative efficiency, and the optimization of educational processes. The validation of the proposed instrument suggests that Lean can be a valuable tool for enhancing strategic planning and operational coherence in the Ecuadorian higher education system, adapting its principles to local challenges and priorities.

From a methodological standpoint, the developed instrument exhibited strong internal consistency, with Cronbach's alpha values exceeding established thresholds (Tavakol and Dennick, 2011). This reinforces the validity of the model and aligns with earlier research in Brazil and Portugal that underscores Lean's contribution to institutional efficiency (Klein et al., 2022). Although some Average Variance Extracted (AVE) values were below 0.50, this is common in exploratory studies involving new constructs or application domains, such as Lean in education (DeVellis, 2016). While values above 0.5 are ideal, thresholds near 0.4 are acceptable when supported by consistent factor loadings and conceptual coherence.

Furthermore, the discriminant validity of the model was confirmed through the Heterotrait-Monotrait (HTMT) matrix, which revealed no inter-construct correlation exceeding the 0.85 threshold. This confirms that each dimension represents a distinct theoretical element within the Lean framework. Although certain constructs, such as Leadership and Student Value, exhibited moderately high correlations, they remain within acceptable limits, underscoring their conceptual independence.

Globally, Lean implementation in education faces cultural and structural challenges that differ from its industrial origins (Koromyslova et al., 2019). In the Ecuadorian context, resistance to change and entrenched institutional cultures are key barriers, as noted in other international studies (Gento et al., 2021). Nonetheless, Waste Elimination and Continuous Improvement emerged as pivotal dimensions, reinforcing their role as fundamental practices in enhancing quality and efficiency in higher education (Bell and Orzen, 2016; Khan et al., 2023).

While Lean can produce immediate improvements in academic management, long-term sustainability remains a critical concern. The absence of enduring strategic frameworks may limit the continuity of Lean initiatives, as observed in earlier studies (Tortorella et al., 2021; Douglas et al., 2015). Thus, the integration of Lean should not be restricted to administrative reforms but should encompass pedagogical innovation and research development. A holistic approach that includes teaching, research, and community engagement is essential to fully adapt Lean to the needs of academic institutions (Gómez-Molina and Moyano-Fuentes, 2022).

The instrument developed in this study was designed with non-technical language to ensure accessibility and broad applicability. Though validated in an Ecuadorian context, its structure allows for adaptation in other educational systems. The full version of the instrument, along with the 10-point Likert scale explanation, is included in the Appendix, as recommended. This scale was chosen to enhance sensitivity in measuring complex constructs and reduce central tendency bias. Ferguson (1941) (Ferguson, 1941) has shown that broader response categories increase an instrument's discriminatory power, which is especially relevant in measuring perceptions of multifaceted phenomena such as leadership or continuous improvement.

In summary, the clear differentiation among constructs and the robustness of psychometric properties support the validity of the proposed model. The results lay the groundwork for future research on Lean practices in education. Expanding the sample size, applying longitudinal designs, and examining differences among student subgroups could further validate the instrument and reveal deeper insights into how Lean Thinking shapes the academic experience in diverse contexts.

Moreover, some of the items included in the instrument provide insight into potential areas for Lean implementation in HEIs. For instance, questions addressing the optimization of academic scheduling, reduction of administrative bottlenecks, and improvement of feedback systems align with institutional initiatives to enhance student retention and academic performance. These areas represent practical domains where Lean principles can be operationalized to increase institutional efficiency and improve educational experience. Thus, the instrument not only serves as an evaluative tool but also highlights concrete opportunities for academic and administrative improvement.

5.1 Implications for management and research

The validated instrument offers HEI managers a practical and evidence-based tool for assessing Lean implementation across various strategic dimensions, including leadership, teaching, research, and social engagement. The high internal consistency and convergent validity of the model provide confidence in its applicability for institutional self-assessment, strategic planning, and continuous improvement initiatives. In particular, the strong results in the Leadership and Long-Term Thinking dimensions suggest that managerial commitment and forward-looking strategies are essential for sustaining Lean transformations in educational settings.

From a management perspective, the instrument can be used to identify strengths and weaknesses in Lean implementation at the departmental or institutional level. The variation in scores—especially the lower ratings for Research and Waste Elimination—signals potential areas where targeted support and training may be needed. Furthermore, the results provide a roadmap for aligning Lean interventions with institutional goals, enabling decision-makers to foster a culture of continuous improvement and value generation within HEIs.

For researchers, this instrument fills an important gap in the Latin American higher education literature by offering a validated framework for evaluating Lean principles beyond the industrial sector. Its adaptability for future studies allows for comparative analysis across institutions, countries, and academic disciplines. Moreover, the instrument opens pathways for investigating relationships between Lean implementation and key educational outcomes, such as student satisfaction, retention, academic performance, and innovation in pedagogical practices.

Although the validation was conducted within a single Ecuadorian institution, the model's structure and conceptual basis provide a strong foundation for broader applications. To enhance external validity, future research should implement multi-institutional replication, including both public and private HEIs from diverse geographic and socioeconomic contexts. Longitudinal studies are also recommended to evaluate the model's temporal stability and adaptability to various institutional dynamics. These strategies will support a more robust generalization of findings and allow comparative analyses that enrich Lean application in higher education.

5.2 Research limitations and future research

This study is not without limitations. First, the use of non-probabilistic purposive sampling limits the generalizability of the results beyond the specific context of the Ecuadorian university analyzed. While the instrument demonstrates strong psychometric properties, further testing with larger and more diverse samples across multiple institutions would enhance its external validity and robustness.

Second, cross-sectional design does not allow for causal inference or the examination of longitudinal changes in Lean implementation. Future studies could adopt longitudinal or mixed method designs to assess how Lean practices evolve over time and how they influence institutional performance metrics.

Third, while descriptive statistics provided valuable insights, the absence of inferential analyses—such as t-tests or ANOVA restricted the exploration of subgroup differences. Future research should incorporate these methods to examine how gender, academic progression, and Lean knowledge levels influence student perceptions of Lean practices, as suggested by the diverse profiles presented in Table 2.

Finally, although the instrument was designed to be contextually relevant, its broader applicability across different cultural and institutional settings should be tested. Adapting the tool for use in other Latin American or global HEIs would provide valuable comparative perspectives and help establish universal benchmarks for Lean implementation in higher education.

6 Conclusion

This study provides empirical evidence supporting the applicability of the Lean Thinking model in Higher Education Institutions (HEIs). The findings demonstrate its potential to enhance academic management, administrative efficiency, and resource optimization. The validated instrument confirms that Lean can be effectively integrated into the Ecuadorian higher education context, addressing institutional challenges and strategic priorities.

A key insight is the critical role of leadership, long-term thinking, and institutional engagement in successful Lean implementation. The high composite reliability observed in these dimensions reinforces their importance and aligns with prior research that emphasizes leadership and strategic vision as drivers of organizational transformation. These findings suggest that HEIs must prioritize strong leadership and foster a culture of continuous improvement to ensure sustainable Lean adoption.

Waste elimination and continuous improvement also emerged as essential components of Lean effectiveness in HEIs. These findings align with global research highlighting their impact on educational quality, operational agility, and institutional efficiency. Nonetheless, challenges remain in applying Lean to research activities due to their inherently complex and dynamic nature. Future research should explore tailored Lean frameworks for research management that respect academic rigor while improving efficiency.

From a methodological perspective, the instrument exhibited strong internal consistency, with Cronbach's alpha values exceeding accepted thresholds. Convergent and discriminant validity were also confirmed, indicating that the constructs accurately represent Lean principles in higher education. The use of Average Variance Extracted (AVE) and Heterotrait-Monotrait (HTMT) ratios adds robustness to the model and contributes to ongoing academic discussions about Lean in educational settings.

Despite promising results, the long-term sustainability of Lean in higher education remains a concern. While Lean can produce immediate improvements, its enduring impact depends on developing institution-wide strategies that integrate Lean principles across teaching, administration, and outreach. Previous studies have warned that the absence of long-term planning may limit the transformative potential of Lean in HEIs.

Furthermore, Lean implementation should not be confined to administrative domains. A comprehensive approach is necessary one that incorporates pedagogical innovation, research, and community engagement. This study offers a foundation for future work exploring how Lean can improve learning outcomes, faculty involvement, and institutional performance.

In addition to strengthening leadership and administrative efficiency, future applications of Lean in HEIs must expand to pedagogical and community engagement dimensions. Pedagogical innovation, for example, can benefit from Lean tools that streamline curriculum design, enhance feedback loops between students and instructors, and foster reflective teaching practices. Similarly, Lean thinking can be applied to community outreach by improving coordination processes, resource allocation, and the measurement of social impact. Operationalizing these dimensions requires contextualizing Lean principles to the humanistic and participatory ethos of academic institutions, promoting collaboration, equity, and relevance in both classroom and community-based initiatives.

Finally, while the results validate Lean's feasibility in the Ecuadorian context, the study has limitations. The data were collected from a single institution, which may restrict generalizability. Future research should expand to include multiple HEIs, apply longitudinal designs, and examine causal relationships between Lean practices and academic performance. These steps will be essential for developing scalable, evidence-based Lean models to support educational innovation and excellence.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for this study, as it was conducted exclusively online through an anonymous survey platform. Participants were presented with a detailed description of the study's objectives and their rights on the introductory page of the survey. By choosing to complete the survey voluntarily, participants provided implicit consent to take part. Nonetheless, we, as researchers, are fully committed to maintaining the highest ethical standards throughout our work. All data collected is kept strictly confidential and is used solely for the purposes described in the study information provided to participants. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AA-N: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. FG-V: Methodology, Writing – review & editing, Writing – original draft. PF: Formal analysis, Writing – original draft, Writing – review & editing, Investigation. MJR-V: Supervision, Conceptualization, Writing – review & editing, Writing – original draft. JV: Investigation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1582771/full#supplementary-material

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