

Research article

SAGES: Analysis System for Gamification in Higher Education

SAGES: Sistema de Análisis para Gamificación en Educación Superior

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Abstract

Introduction: Bibliometric evidence indicates that educational gamification lacks validated instruments that evaluate meaningful learning perceptions in higher education contexts where Serious Games are applied. The objective of this research exercise is to develop a psychometric instrument to evaluate student perceptions about meaningful learning in gamified educational experiences. **Methodology:** SAGES is the result of a psychometric validation process with 214 university students in business sciences with experience in gamified activities. Exploratory and confirmatory factor analysis was applied following COSMIN standards. **Results:** The CFA demonstrated quality and purpose-appropriate fit: $\chi^2(44) = 87.225$; CFI = 0.974; TLI = 0.961; RMSEA = 0.068. The final 12-item instrument showed high reliability ($\omega = 0.944$). **Discussion:** SAGES constitutes a psychometrically validated tool to evaluate student perceptions about the effectiveness of Serious Games in generating meaningful learning experiences, providing a useful instrument for researchers and educators. **Conclusions:** The results confirm the stated hypothesis: meaningful learning in Serious Games contexts responds to a multifactorial

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structure composed of andragogical elements (Collaboration and Autonomy), technological design (Practicality), and diversity and inclusion.

Keywords: learning perceptions; educational gamification; *Serious Games*; psychometric validation; higher education; business sciences; meaningful learning; instrument development.

Resumen

Introducción: La evidencia bibliométrica indica que la gamificación educativa carece de instrumentos validados que evalúen las percepciones de aprendizaje significativo en contextos de educación superior donde se aplican *Serious Games*. El objetivo de este ejercicio de investigación es desarrollar un instrumento psicométrico para evaluar las percepciones estudiantiles sobre el aprendizaje significativo en experiencias educativas gamificadas.

Metodología: SAGES es el resultado de un proceso de validación psicométrica con 214 estudiantes universitarios de ciencias empresariales con experiencia en actividades gamificadas. Se aplicó análisis factorial exploratorio y confirmatorio siguiendo estándares COSMIN. **Resultados:** El AFC demostró un ajuste de calidad y apropiado para el propósito: $\chi^2(44) = 87.225$; CFI = 0.974; TLI = 0.961; RMSEA = 0.068. El instrumento final de 12 ítems mostró alta confiabilidad ($\omega = 0.944$). **Discusión:** SAGES constituye una herramienta psicométricamente validada para evaluar las percepciones estudiantiles sobre la efectividad de los *Serious Games* en generar experiencias de aprendizaje significativo, proporcionando un instrumento útil para investigadores y educadores. **Conclusiones:** Los resultados confirman la hipótesis planteada: el aprendizaje significativo en contextos de *Serious Games* responde a una estructura multifactorial compuesta por elementos andragógicos (Colaboración y Autonomía), diseño tecnológico (Practicidad), y diversidad e inclusión.

Palabras clave: percepciones del aprendizaje; gamificación educativa; juegos serios; validación psicométrica; educación superior; ciencias empresariales; aprendizaje significativo; desarrollo de instrumentos.

1. Introduction

Gamification in higher education shows academically reported growth, with the phenomenon being observed as consolidating as a pedagogical strategy that combines ludic elements with well-defined learning objectives (Pelizzari, 2023). Recent studies support its impact; according to a meta-analysis by Huang et al. (2019), learning through digital games shows moderate to large effects compared to traditional methods in STEM areas.

Meanwhile, Zhonggen (2019) also concluded that serious games are considerably more effective than conventional forms of teaching. As observed in Table 1, none of the existing instruments directly evaluates meaningful learning according to Ausubel in *Serious Games* contexts in business sciences. This methodological gap justifies the development of the SAGES instrument. See table 1.

Table 1.

Previous instruments on learning and gamification in higher education

Instrument	Main Objective	Evaluated Dimensions	Limitations in Relation to Meaningful Learning (Ausubel)	Reference
CAP Perceived Learning Scale	Measure perceived learning in cognitive, affective, and psychomotor domains	Cognitive, affective, psychomotor	Does not evaluate substantive integration between prior and new knowledge	(Rovai et al., 2009)
R-SPQ-2F	Identify deep vs. surface study approaches	Deep, surface	Evaluates study strategies, but not meaningful learning outcomes	(Biggs et al., 2001)
MSLQ	Measure motivation and learning strategies	Learning strategies, motivation	Does not determine if cognitive integration occurs	(Pintrich et al., 1991)
GAMEX	Evaluate gamified experience	Fun, absorption, creativity	Focused on experience, not meaningful learning outcomes	(Eppmann et al., 2018)
UGES	Measure general engagement	Vigor, dedication, absorption	Generic engagement, without educational specificity	(Schaufeli, 2017)
GAQ	Measure andragogical principles in gamification	Autonomy, relevance, applicability	Measures design principles, but not Ausubel's cognitive outcomes	(Zainuddin et al., 2023)
GAMEFULQUEST	Evaluate perception of "gamefulness"	Fun, ludic motivation	Does not evaluate educational effectiveness nor deep learning	(Högberg et al., 2019)

Source: Own elaboration (2025).

This allows for generating the central research question: How to operationalize and empirically measure meaningful learning according to Ausubel in *Serious Games* contexts in higher education business sciences?

1.1. Integrated Theoretical Framework

The development of the instrument that serves as an Analysis System for Gamification in Higher Education (SAGES) is based on the integration of various theoretical frameworks that converge on meaningful learning. Table 2 synthesizes the main theories considered and their relationship with the proposed model.

Table 2.

Integrated theoretical framework for SAGES development

Theory/Approach	Central Concepts	Application in Serious Games	Relationship with Meaningful Learning (Ausubel)
Meaningful Learning Theory (Ausubel, 2002)	Connection between prior and new knowledge; substantive integration; cognitive structure expansion	Games that allow applying theoretical frameworks to students' prior experiences	Core of the model: evaluates comprehension, relevance, applicability and skill development
Self-Determination Theory (Ryan & Deci, 2017)	Autonomy, competence and relatedness as basis of intrinsic motivation	Role choice, appropriate challenges, virtual team collaboration	Facilitates motivation and involvement that enhance cognitive integration
Technology Acceptance Model (TAM), Davis (1989)	Perceived utility and ease of use determine technology adoption	Intuitive interface, clarity of mechanics, accessible navigation	Ensures technology is adopted and used as a means to achieve meaningful learning
Andragogical Principles Knowles et al. (1980) Clair (2024) Knapke et al (2024) Grasse et al (2022)	Practical relevance, immediate applicability, connection with prior experiences, learning autonomy	Real business simulations, professional cases, strategic decision-making	Guide the design of gamified activities with relevance for adults in higher education
Diversity and Inclusion (Chang et al., 2024)	Cultural representation, sense of belonging, accessibility	Diverse avatars, multicultural scenarios, accessibility for students with disabilities	Favors equity and multiple cognitive anchoring points that enrich meaningful integration

Source: Own elaboration (2025)

Ausubel's theory (2002) constitutes the core of the model, emphasizing substantive integration of knowledge. Recent research supports its validity in digital contexts: Agra et al. (2019) operationalized its fundamental attributes, while Craig et al. (2020) and Checa-Romero & Giménez-Lozano (2025) demonstrated that *Serious Games* favor metacognitive processes that allow students to consciously identify moments of cognitive integration.

Regarding andragogical principles, it is important to note that while Knowles et al. (1980) propose that adult learning requires practical relevance, immediate applicability, connection with prior experiences and autonomy. In the context of **Serious Games**, these principles are decisive, as their absence can lead to activities being perceived as childish or irrelevant (Grasse et al., 2022). Recent studies highlight that to be effective in higher education, games must explicitly integrate andragogical approaches andragógicos (Clair, 2024; Knapke et al., 2024), which is operationalized through real business situation simulations, tools applicable in professional practice and scenarios that reflect the diversity of students' experiences.

The representation of diversity in gamified environments favors engagement and learning by offering culturally relevant cognitive anchors (Chang et al., 2024). In *Serious Games*, diversity not only increases motivation, but also facilitates meaningful connections with content (Checa-Romero & Gimenez-Lozano, 2025). Bowman et al (2023) show that minority representation reinforces sense of belonging and motivation, while its absence can generate disconnection and higher dropout rates in vulnerable (Janke et al., 2024; Rittle-Johnson et al., 2024).

Inclusion, therefore, must go beyond visual representation, actively integrating multiple forms of learning, diverse capabilities and cultural perspectives. In business sciences, this is operationalized through inclusive avatars, multicultural scenarios, varied case studies and accessibility options that reflect the global and multicultural reality of professional teams.

1.2. Study Justification

This methodological gap is especially critical in business sciences, where practical applicability constitutes a central element of the formative process. In this formative scenario, knowledge transfer is fundamental for professional development. This is a population where andragogical principles require immediate relevance and experiential connection due to the formative level, which develops in student diversity that demands inclusive approaches. Recent meta-analyses show variable effects of gamification according to the application domain (Ledesma, 2024; Universidad Cooperativa de Colombia et al., 2017) which suggests the need for specific instruments to optimize effectiveness in specific contexts.

1.3. Study Objective

The present study has as its general objective to develop and validate a psychometric instrument to identify the determining factors of meaningful learning according to Ausubel in gamified experiences with *Serious Games* in higher education business sciences.

Specific objectives:

- Identify the determining factors of meaningful learning according to Ausubel in *Serious Games* contexts.
- Validate the identified factorial structure establishing evidence of construct validity.
- Establish the psychometric properties of the instrument

1.4. Hypothesis

H1: Meaningful learning observed according to Ausubel's proposal in *Serious Games* contexts within educational gamification in higher education, responds to a multifactorial structure composed of andragogical elements, technological design, and diversity and inclusion.

2. Methodology

2.1. Study Design

This is a non-experimental research with cross-sectional temporal cut, with quantitative approach and relational scope whose purpose is to establish the factors related to the meaningful learning process of people who participate in formative processes with gamified activities.

In this research, a methodological design for development and validation of psychometric instruments is implemented following the recommendations of Kline (2016) and COSMIN standards for measurement instruments (Prinsen et al., 2018). The process included four sequential phases:

Phase 1: development and content validation. A diagnostic survey of 30 items was developed based on systematic literature review, to which content validation and objectivity is performed through a panel of 4 expert doctors in two rounds (4 and 2) obtaining a Fleiss Kappa = 0.81 for substantial agreement, and Cohen's Kappa = 0.96 (almost perfect agreement) respectively for application relevance. This is complemented with a test-retest temporal stability verification ($\rho = 0.972$) in a pilot sample of 25 subjects with a 15-minute interval, indicating strong instrument stability.

Phase 2: Correlation Analysis and Item Pre-selection. The complete survey was applied to 250 university students in business science programs, including undergraduate and graduate levels. An inclusion criterion based on verifiable prior experience with gamified activities was implemented (item 5 as exclusion filter), resulting in 214 valid cases (retention rate = 85.6%). The AS variable was calculated as the average of items 27-30, corresponding to Ausubel's theoretical dimensions. The Shapiro-Wilk test was used to confirm the non-normal distribution of variables ($p < 0.05$), thus justifying the use of non-parametric correlation tests. Sample adequacy was verified through KMO = 0.832 (very good). Spearman correlation analysis was performed between all items and the AS variable, selecting only items with statistically significant associations ($p < 0.05$) for subsequent factor analysis, ensuring theoretical relevance and reducing statistical noise from spurious associations.

It should be noted that items 27-30 were established a priori as theoretical anchor items based on Ausubel's assimilation theory and validated by expert judgment in Phase 1, prior to and independent of the screening process. This approach corresponds to predictive item screening (DeVellis & Thorpe, 2022; Nunnally & Bernstein, 1994), in which items are retained based on their association with a theoretically grounded criterion, avoiding circular selection. Theoretical coherence was further preserved by confirming that each retained item represented one of the pre-defined dimensions of meaningful learning (Collaboration, Autonomy, Practicality, and Diversity & Inclusion) established in the conceptual framework before data collection.

Phase 3: Exploratory Factor Analysis (EFA). EFA was implemented with pre-selected items using principal axis factorization with promax rotation, given that correlations between factors were expected according to the integrated theoretical framework. The AS variable (calculated as the average of items 27-30) was treated as a grouping factor during this exploratory phase to identify the underlying factorial structure of design-related predictors. The defined retention criteria were: KMO > 0.70 with significant Bartlett's test ($p < 0.05$), eigenvalues greater than 1.0 and factor loadings superior to 0.40. The selected item must present theoretical coherence of emerging factors.

Phase 4: Confirmatory Factor Analysis (CFA). Contemporary practices for psychometric instrument development proposed by Carpenter (2018) and Hair et al (2019) are assumed, adopting the criteria of sequential EFA-CFA approach with a single sample (N=214). This approach is methodologically sound when sample size exceeds 200 participants (Kyriazos, 2018) and is justified by three reasons:

- (1) exploratory nature of the domain - SAGES constitutes the first specific instrument to evaluate meaningful learning perceptions in gamification, requiring initial identification of factorial structure;
- (2) multiple convergent validation - complemented with reliability analysis, convergent/discriminant validity and theoretically expected correlations;

(3) practical resource limitations - given restricted access to specific population, sample division would reduce statistical power below recommended thresholds (Kyriazos, 2018). The emergent structure from EFA is validated through CFA with maximum likelihood estimation, evaluating fit through standard indices (CFI, TLI, RMSEA, SRMR).

2.2. Population and Sample

The target population were university students in business science programs, over 18 years old, with verifiable prior experience in *Serious Games* or gamified activities. The sampling frame included students from the Faculty of Business Sciences of Corporación Universitaria Minuto de Dios (UNIMINUTO) in Colombia, at technological, professional, specialization and postgraduate levels, within face-to-face, distance and virtual modalities.

UNIMINUTO constitutes a mega-institution with 93,195 students (2023) distributed nationally in multiple educational modalities (Corporación Universitaria Minuto de Dios, 2023). This institutional diversity in modalities, geographic coverage and socioeconomic strata provides relevant sample heterogeneity for instrument validation in massified higher education contexts. Non-probabilistic convenience sampling was used, establishing a minimum size of 200 participants, considered sufficient for factor analysis factorial (Carpenter, 2018; Hair et al., 2019; Kyriazos, 2018).

2.2.1 Inclusion Criteria

- Main criterion: Prior experience with immediate recall of activity details performed with *Serious Games* or gamified activities in higher education business sciences. For this, an exclusion item was applied (question 5 of the diagnostic questionnaire) to verify prior participation in gamification.
- Being an active student in a program affiliated with the business sciences faculty.

2.3. Procedures

Data collection is done through digital self-report modality with internet form. For this, support is received from teachers of different subjects in formative programs that had conducted gamified activities with *Serious Games* in their classrooms, who requested voluntary participation from their students.

2.4. Instrument

From the referent theoretical construct, an initial ad hoc questionnaire is derived, which once validated with experts, becomes the analysis point to derive the final calibrated tool that allows observing the phenomenon in contexts similar to its origin. The instrument is elaborated from three variables, observed by dimensions and for which corresponds an inquiry item, thus reaching a total of 30 questions. See table 3.

Table 3.

Questionnaire Basic

Variable	Observation Dimensions	Item Number
Sociodemographic Factors (Intervening variable)	Gender	1
	Age	2
	Study Program	3
	Knowledge Area	4
	Gamification Participation	5 (exclusion item)
Design Factors (Independent variable) Based on contributions from various authors	Basic design elements	6
	TAM	7, 16, 20, 21
	SDT (Motivational elements)	8, 18, 22
	GPA (Progressive challenges)	19, 23
	Andragogical factors	9, 10, 11, 12, 15, 17
	Inclusion and Diversity factors	13, 14, 24, 25, 26
	Meaningful Learning (Dependent variable) (Ausubel, 2002)	Comprehension
	Relevance	28
	Applicability	29
	Skill Development	30

Source: Own elaboration (2025).

Prior to the Likert-scale items, two screening questions verified participant eligibility: item 4 (currently enrolled in higher education) and item 5 (recall of gamified activities in class). Respondents who did not meet both criteria were excluded and did not proceed to the instrument items. The remaining items (6–30) were rated on a four-point Likert-type scale (1 = Strongly disagree, 2 = Disagree, 3 = Agree, 4 = Strongly agree), with no “Not applicable” option.

2.5. Generalization Limitations

- Validation is limited exclusively to business science students in Colombian higher education institutions. Generalization of results to other academic disciplines (exact sciences, humanities, engineering) or different cultural contexts will require additional validation processes that confirm the factorial invariance of the instrument.
- Evaluation is based on student retrospective perceptions about prior gamified experiences, especially with Serious Games, without longitudinal follow-up that allows evaluating temporal stability of measurements or predictive validity of the instrument on future academic results.
- This research measures meaningful learning perceptions rather than direct objective evidence of cognitive integration, requiring convergent validation with objective learning measures in future studies. However, this approach is coherent with established and contemporary instruments in the educational field such as Ratmono et al. (2024) in accounting education with VR and Ji et al. (2024) in educational AI systems, where “perceived learning effectiveness” measures are successfully used as valid indicators of formative results.

- This study constitutes the initial phase of SAGES instrumental validation, establishing robust preliminary psychometric evidence. The research is part of a doctoral exercise, which in a subsequent phase will allow strengthening validity evidence through replication in independent samples, confirming temporal stability and factorial invariance of the instrument in a specific regional context.

2.6. Ethical and Quality Considerations

This is research whose data are obtained with written informed consent from participants, who are detailed objectives, procedures, data use, confidentiality, right of voluntary withdrawal and researcher contacts. It is governed under data protection following Colombia's Law 1581 of 2012 and GDPR principles: anonymization through alphanumeric codes, secure storage with restricted access, and processing exclusively for academic purposes. Participation was completely voluntary without incentives to students, nor coercive actions, with effects of academic consequences.

3. Results

3.1. Item Pre-selection

As established in the methodology, items 27–30 were designated a priori as theoretical anchors grounded in Ausubel's assimilation theory and validated by expert judgment, ensuring that the criterion variable (AS) was defined independently of the screening process, constituting a predictive item screening approach that precludes circular selection. The initial correlation of the dependent variable AS with all 30 elements of the preliminary diagnostic instrument allows identifying that 14 of them evidence a statistically significant association, as detailed in Table 4.

Table 4.

Initial associations with Spearman's Rho

Variable	Meaningful_learning	P Value
1. Meaningful_learning	---	---
2. p9_and_Applicability	0.274***	< .001
3. p10_and_relev	0.314***	< .001
4. p11_and_autonomy	0.243***	< .001
5. P12_and_effect	0.328***	< .001
6. p13_ID_incl	0.402***	< .001
7. P14_ID_div	0.261***	< .001
8. p15_and_clarity_obj	0.271***	< .001
10. p17_and_collabor	0.361***	< .001
11. p18_sdt_feedback	0.221**	< .001
12. p19_GPA_challenges	0.243***	< .001
14. p21_utility	0.342***	< .001
15. p22_sdt_Motiv	-0.139*	0.043
16. p23_GPA_divers	0.518***	< .001
17. p24_ID_Igender	0.227***	< .001
18. p25_ID_divcult	0.278***	< .001
19. p26ID_disability	0.265***	< .001

*p < .05, **p < .01, ***p < .001

Source: Own elaboration (2025).

Having a relational construct of items related to the level of perceived learning, we proceed to establish the construct reliability with McDonald's ω , which initially reaches a value of 0.869. However, it was decided to eliminate items 22 and 24 from the preliminary construct, as these variables evidenced being poorly reactive within the set of items. This reliability optimization procedure reduces the construct to 12 elements and improves McDonald's ω to 0.894. Individual item reliability reflects that if any additional element were eliminated, reliability would not improve. See table 5.

Table 5.

McDonald's ω if items are eliminated

Individual Item Reliability Statistics	if item is eliminated
Item	McDonald's ω
p9_and_Applicability	0.867
p10_and_relev	0.856
p11_and_autonomy	0.853
P12_and_effect	0.845
p13_ID_incl	0.827
P14_ID_div	0.860
p17_and_collabor	0.859
p19_GPA_challenges	0.860
p21_utility	0.864
p23_GPA_divers	0.860
p25_ID_divcult	0.856
p26ID_disability	0.858

Source: Own elaboration (2025).

With the items that integrate the set of predictive factors, KMO test is performed again to verify their relevance, obtaining $KMO = 0.827$ which enables factorial procedures (higher than initial), ratified by Bartlett's test of $\chi^2(78) = 1299.978$, $p < .001$. The factor loading reveals that the instrument is calibrated with 12 predictor items initially grouped into three factors. Likewise, it is identified that initial items p21, p25 and p26 have the lowest factorial weight, but exceed the acceptable minimum. See table 6.

Table 6.

Kaiser-Meyer-Olkin Test

	MSA
General MSA	0.827
p9_and_Applicability	0.842
p10_and_relev	0.857
p11_and_autonomy	0.846
P12_and_effect	0.854
p13_ID_incl	0.831
P14_ID_div	0.844
p17_and_collabor	0.863
p19_GPA_challenges	0.879
p21_utility	0.795
p23_GPA_divers	0.816
p25_ID_divcult	0.767
p26ID_disability	0.762
Meaningful_learning	0.868

Source: Own elaboration (2025)

The factor loading of the exploratory analysis reveals that the elements have an explained variance of 62.8% which is acceptable in social sciences, with equitable variance proportions between the three components (21.8%, 21.1%, and 19.9%) respectively. See table 7.

Table 7.

Component Loading

	RC1	RC2	RC3	Uniqueness
p21_utility	0.836			0.312
p23_GPA_divers	0.772			0.340
p10_and_relev	0.703			0.342
p9_and_Applicability	0.613			0.360
Meaningful_learning	0.516			0.654
p13_ID_incl	0.507			0.404
P12_and_effect		0.870		0.256
p11_and_autonomy		0.861		0.310
p19_GPA_challenges		0.598		0.418
p17_and_collabor		0.588		0.505
p25_ID_divcult			0.877	0.158
p26ID_disability			0.867	0.203
P14_ID_div			0.460	0.569

Note. The applied rotation method is promax.

Source: Own elaboration (2025).

3.2. Confirmatory Factor Analysis (CFA)

To confirm the factorial structure identified in the EFA, we proceeded with the CFA. For this confirmatory analysis, the AS variable (calculated as the average of items 27-30) was disaggregated into its primary theoretical components corresponding to Ausubel's dimensions: comprehension (item 27), relevance (item 28), applicability (item 29), and skill development (item 30). This disaggregation allows independent evaluation of each meaningful learning component within the structural model, providing a more precise assessment of the theoretical construct.

This methodological process followed the recommendations of Kline (2016) for the development and validation of psychometric instruments in social sciences, the calculated variable is disaggregated into its primary components. The results for N=214, demonstrated a fit of: $\chi^2(44) = 87.225$, $p < 0.001$; CFI = 0.974; TLI = 0.961; RMSEA = 0.068 [90% CI: 0.047-0.089]; SRMR = 0.049. All factors showed adequate reliability ($\omega = 0.793-0.944$) and convergent validity (AVE = 0.574-0.853).

The factorial model proved to be 19.7 times superior to the base model (1719.797/87.225). The significance of chi-square ($p < 0.001$) indicates discrepancy between the proposed model and observed data, which is common in samples superior to 200 cases where chi-square becomes highly sensitive to minor deviations (Kline, 2016). Therefore, fit evaluation is based primarily on practical fit indices (CFI, TLI, RMSEA, SRMR). See table 8.

Table 8.*Additional fit measures*

Index	Value
Comparative Fit Index (CFI)	0.974
Tucker-Lewis Index (TLI)	0.961
Bentler-Bonett Non-normed Fit Index (NNFI)	0.961
Bentler-Bonett Normed Fit Index (NFI)	0.949
Parsimony Normed Fit Index (PNFI)	0.633
Bollen's Relative Fit Index (RFI)	0.924
Bollen's Incremental Fit Index (IFI)	0.974
Relative Noncentrality Index (RNI)	0.974

Source: Own elaboration (2025).

On the other hand, absolute fit indicators confirm model precision. RMSEA = 0.068 represents a very good average error per degree of freedom, situated within the acceptable range (<0.08) and approaching the excellence threshold (<0.06). SRMR = 0.049 indicates minimal standardized residuals, demonstrating excellent fit by being below the strict criterion of 0.05. Meanwhile, GFI = 0.991 reflects practically perfect goodness of fit, without being saturated and approaching the theoretical maximum value of 1.00. See table.

Table 9.*Other fit measures*

Metric	Value
Root Mean Square Error of Approximation (RMSEA)	0.068
RMSEA 90% CI lower limit	0.047
RMSEA 90% CI upper limit	0.089
RMSEA p-value	0.080
Standardized Root Mean Square Residual (SRMR)	0.049
Hoelter's Critical N ($\alpha = .05$)	149.39
Hoelter's Critical N ($\alpha = .01$)	169.57
Goodness of Fit Index (GFI)	0.991
McDonald's Fit Index (MFI)	0.904
Expected Cross-Validation Index (ECVI)	0.838

Source: Own elaboration (2025).

The Kaiser-Meyer-Olkin measure of sampling adequacy demonstrates data suitability for confirmatory factor analysis, with general KMO = 0.823. At individual level, all items present MSA values superior to 0.70 (range: 0.709-0.886), indicating that each variable contributes adequately to the factorial structure without generating multicollinearity or inadequacy problems. This a posteriori validation confirms that methodological decisions adopted during instrument development were correct.

R² values allow observing two extreme elements, on one side p19 relative to challenges contributes 30% to factor 2, while p25 does so exceeding 98% in factor 3. However, explained variance confirms that each factor effectively captures the corresponding theoretical construct. Factors 1 and 3 show particular robustness while 2 and 4 generate the observational complementarity of the phenomenon. Items with extreme loadings are of particular observation in contexts requiring careful review to ensure validity of the final model, see table 10.

Table 10.*R² Behavior*

Factor	Item	R ²	% Explained	Evaluation	Denomination
1 Meaningful Learning	p29_applicability	0.852	85.2%	Very high	Exceptional
	p28_relevance	0.809	80.9%	Very high	
	p27_comprehension	0.786	78.6%	High	
2 Collaboration and Autonomy	p30_skill_development	0.780	78.0%	High	Good
	p17_and_collabor	0.705	70.5%	High	
	p12_and_effect	0.687	68.7%	Good	
	p11_and_autonomy	0.593	59.3%	Moderate	
3 Diversity and Inclusion	p19_GPA_challenges	0.329	32.9%	Low	Exceptional
	p25_ID_divcult	0.981	98.1%	Excellent	
	p26ID_disability	0.739	73.9%	High	
4 Practicality	p23_GPA_divers	0.870	87.0%	Very high	Acceptable
	p21_utility	0.446	44.6%	Moderate	

Source: Own elaboration (2025)

Simultaneously, factor loadings demonstrate statistically robust relationships between items and their corresponding factors. All loadings reached statistical significance at $p < 0.001$ level, with a range of 0.447 to 0.920 spanning from acceptable to exceptional. The Meaningful Learning Factor exhibits the highest loadings (0.791-0.920), evidencing its particular strength in the model structure. 95% confidence intervals for all estimations exclude zero, confirming stability and precision of identified item-factor relationships.

When analyzing factor covariance, correlations between factors reveal a theoretically coherent and methodologically appropriate association pattern. The correlation range (0.288-0.503) is situated at moderate level, preserving discriminant validity by maintaining all below the critical threshold of 0.70. A theoretically linked pattern is observed where AS shows greater association with Practicality ($r = 0.503$), suggesting that perceived utility and fun of the *Serious Game* are closely linked with learning outcomes. Other correlations evidence that factors are conceptually related, but maintain distinctive identities, confirming the multidimensional structure of the construct.

Factor 3 'Diversity and Inclusion' presents methodological characteristics requiring careful interpretation. With only two items and extremely high explained variance in p25_ID_divcult ($R^2 = 0.981$), this factor shows signs of over-identification. Although it meets minimum criteria for factorial identification, future studies should include additional items to strengthen the conceptual robustness of this dimension. See table 11.

Table 11.

Factor Covariances

Factors			Estimate	Standard Error	z Value	P	95% Confidence Lower
Meaningful Learning	↔	Collaboration and Autonomy	0.334	0.065	5.149	< .001	0.207
Meaningful Learning	↔	Diversity and Inclusion	0.288	0.066	4.342	< .001	0.158
Meaningful Learning	↔	Practicality	0.503	0.060	8.377	< .001	0.386
Collaboration and Autonomy	↔	Diversity and Inclusion	0.466	0.063	7.429	< .001	0.343
Collaboration and Autonomy	↔	Practicality	0.387	0.066	5.903	< .001	0.258
Diversity and Inclusion	↔	Practicality	0.475	0.069	6.906	< .001	0.340

Source: Own elaboration (2025).

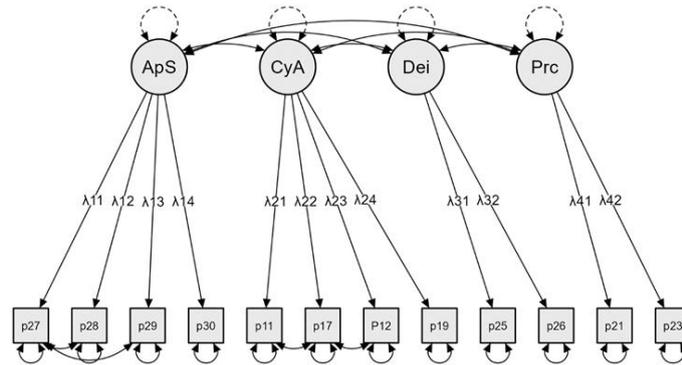
Convergent Validity (AVE) confirms that each factor coherently captures its theoretical construct. Average Variance Extracted values exceed the critical threshold of 0.50 in all factors, meeting international standards: Meaningful Learning (AVE = 0.808), Diversity and Inclusion (AVE = 0.853), Practicality (AVE = 0.665), and Collaboration and Autonomy (AVE = 0.574). Values superior to 0.80 in the first and third factors indicate exceptional convergent validity, while the second and fourth factors demonstrate acceptable levels that confirm internal coherence of each dimension.

The final instrument, which we will call the Analysis System for Gamification in Higher Education (SAGES for its acronym in Spanish) demonstrated exceptional reliability with a total omega of 0.944, amply meeting international standards.

Individual factors maintain robust internal consistency: Meaningful Learning ($\omega = 0.944$, exceptional), Diversity and Inclusion ($\omega = 0.921$, excellent), Collaboration and Autonomy ($\omega = 0.902$, excellent), and Practicality ($\omega = 0.793$, acceptable). Three of the four factors reach levels superior to 0.90, confirming exceptional stability of measurements, while the Practicality factor, although with the lowest value, meets acceptability criteria (>0.70) established in psychometric literature. The graphic interpretation of factor behavior is presented in the figure 1.

Figure 1.

Model Diagram



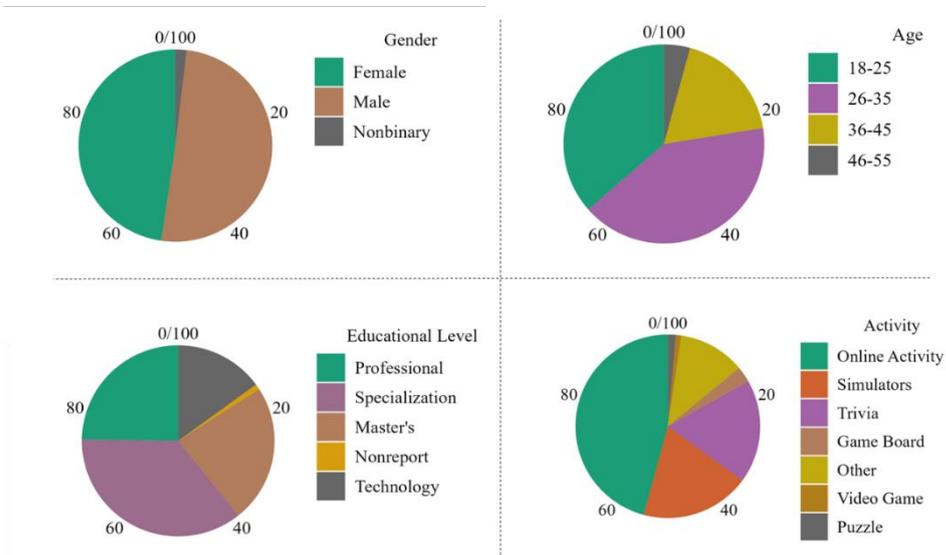
Source: Own elaboration (2025).

3.3. Behavior of Characterization Items

The sample of 214 data obtained presents non-normalized distributive behaviors (Shapiro-Wilk test with p-value < 0.05) for the intervening variables Gender, Age, Education Level and Gamification Activity. At the same time, it can be observed that the instrument captures the heterogeneity of sample composition, see figure 2.

Figure 2.

Behavior of intervening variables



Source: Own elaboration (2025).

Simultaneously, when contrasting characterization variables with respect to the calculated dependent variable Meaningful Learning, in a cross-correlation exercise, it is obtained that meaningful learning presents specific low associations with age and education level and gamification activity. The area of studies and gender of people do not present statistically significant association with reported learning. See table.

Table 12.

Correlations of intervening variables

Variable	Meaningful_learning	Age	Activity	Gender	Education Level	Area
1. Meaningful_learning	Spearman's Rho: --- p-value: ---					
2. Age	Spearman's Rho: 0.180** p-value: 0.008	---				
3. Activity	Spearman's Rho: 0.001 p-value: 0.988	-0.185**	---			
4. Gender	Spearman's Rho: -0.065 p-value: 0.344	-0.001	-0.063	---		
5. Education Level	Spearman's Rho: 0.179** p-value: 0.009	0.670***	-0.119	0.035	---	
6. Area	Spearman's Rho: 0.027 p-value: 0.690	0.254***	0.123	0.029	0.165*	---

*p < .05, **p < .01, ***p < .001

Source: Own elaboration (2025).

Simultaneously, it is observed how age is clearly associated with the distribution of the sample within other observed variables, while gender poses relational independence in the phenomenon that initially reaffirms the equality of people's capacity to develop meaningful learning regardless of their gender. This factor is important to observe permanently since from the design of *Serious Games* this pattern should not be altered.

Variables such as activity type and application area provide important information to *Serious Games* designers to observe application and acceptance trends.

Therefore, in this calibration process it is concluded that population characterization items are adequate within the instrument since they provide useful information for its purpose.

3.4. Behavior of Design Elements

Original questions 6 and 8 were part of the SDT construct, however, the multiple selection scale allowed observing design elements connected to motivation to participate in the activity. And although their presence in games did not present association with learning, it does signal a clear association with types of gamification applied; therefore, item 6 is adjusted to serve to capture specific gamification mechanics identified as relevant by participants, providing a complementary perspective to the four main factors of the SAGES model.

Although these design elements do not directly predict meaningful learning, they are linked to aspects of technological acceptance and initial motivation that can facilitate engagement with the gamified experience, which will be useful for adjustment and calibration processes of pedagogical tools see appendix 1.

4. Discussion

Results confirm the stated hypothesis: meaningful learning in *Serious Games* contexts responds to a multifactorial structure. The SAGES model identified four dimensions that explain 62.8% of total variance, evidencing that educational effectiveness in gamification transcends simple fun or technological engagement, coherent with previous findings by Huang et al. (2019) about the complexity of factors in effective digital learning.

The factorial structure shows coherent patterns.

Factor 1 - Perceived Meaningful Learning ($\omega = 0.944$) captures the Ausubelian components of comprehension, relevance, applicability and skill development, empirically validating Agra et al.'s (2019) proposal on operationalizing Ausubel's three attributes. The elevated factor loadings (0.791-0.920) confirm that students can discriminate between experiences that generate genuine cognitive integration versus superficial entertainment, supporting Craig et al.'s (2020) findings on the validity of metacognitive self-reports.

Factor 2 - Collaboration and Autonomy integrates elements from Self-Determination Theory (Ryan & Deci, 2017) and andragogical principles (Knowles, 1980). The moderate correlation with Factor 1 ($r = 0.334$) indicates that these elements facilitate but do not guarantee Ausubelian cognitive integration, contrary to previous assumptions that autonomy automatically produces deep learning. This aligns with Grasse et al. (2022), who found that satisfaction of basic psychological needs in games does not always translate to superior educational outcomes.

The significant correlation between Factor 2 (Collaboration and Autonomy) and Factor 1 ($r=0.334$) empirically validates the importance of autonomy proposed in the RAMP model (García-López, 2024). Additionally, the effectiveness demonstrated by Alarcón Martínez and Tejero Claver (2025) in formal sciences finds theoretical support in our results on meaningful learning. Finally, SAGES complements CAP-GD by demonstrating that the teaching competencies identified by Pinzón-Salazar et al. (2024) can be measured in terms of their actual educational results.

Factor 3 - Diversity and Inclusion presents only two items, but demonstrates conceptual relevance coherent with Bowman et al. (2023) on “belonging cues”. The extremely high explained variance ($R^2 = 0.981$) suggests that inclusive representation constitutes a critical differentiator in diversified higher education contexts, especially relevant considering Janke et al.'s (2024) findings on lower sense of belonging in ethnic minority students.

Factor 4 - Practicality ($\omega = 0.793$) combines elements from the Technology Acceptance Model (Davis, 1989) with ludic aspects. Its highest correlation with Factor 1 ($r = 0.503$) validates Liu et al (2023) findings on the importance of perceived utility in educational contexts, but extends this relationship to the specific domain of business gamification where practical relevance is fundamental (Clair, 2024; Knapke et al., 2024).

SAGES fills a specific methodological gap that previous instruments do not address. While **GAMEX** (Eppmann et al., 2018) measures general gamified experience centered on fun and absorption, SAGES specifically evaluates whether that experience results in Ausubelian cognitive integration. This differentiation is crucial considering that fun and meaningful learning can be independent or even contradictory processes in certain contexts.

Compared with **GAQ** (Zainuddin et al., 2023) that evaluates andragogical principles in gamification, SAGES measures the *results* of those principles in terms of perceived meaningful learning. Findings on metacognition in educational video games (Checa-Romero & Gimenez-Lozano, 2025) support the conceptual validity of measuring meaningful learning through self-report, since *Serious Games* effectively improve metacognitive awareness, allowing students to identify when they experience genuine cognitive integration.

The CAP Perceived Learning Scale (Rovai et al., 2009) measures perceived learning in cognitive, affective and psychomotor domains, but does not verify the substantive integration characteristic of Ausubelian meaningful learning. SAGES complements CAP by specifically evaluating whether perceived learning involves connection with prior knowledge, cognitive integration and structural expansion, the three distinctive attributes of Ausubel. While a student might report high cognitive learning in CAP, SAGES would determine whether that learning was meaningful or merely memoristic.

4.1. Study Limitations

This research presents limitations that we explicitly recognize as part of the doctoral design by phases. Validation was performed in one institution, although of large scale and modal diversity, which constitutes an appropriate first methodological approximation for initial instrumental development.

The use of the same sample for EFA and CFA constitutes an acknowledged limitation of this initial validation study. Although this sequential approach is defensible given the sample size and the exploratory-confirmatory nature of the first phase, replication in an independent sample with cross-validation and factorial invariance analysis is required to consolidate the structural evidence.

Factor 3 presents a two-item complementary structure that captures specific dimensions of cultural diversity and accessibility, reflecting the reality that inclusion in *Serious Games* can be operationalized concisely but effectively. Measurement based on retrospective perceptions is coherent with established instruments in the educational field (Ji et al., 2024; Ratmono et al., 2024) and will be complemented in subsequent phases through longitudinal predictive validation.

4.2 Implications for Future Instrumental Development

SAGES establishes a solid psychometric base for instrumental expansion and refinement. Initial results confirm the conceptual and operational viability of the construct, providing foundations for broader applications of the instrument in diverse institutional contexts.

The identified factorial structure offers a stable reference framework for future studies, which should include replication in independent samples, cross-validation procedures, and factorial invariance analysis across institutional contexts and student profiles. The demonstrated psychometric properties ($\omega = 0.944$) establish a quality standard that must be maintained in subsequent instrument applications.

For researchers seeking to use SAGES, we recommend considering current limitations as refinement opportunities rather than definitive restrictions. The instrument is designed for progressive methodological evolution.

5. Conclusions

SAGES was successfully developed as the first psychometric instrument specifically designed to evaluate meaningful learning perceptions according to Ausubel in *Serious Games* contexts applied to higher education business sciences.

The four-dimension factorial structure establishes a solid conceptual model for future applications. The instrument's psychometric properties ($\omega = 0.944$) confirm its technical viability as a reliable measurement tool in educational research contexts.

SAGES provides a methodological base for empirical evaluation of effectiveness in educational gamification, filling a specific instrumental gap in the field. Its development constitutes the first step toward a more comprehensive evaluation system of game-based pedagogical innovations.

As an initial result of doctoral research, SAGES establishes conceptual and methodological foundations for future instrumental expansion. Identified limitations represent clear directions for subsequent phases of validation and refinement.

The instrument remains available for application in similar contexts of higher education business sciences, with the recommendation to consider current methodological limitations in result interpretation until completing additional validations in subsequent research phases.

SAGES offers universities a tool to evaluate the impact of their gamified strategies on meaningful learning, motivation and equity, which guides curricular and instructional design improvements. The complete instrument is included in **Appendix A**.

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