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Diseño y Estandarización Estadística de un Instrumento para la Evaluación de Competencias Profesionales en Educación Superior

Design and Standardization of an Instrument for the Educational Assessment of Professional Competencies in Higher Education

Desenho e Padronização Estatística de um Instrumento para Avaliação de Competências Profissionais no Ensino Superior

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Resumen

La investigación de este trabajo aborda la actualización y estandarización estadística de indicadores de alcance de un instrumento de evaluación del aprendizaje, según los atributos de egreso establecidos en el Acuerdo de Washington para la formación de ingenieros en el Tecnológico Nacional de México, TecNM. Mediante la aplicación de la técnica Delphi se obtuvieron once indicadores como variables latentes, con seis ítems a los que se le determinó su validez de contenido con un panel de 25 expertos. La validez de constructo se realizó con 337 estudiantes de asignaturas de ciencias básicas mediante el análisis de ecuaciones estructurales (SEM). Se utilizaron las variables latentes obtenidas como indicadores del logro de las competencias profesionales definidas en el perfil de egreso de Ingeniería Bioquímica. La reducción de dimensionalidad se realizó mediante un análisis factorial exploratorio y confirmatorio AFE/AFC, bajo la hipótesis de ortogonalidad, análisis de componentes principales y rotación Varimax. Se obtuvieron finalmente ocho factores latentes con un total de 52 ítems. El alfa de Cronbach fue igual a 0.937 y se confirmó la validez de contenido (CVR) y de constructo a través de las métricas de Lawshe y el modelo SEM, lo que respaldó la confiabilidad psicométrica del modelo teórico del instrumento. Las variables latentes y sus ítems correspondientes permiten evaluar de manera adecuada las competencias profesionales; además, el análisis del modelo SEM desarrollado permite aplicar esta metodología para evaluar competencias profesionales de otras carreras.

Palabras clave: instrumentos de evaluación; análisis factorial; psicometría / evaluación por competencias, análisis de contenido.

Abstract

This research addresses the updating and statistical standardization of indicators for a learning assessment tool, based on the graduate attributes established in the Washington Accord for the training of engineers at the National Technological Institute of Mexico (TecNM). Using the Delphi method, eleven indicators were obtained as latent variables, with six items whose content validity was determined by a panel of 25 experts. Construct validity was assessed with 337 students of basic science subjects using structural equation modeling (SEM). The latent variables obtained were used as indicators of the achievement of the professional competencies defined in the Biochemical Engineering graduate profile. Dimensionality reduction was performed using exploratory and confirmatory factor analysis

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(EFA/CFA), under the hypothesis of orthogonality, principal component analysis, and Varimax rotation. Finally, eight latent factors with a total of 52 items were obtained. Cronbach's alpha was 0.937, and content validity (CVR) and construct validity were confirmed through Lawshe's metrics and the SEM model, which supported the psychometric reliability of the theoretical model of the instrument. Latent variables and their corresponding items allow for the adequate evaluation of professional competencies; furthermore, analysis of the SEM model developed allows this methodology to be applied to assess professional competencies in other engineering programs.

Keywords: evaluation instruments; factor analysis; psychometrics / competency-based learning, content analysis.

Resumo

Este artigo aborda a atualização e padronização estatística de indicadores de desempenho para um instrumento de avaliação da aprendizagem, com base nos atributos de graduação estabelecidos no Acordo de Washington para a formação de engenheiros no Instituto Tecnológico Nacional do México (TecNM). Onze indicadores foram obtidos como variáveis latentes usando a técnica Delphi, com seis itens cuja validade de conteúdo foi determinada por um painel de 25 especialistas. A validade de construto foi determinada com 337 alunos de cursos de ciências básicas usando análise de equações estruturais (MEE). As variáveis latentes obtidas foram usadas como indicadores do alcance das competências profissionais definidas no perfil de graduação em Engenharia Bioquímica. A redução da dimensionalidade foi realizada usando análise fatorial exploratória e confirmatória (AFE/AFC), sob a hipótese de ortogonalidade, análise de componentes principais e rotação Varimax. Oito fatores latentes com um total de 52 itens foram finalmente obtidos. O alfa de Cronbach foi de 0,937, e a validade de conteúdo (CVR) e de construto foram confirmadas usando as métricas de Lawshe e o modelo SEM, apoiando a confiabilidade psicométrica do modelo teórico do instrumento. As variáveis latentes e seus itens correspondentes permitem uma avaliação adequada das competências profissionais; além disso, a análise do modelo SEM desenvolvido permite que esta metodologia seja aplicada para avaliar competências profissionais em outras carreiras.

Palavras-chave: instrumentos de avaliação; análise fatorial; psicometria/avaliação baseada em competências; análise de conteúdo.

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Introduction

This study is based on two key premises for assessing competencies: the first states that human beings are naturally predisposed toward learning; the second is based on the assumption that commitment fosters growth. These premises support the design of the professional competency assessment instrument. Furthermore, the research considers that learning to design reliable and valid surveys requires that the assessment be based on teacher-learner interaction, as well as the effective use of language as a superior tool, because it facilitates critical thinking and an internal regulator of behavior, characteristics necessary for active learning (Freire, 2004; Vygotsky, 2012) .

Additionally, it is known that during learning, various cognitive processes are involved in collaborative work, so the design of an evaluation instrument under the expert panel strategy, as well as its standardization through factor analysis, must consider a rigorous methodology about the ways in which learning is evaluated, individually and as a team (López-Gómez, 2018; Tovakol & Wetzel, 2020) .

Furthermore, when considering the value of teaching, Freire (1972) and Morin (1999) They agree that teaching should awaken curiosity and creativity in students, which is associated with a desire for freedom and growth. Therefore, teachers must understand the human condition of those who learn. This represents significant challenges for incorporating diverse constructs into teaching that allow for the assessment of learning through performance indicators from a humanistic perspective.

Therefore, the determination of constructs in the design of the assessment instrument to measure the achievement of professional competencies allowed the identification of professional performance through a content analysis. This analysis was carried out during the consultation of the design of the new educational model of the National Technological Institute of Mexico (TecNM, 2024) and the graduation profile in academic engineering programs, defined by national and international accrediting bodies, such as the Washington Accord and the Accreditation Council for Engineering Education, CACEI (IEA, 2021; Loría et al., 2024) .

Content analysis is largely based on the methodological proposal of Krippendorff (1990) and Piñeiro-Naval (2020) . The authors provide a theoretical and practical framework

for carrying out this analysis. The approach encompasses the identification of units of analysis and their grouping into categories that lead to interpretation and meaning. In this study, the categories in the assessment instrument were represented by the scope indicators as latent variables, with the items of the assessment instrument being the observable variables. These latent variables represent the minimum indicators in engineering training: the International Engineering Alliance (IEA) calls them graduation attributes (IEA, 2021) .

Thus, in the present research study, the *achievement indicators* established in the Course Accreditation Manual of a Mexican government higher education institution were updated. In the wording and nomenclature of these learning assessment criteria, there are indications of the presence of performance indicators; however, there is also a perceived degree of redundancy and conceptual overlap. For example, the concept of *"interdisciplinary"* in section 5 of the accreditation manual suggests that it is part of the complex thinking envisioned in the first indicator (TecNM, 2016, p. 17). By performing the content analysis of these indicators and the international demands for quality in engineering training, eleven variables were determined and defined for the construction of the theoretical model of the evaluation instrument, which was subjected to its content and construct validity, through an exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) determining the KMO, Bartlett, factor loading indices, among others.

Problem formulation

The TecNM Subject Accreditation Manual notes a numerical bias in the performance indicators defined for assigning the summative grade (the student receives accreditation with only two indicators passed, out of a total of six); furthermore, it does not specify how formative assessment is considered and what criteria are used to consider the indicators as excellent, as indicated in the table of assessment of indicators to be achieved (TecNM, 2016, p. 17). Accordingly, the problem formulation is described as follows:

> The scope indicators used to verify the achievement of a competency in the "Guidelines for the Subject Evaluation and Accreditation Process" section of the Academic-Administrative Guidelines Manual are not conceptually defined as variables or constructs. Therefore, their respective statements do not clearly characterize the learning outcomes. This does not comply with the methodological concept of operationalizing the variable defined as the

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"achievement or non-achievement of the competency" (Pedrosa et al., 2013; TecNM, 2016) .

General objective

To design and evaluate the factor loading and psychometric indices of the performance indicators of the TecNM regulatory manual's assessment instrument, based on the graduate attributes for engineering training and considering the Biochemical Engineering educational program.

Specific objectives

1. Conduct a content analysis of the scope indicators of the Subject Accreditation Manual, in order to determine the constructs of the assessment instrument and verify the correspondence of the statements with learning outcomes, using internal consistency and content validity indices.
2. Operationalize the variable *of competency achievement* in terms of the teaching intention and sequence, to be used in the design of teaching instruments.
3. Conduct an exploratory factor analysis to propose the theoretical model of the instrument and perform a factor reduction, under the hypothesis of independence (orthogonality) between latent factors, using a Varimax rotation.
4. Determine the validity of the theoretical model and construct validity of the assessment instrument through confirmatory factor analysis using the AMOS 29 tool from SPSS.

General hypotheses

1. H_1 Reliability and content validity: The assessment instrument meets reliability and content validity criteria, and the items correspond significantly with learning outcomes.
2. H_2 Operationalization of the variable: The variable *"achievement of competencies"* can be operationalized in terms of the didactic intention and sequence through scope indicators based on learning outcomes, relevant and measurable.
3. H_3 (AFE): There is an underlying structure of latent factors that explains the relationships between the scope indicators written as learning outcomes, justifying the reduction of factors through an exploratory factor analysis with Varimax rotation.

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4. H $_4$ (AFC): The theoretical model for assessing professional competencies is adequately adjusted to the empirical data, which determines the discriminant and construct validity, through psychometric measures of acceptable adjustment indices. (CFI, TLI, RMSEA, among others).

Learning assessment

Evaluating learning implies great responsibility for those who teach, since it constitutes the essential purpose of their teaching role through didactic intention and sequence. When evaluating learning outcomes, they must be operationalized from the didactic activities (González-Segura et al., 2018; Parmigiani et al., 2024) . In the quality assessment of current higher education, the specific focus is on whether the competencies were achieved within a subject and throughout the entire curriculum. This research addresses competency development using well-defined performance indicators as constructs, allowing for the operationalization of learning activities associated with these indicators. Based on the competencies to be developed, learning outcomes are defined to assess competencies within a subject or in the construction of competency maps (CACEI, 2021; Fulcher et al., 2025) .

Based on these statements, the items or statements of a measurement instrument, written as learning outcomes, are considered observable, measurable variables and, therefore, associated with a theoretical model made up of latent variables or constructs, to evaluate the professional competencies included in a graduation profile (Ferrando et al., 2022) .

In this sense, Boyatzis (2018) states that in the evaluation of a skill, action and job performance are determined by maximum performance, stimulation, and commitment. The author takes Anderson et al., (2001) and Ayyanathan (2022) as a reference when stating that learning competencies involves three fundamental aspects:

- Cognitive skills: Examples include constructive learning, systemic thinking, and pattern recognition, among others.
- Emotional intelligence skills: Including self-awareness and self-management skills, such as emotional self-awareness and emotional self-control.
- Social intelligence skills: These include social awareness and relationship management skills: empathy and teamwork (Boyatzis, 2008, p. 7).

On the other hand, several authors such as Leyva (2010) and Bezanilla and Arranz (2016) agree that competency-based assessment seeks the development of cognitive, procedural and attitudinal skills. Leyva reviews when and how the professional competency-

based assessment model was established in Mexico. He suggests that competencies are the result of three factors: *knowing how to proceed, wanting to do and being able to do* . In particular, Bezanilla and Arranz (2016) use the Moodle gradebook to assess competencies through indicators called learning outcomes, as the items were drafted in this work.

Graduation attributes in engineering training

Taking as a basis the content analysis and the construction of the theoretical model for the development of graduation attributes described by the CACEI, in its Reference Manual 2025 (Loría et al., 2024) and in the Washington Agreement for the training of engineers, Eleven graduation attributes were identified as performance indicators to support the theoretical model of the professional competency assessment instrument, in accordance with the training of an engineer with social commitment. The following constructs grouped into three dimensions resulted from this analysis. First, three types of thinking considered as cognitive resources for *"Processing information"* : 1) critical thinking and literacy (Morales Bautista and Barriga Arceo, 2021; Paul and Elder, 2005) ; 2) complex thinking (Morin, 1999; Tobón, 2008) ; and 3) systemic thinking, from the point of view of systems engineering (Montilla-García, 2022; O'Connor and McDermott, 1998; Watzlawick et al., 1991) .

For professional performance based on specific competencies, which requires a commitment to learning and collaboration in the development of processes and projects for problem solving, four latent variables grouped into the dimension *"Ability to solve complex problems" were defined* : 4) ability to investigate with the help of scientific thinking (Hyytinen & Toom, 2024) ; 5) effective communication and digital literacy (Cassany, 2006); 6) autonomous and self-regulated learning (Bello et al., 2022; Sung-Hee et al., 2023) and 7) problem-solving ability (Heredia et al., 2024) .

"Managing projects and processes with a vision for the future" was defined, integrating four constructs: 8) leadership and teamwork; 9) management and development of innovative processes and projects (Guaman-Quintanilla et al., 2023; Limbani et al., (2019) ; 10) social and environmental responsibility (Coelho & Menezes, 2021; Yohan et al., 2023) and 11) teaching an understanding of the human condition (Morin, 1999) .

In total, eleven latent variables constituted the initial theoretical model that underpins the assessment instrument. In the content and construct validation, these eleven graduation attributes were considered as latent variables, each with six observable variables or items, written as learning outcomes (Tobón et al., 2010) . They specifically integrate social

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responsibility and forward-looking education for the training of engineering professionals (Morin, 1999). It is important to note that the Washington Accord updated the graduation attributes for the training of engineers in 2021 (IEA, 2021) and that in 2024, CACEI published the *Manual of the 2025 Reference Framework for the Accreditation of Engineering Programs. Categories and Criteria* , which defines the graduation attributes, corresponding to the professional competencies that an engineer must acquire during their professional training (Loría et al., 2024) .

Operationalization of Competence Achievement

The constructivist model agrees with the idea *of achieving a learning purpose* , using all available pedagogical and didactic resources (Barboza and Calderón, 2020) . However, in various training models, the way in which the learning purpose is assessed is of a very different pedagogical and didactic nature. It can be focused on the behaviorist model, oriented simply towards an observable result. On the other hand, it can focus on the process, where the evaluation of learning outcomes is carried out throughout the training cycle. In this socio-constructivist model, it is required to demonstrate how learning is *"constructed" to develop the graduation profile* (Bruner, 1989; Coll and Onrubia, 2012; Vygotsky, 1979) .

It is in this context that a graphic model was developed that integrates the description of the didactic intention and sequence, to evaluate the development of the graduation attributes through learning outcomes. This operationalization involves a statistical measurement cycle for which a standardized evaluation instrument must be used (Creswell, 2012; Espinoza, 2019) . This research work also points out that the *scope indicator* is the operational way of evaluating the latent variable, understood as the achievement of the competence from the observable variables or items of the evaluation instrument, which are essentially *learning outcomes* derived from the didactic activities planned by the teacher (Ferrando et al., 2022).

Factor analysis using the SEM model

The SEM model includes fundamental statistical tools for validating assessment instruments in various disciplines, including education (Byrne, 2010) . Its importance lies, first, in the EFA's ability to reduce the dimensionality of the theoretical model and provide content validity; meanwhile, the CFA aims to support the confirmation of the theoretical model and construct validity (Brown, 2006). According to Byrne (2010), in an assessment

instrument, latent variables represent theoretical constructs that cannot be directly measured because they are unobservable. Thus, constructs such as critical thinking or self-regulated learning, among others, can be inferred through observable variables described with appropriate items in questionnaires or surveys. The items are specific indicators that manifest observable behaviors of the latent variable, allowing for the evaluation of its presence and magnitude. This indirect assessment approach uses SEM modeling, which includes the measurement of indices and the underlying structure of the latent variables.

By identifying the latent structures underlying the relationships between observable variables, the CFA allows to simplify the initial model and eliminate redundancies or unrepresentative items (Kline, 2016; Brown, 2006) . This analysis evaluates the coherence between the observed data and the theoretical latent structure, which allows determining the construct validity of the model, providing it with reliability (Ferrando and Lorenzo-Seva, 2017) . It is worth mentioning that the standardization of evaluation instruments worldwide in educational research is so necessary that Hernández et al. (2019) propose an evaluative checklist based on the guidelines of the International Testing Commission to improve the adaptation of standardized tests, facilitating their implementation and guaranteeing cultural comparability in educational research worldwide .

Materials and methods

For the development of this study, a quantitative, non-experimental approach with an instrumental design was used. The methodological stages correspond to the complete cycle of design, validation, and statistical standardization of a learning assessment instrument. These stages are shown in Table 1. They were designed under the methodological precepts of Creswell (2023) and Ferrando et al. (2022) using the SEM modeling approach . To this end, an assessment instrument aimed at measuring professional competencies was constructed, validated, and statistically standardized, based on the graduation attributes of the educational model of the National Technological Institute of Mexico (TecNM), CACEI (2024), and the Washington Agreement (2021).

The procedure followed in this research is presented in Table 1, which summarizes the key stages, activities developed, techniques used, and corresponding methodological purposes. This synthesis allows a structured visualization of the design, validation, and analysis process of the professional competency assessment instrument. In the design, eleven latent variables were identified, defined as constructs that group items written as learning

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outcomes. The items were validated by a panel of 25 experts, using the Delphi technique of López-Gómez (2018) and the methodology of Lawshe (1975), as well as the determination of Cronbach's alpha, in order to guarantee content validity and internal consistency, respectively.

Table 1. Summary of the study stages

Stage of the process	Activity	Technique / Instrument	Methodological purpose
Document review	Identification of latent variables and item writing	Content analysis	Theoretical basis of the instrument
Expert evaluation	Qualitative and quantitative assessment	Delphi Technique	Content validity and determination of internal consistency
Pilot application	Data collection	Preliminary evaluation of the instrument in the Moodle Feedback activity	Preliminary reliability estimate
Exploratory factor analysis (EFA)	Factor extraction and item validation	SPSS, Varimax rotation	Identification of factorial structure
Confirmatory Factor Analysis (CFA)	Confirmation of the theoretical model	AMOS, by SPSS	Structural validation of the theoretical model
Final adjustment of the evaluation instrument	Obtaining the validated instrument proposal	Analysis of results Cronbach's alpha and construct validity (KMO, CFI, TLI, RMSEA indices)	Description of evidence of content, construct, and internal consistency validity

Note: Own elaboration

The latent variables and their corresponding items as observable variables were formulated through a content analysis of the engineering training requirements described by national and international accreditation bodies. Their evaluation was conducted using the Moodle platform, using the Feedback tool as a digital application medium. For this study, a seven-level Likert-type scale was chosen instead of the traditional five-point scale, in order to reduce random variability in the responses (Kline (2016). Increasing the scale level is intended to more accurately capture differences in student achievement. This methodological step responded to the need to increase the instrument's sensitivity and improve the distribution of responses, with the intention of obtaining an increase in the percentage of

variance explained during the exploratory and confirmatory factor analysis, thus optimizing the construct validity of the theoretical model.

For the validation of the theoretical model, factor analyses were performed according to the criteria of Kline (2016) and Byrne (2010), with the objective of identifying the underlying structure of the latent variables, reducing the dimensionality of the instrument and evaluating the grouping of the items through Varimax rotation . Sampling adequacy criteria were applied using the Kaiser-Meyer- Olkin (KMO) index and Bartlett's sphericity test. The CFA was performed with the AMOS 29 software, using indicators such as the comparative fit index (CFI), the Tucker-Lewis index (TLI) and the root mean square error of approximation (RMSEA), the psychometric guidelines proposed by Byrne (2010) . To perform the EFA and EFC, the documentary review allowed the latent and observed variables (the items) to be classified into the following dimensions shown in Table 2, which served for the preliminary estimation of the theoretical model.

Table 2. Dimensions and latent variables

Dimensions and latent variables of classification of the theoretical model		
Information processing	Solving complex problems	Manage projects and processes with a vision for the future
Critical thinking and literacy Complex thinking Systems thinking	Ability to investigate Effective communication and digital literacy Problem-solving skills Autonomous and self-regulated learning	Leadership and teamwork Social and environmental responsibility Process and project management and innovation Teaching understanding and the human condition

Note: Own elaboration

In summary, this methodology allowed for the empirical construction of a standardized, theoretically based instrument for engineering students from a professional competency-based educational approach.

Results

Objective 1: Construction of the theoretical model of the evaluation instrument

In this objective, we assume that the professional competency assessment instrument is based on *indicators to be achieved* from the TecNM subject accreditation manual; that the competency assessment instrument is not statistically standardized, and that its latent and observable variables, which would confer reliability and content and construct validity, are not conceptually defined (TecNM, 2015, p. 14). Table 3 It shows the grouping of the latent variables of the initial theoretical model, with the overall Cronbach's alpha internal consistency values obtained for each group and the Content Validity Index (CVI) for each latent variable, measured using Lawshe 's criteria (1975).

Table 3. Psychometric reliability indices of the assessment instrument

Dimension	Latent variables	Cronbach's alpha	IVC (Lawshe)	Average alpha / IVC
Information processing	Complex thinking	0.899	0.65	
	Systems thinking	0.902	0.52	
	Critical thinking and literacy	0.921	0.53	0.907 / 0.57
Solving complex problems	Ability to investigate	0.897	0.63	
	Communication and digital literacy	0.924	0.56	
	Ability to solve complex problems	0.909	0.84	
	Autonomous and self-regulated learning	0.868	0.63	0.899/ 0.66
Designing projects and processes with a vision for the future	Leadership and teamwork	0.898	0.50	
	Social and environmental responsibility	0.939	0.60	
	Project management and innovation	0.938	0.60	
	Teaching human understanding	0.891	0.61	0.916 / 0.58

Note: Prepared by the authors based on results

The internal consistency index values are close to 0.9 or exceed it for some latent variables. For the content validity index (CVI), it is observed that on average, the indices have a value above 0.5, a value considered acceptable. In Lawshe's mathematical model, there is an inverse relationship between the number of experts validating an assessment instrument and the CVI value obtained. For 25 participating experts, the minimum value recommended by the author is 0.37 (Lawshe, 1975, p. 568). The table shows that values above 0.5 were obtained for each latent variable or construct. This allows us to affirm that the assessment instrument is reliable and has adequate internal consistency.

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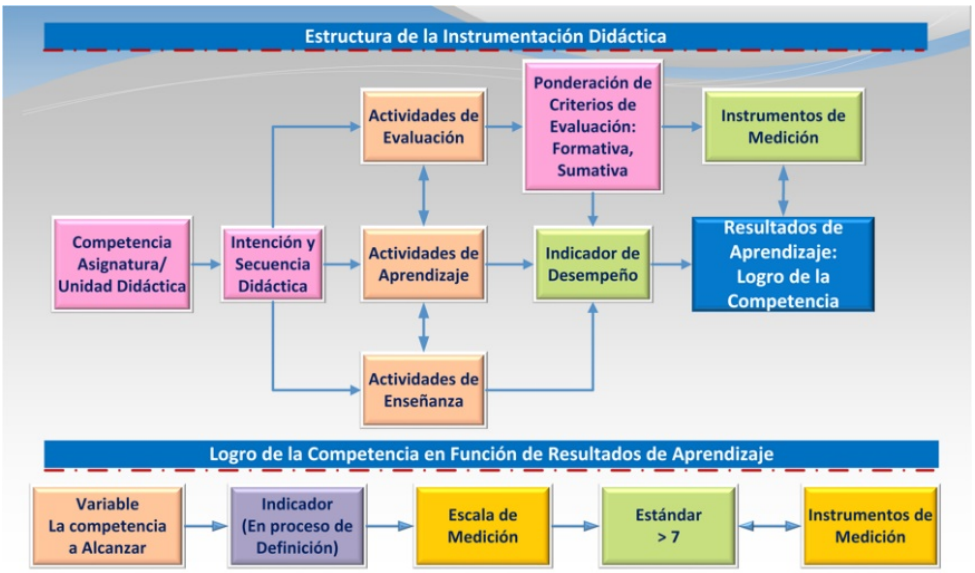
Objective 2: Operationalization of the Competence Achievement variable

Figure 1 shows the operationalization process of the variable, Competency Achievement, with its characteristic constituent elements. The figure demonstrates the close relationship between the teaching function and the statistically validated assessment instruments.

Figure 1. Operationalization of the variable Achievement of specific or generic competence



Note. Prepared by the authors.

The interrelationship between the indicator, the measurement scale, the standard, and the measuring instrument can be seen below. According to Creswell and Creswell (2023) , the functions of these elements with which a variable is operationalized are:

- The indicator: The item in an assessment instrument is an observable and measurable representation or manifestation of a latent variable that we want to study and measure. Indicators are concrete, observable, and measurable aspects of the variable being studied in order to quantify it.
- The measurement scale: defines how the indicators will be measured and, therefore, the variable they represent. The measurement scale establishes the categories or levels into which the variable will be classified and quantified.

- The standard: provides a reference or point of comparison for measuring indicators on the chosen scale. The standard is a point of reference that helps contextualize and specify the value of the scale (Espinoza, 2019) . In the TecNM, the minimum passing grade is equal to or greater than 70 (TecNM, 2016).

Figure 1 can be used to represent and operationalize the competency assessment process using the teaching instruments of the TecNM educational model.

Objective 3: Exploratory factor analysis

This objective aimed to explore the validity of the theoretical model by reducing its dimensionality, as expressed in the hypothesis: There is an underlying latent factor structure that explains the relationships between the achievement indicators formulated as learning outcomes, justifying factor reduction through exploratory factor analysis with Varimax rotation. Two EFAs were performed to reduce factors from the eleven latent variables; the first used an absolute factor loading value below 0.4, and the second, values below 0.5.

By performing the first factor reduction process using the EFA, Table 4 was obtained for the *Information Processing group of latent variables.* It is observed that the communality indices have values that are considered acceptable, above 0.5 for each factor, in accordance with what was established by Brown (2006), who states that the factors are capturing a significant portion of the variance of the observed variables.

Table 4. Factor loadings of the Information Processing dimension

Latent variables	Observable variables or items	Factor loading of rotated components		Communities
		Factor 1	Factor 2	
Complex thinking	Holistic capacity for analysis and synthesis		0.725	0.676
	Integration of feedback		0.735	0.789
	Integration of disciplines		0.780	0.694
	Evaluating uncertainty and error		0.756	0.649
	Transdisciplinary orientation		0.785	0.638
	Principle of emergency		0.753	0.614
Critical Thinking	Credibility of the information*	0.497	0.572	0.575
	Identifying biases and fallacies	0.531	0.504	0.536
	Coherent and cohesive argumentation*	0.477	0.584	0.569
	Ability to argue independently	0.539	0.558	0.569

	Assertiveness	0.545	0.499	0.546
	Ethical implications*	0.526	0.552	0.581
Systems thinking	Understanding the idea of systems	0.766	0.725	0.884
	Interaction of system elements	0.808	0.735	0.692
	Feedback loops	0.792	0.780	0.666
	System optimization	0.784	0.756	0.737
	Identification of "bottlenecks"	0.750	0.785	0.665
	Perception of change	0.763	0.753	0.680

Note. N = 337. Extraction method in the first Varimax rotation. Factor loadings above 0.5 are shown in bold.

After the first EFA, the observed variables for the latent variable *Complex Thinking* were grouped into a single factor, with appropriate factor loadings above 0.7, as shown in Table 4. An asterisk indicates the variables that were eliminated when performing the second exploratory factor analysis. When the Varimax rotation was performed again after eliminating these three latent variables, the values shown in Table 5 were obtained for both the Kaiser-Meyer-Olkin (KMO) test and the Bartlett's test of sphericity and the percentage of the total variance obtained.

Table 5. KMO Values and Bartlett's Test for Information Processing

KMO [b]	Bartlett's Test: First Reduction [to]			Total variance explained (%)
	Chi square	gl	p-value	
0.964	4193.214	153	0.001	63,753
Second reduction				
0.956	3107.908	91	0.001	65,733

Note: a. Based on correlations; b. Kaiser-Meyer-Olkin measure of sampling adequacy

After the Varimax rotation with absolute value in the factor loadings greater than 0.5, we observe in Table 6 that the factor loadings of the latent variables *Critical and Systemic Thinking* and *Critical Thinking and Literacy* tend to group together in a single factor, now called *Critical and Systemic Thinking,* indicating that the observable variable *Independent Argumentation Capacity* marked with an asterisk can be eliminated, since its factor loading in one of its components is less than 0.5, if the theoretical model is not compromised.

Table 6. Factor loadings in the Information Processing dimension

Latent variables	Observable variables or items	Factor loadings on rotated components		Communities
		1	2	
Thought critical and systemic	Interaction of system elements	0.814		0.706
	Feedback loops	0.800		0.682
	System optimization	0.793		0.748
	Understanding the idea of systems	0.771		0.700
	Perception of change	0.770		0.684
	Identification of "bottlenecks"	0.758		0.683
	Assertiveness	0.556		0.531
	Ability to argue independently*	0.493	0.521	0.559
	Identifying biases and fallacies	0.536		0.502
	Integration of disciplines		0.788	0.696
	Transdisciplinary orientation		0.783	0.638
Thought complex	Evaluating uncertainty and error		0.768	0.681
	Principle of emergency		0.767	0.645
	Integration of feedback		0.744	0.724
	Holistic capacity for analysis and synthesis		0.730	0.702

Note. $N = 337$. Extraction method in the second Varimax rotation. Factor loadings above 0.5 are shown in bold. The rotation converged in three iterations.

It is also observed that the latent variable *Complex Thought* continues to retain all of its unobservable variables, denoting the importance of this variable in the training of engineers.

Exploratory factor analysis of the Problem-solving ability dimension

The first factor reduction for the latent variables grouped under the *Complex Problem Solving dimension* is presented in Table 7. This first dimensionality reduction shows that the latent variable *Autonomous and Self-Regulated Learning* maintains all of its latent variables with appropriate factor loadings. Variables shown with an asterisk are eliminated to perform the second CFA.

Table 7. Factor loadings of the dimension Solving complex problems

Latent variables	Observable variables or items	Factor loadings of rotated components			Communities
		1	2	3	
Autonomous and self-regulated learning	Management and organizational skills	0.748			0.670
	Project monitoring and development capacity	0.714			0.685
	Planning capacity	0.699			0.673
	Use of teaching resources	0.698			0.650
	Capacity for reflection	0.675			0.585
	Performance self-assessment	0.647			0.586
Problem-solving skills	Proposal for improvements	0.631			0.625
	Performance evaluation*	0.628	0.436		0.646

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	Resource management*	0.615	0.483		0.693
	Evaluation of solution alternatives	0.586	0.466		0.595
	Systemic application of cause and effect	0.524	0.648		0.674
	Formulation and relevance of the problem*	0.586	0.506		0.631
Ability to investigate	Ability to design experiments		0.764		0.758
	Justification and relevance		0.748		0.718
	Application of statistical methods		0.665		0.690
	Clear and precise formulation of the research problem		0.615	0.452	0.725
	Ethical interpretation of data		0.565		0.572
Communication and digital literacy	Effective use of digital tools in presentations			0.777	0.731
	Digital adaptation			0.776	0.749
	Improving digital communication			0.722	0.716
	Planning capacity*		0.425	0.647	0.717
	Effective communication				0.640
	Confidence and mastery of the subject*		0.413	0.563	0.621

Note. N = 337. Extraction method in the first Varimax rotation. Factor loadings above 0.5 are shown in bold.

Table 7 shows that the observable variable *Planning Capacity* overlaps in two different latent variables, so it is decided to mark it with an asterisk to eliminate it from the latent variable *Communication and digital literacy,* since it is considered more pertinent for the theoretical model to keep it in the latent variable *Autonomous and self-regulated learning.*

The EFA performed for these latent variables or constructs yields the following KMO/Bartlett values, sampling adequacy/underlying structure shown in Table 8. These indices correspond to adequate values for the percentage of total variance explained, as well as for the KMO.

Table 8. KMO Values and Bartlett's Test for Solving Complex Problems

KMO [b]	Bartlett's Test: First Reduction [to]			Total variance explained (%)
	Chi square	gl	p-value	
0.974	7663.333	276	0.001	72.695
Second reduction				
0.968	5808.404	171	0.001	74.290

Note: a. Based on correlations; b. KMO: Kaiser-Meyer-Olkin measure of sampling adequacy

After a second component reduction with a minimum factor loading of 0.5, Table 8 shows that the Chi-square value decreases, in line with the decrease in the degrees of freedom, a product of the decrease in the observed variables . Table 9 groups the three latent variables as results of the second Varimax rotation with a minimum value for the factor loadings of 0.5. This table shows the union of the latent variable Autonomous and self-

regulated learning with that of Problem-solving ability, which simplifies the dimensionality of the theoretical model. This leads to renaming these two latent variables Self-regulated learning for problem solving.

Table 9. Factor loadings of the dimension Solving complex problems

Latent variables	Observable variables or items	Factor loadings on rotated components			Communities
		1	2	3	
Autonomous and self-regulated learning for solving complex problems	Management and organizational skills	0.757			0.686
	Monitoring capacity, project development	0.727			0.703
	Capacity for reflection	0.705			0.602
	Use of teaching resources	0.703			0.655
	Planning capacity	0.701			0.677
	Performance Self-Assessment:	0.663			0.586
	Proposal for improvements	0.612			0.600
	Evaluation of solution alternatives	0.574			0.590
	Digital adaptation		0.783		0.777
	Using digital tools in presentations		0.762		0.744
Communication and	Improving digital communication:		0.736		0.738
digital literacy	Effective communication		0.637		0.645
	Confidence and mastery of the subject		0.578		0.624
Ability to investigate	Ability to design experiments			0.779	0.774
	Sufficient justification and relevance			0.767	0.734
	Application of statistical methods			0.692	0.716
	Clear and precise formulation of the research problem			0.606	0.721
	Ethical interpretation of data			0.597	0.589
	Systemic application of cause and effect			0.648	0.639

Note. $N = 337$. Extraction method in the second Varimax rotation. Factor loadings above 0.5 are shown in bold . The rotation converged in 6 iterations.

It is also observed how the latent variable *Research Ability* adds another observable variable, *Systemic Application of Cause* and *Effect* , originally integrated into the latent variable *Problem-Solving Ability* . In the opinion of the panelists, this observable variable gives rise to the cause-and-effect type of research. Finally, it is the researchers' responsibility to analyze the final placement of the items in accordance with the study's theoretical model.

Exploratory factor analysis of the process and project management and innovation dimension

For the *Process and Project Management and Innovation dimension* , Table 10 shows the red lines of the observable variables whose factor loadings are located in two or more components after the first Varimax rotation. It also shows those where there is conceptual

redundancy, such as in the learning outcomes related to *Environmental Responsibility,* also marked with an asterisk for elimination.

Table 10. Factor loadings of the Process and Project Management and Innovation dimension

Latent variables	Observable variables or items	Factor loadings of rotated components			Communities
		1	2	3	
Leadership and teamwork	Roles and responsibilities	0.801			0.796
	Effective collaboration	0.814			0.759
	Decision making:	0.777			0.766
	Leadership and conflict mediation	0.764			0.715
	Propose ideas and solutions	0.747			0.770
	Work dynamics	0.671			0.683
Teaching understanding and the human condition	Empathy and cultural understanding	0.611	0.485		0.697
	Interdisciplinary and transdisciplinary collaboration	0.555	0.504		0.742
	Assertiveness in decision-making*	0.539	0.476		0.657
	Reflective training in human development	0.540	0.651		0.618
	Initiative to reduce environmental impact		0.730		0.763
	Resilience Management*	0.460	0.554	0.403	0.672
Social and environmental responsibility	Ethical and moral responsibility		0.720		0.679
	Promoting environmental awareness*		0.751		0.741
	Environmental quality indicators*		0.671	0.425	0.753
	Awareness of the project's impact*	0.441	0.599		0.668
	Application of ethical solutions*	0.487	0.540	0.438	0.736
	Promoting social well-being and sustainability	0.743			0.766
Process and project management and innovation	Development of continuous improvement projects			0.838	0.821
	Process design			0.770	0.788
	Digitalization for process optimization*	0.423		0.657	0.753
	Systemic evaluation			0.678	0.696
	Efficient resource management		0.403	0.660	0.723
	Design thinking			0.629	0.691

Note. N = 337. Extraction method in the first Varimax rotation. Factor loadings above 0.5 are shown in bold.

These observable variables marked with an asterisk were eliminated when performing the second Varimax rotation to simplify the theoretical model. Table 11 presents the percentage values of the total observed variance, with a value of 66.735 and KMO indices of 0.97, above 0.95 for both reduction processes, which are considered acceptable.

Table 1 1. Rotation in the Process and Project Management and Innovation dimension

KMO [b]	Bartlett's Test: First Reduction [to]			Total variance explained %
	Chi square	gl	p-value	
0.970	5852.096	253	0.001	66,735
Second Reduction				
0.964	4508.256	171	0.001	67,619

Note: a. Based on correlations; b. Kaiser-Meyer-Olkin measure of sampling adequacy

It is also observed that there is a reduction in the Chi-square value due to the reduction in the degrees of freedom. Table 12 shows how the four original constructs are grouped before the EFA into three latent variables. The latent variables *Social and Environmental Responsibility* and *Teaching Understanding and the Human Condition* are grouped into the variable *Human Development and Social Responsibility* , which further simplifies the theoretical model.

Table 12. Factor loadings in the Process and Project Management and Innovation dimension

Latent variables	Observable variables or items	Factor loadings on rotated components			Communities
		1	2	3	
Leadership and teamwork	Effective collaboration	**0.814**			0.781
	Roles and responsibilities	**0.797**			0.805
	Decision making:	**0.782**			0.780
	Leadership and conflict mediation	**0.756**			0.715
	Propose ideas and solutions	**0.733**			0.778
	Managing work dynamics	**0.672**			0.723
	Empathy and cultural understanding:	**0.573**			0.721
	Interdisciplinary and transdisciplinary collaboration	**0.527**			0.762
Process and project management and innovation	Development of continuous improvement projects		**0.854**		0.809
	Process design		**0.796**		0.794
	Systemic evaluation		**0.691**		0.698
	Efficient resource management		**0.667**		0.727
	Design thinking		**0.666**		0.721
	Digitalization for process optimization		**0.662**		0.737
Training in human development and social responsibility	Ethical and moral responsibility			**0.743**	0.797
	Assertiveness in decision-making			**0.653**	0.767
	Promoting social well-being and sustainability			**0.642**	0.677
	Reflective training in human development:			**0.630**	0.727
	Promoting environmental awareness			**0.629**	0.665

Note. $N = 337$. Extraction method in the second Varimax rotation. Factor loadings above 0.5 are shown in bold. The rotation converged in 6 iterations.

The item *Promoting environmental awareness* has a factor loading above 0.600, and its conceptual content complements the item *Promoting social well-being and sustainability,* both of which are considered important for the theoretical model of the assessment instrument. Given that the factor loading and the communality index value are greater than 0.500 and 0.600 for both, respectively, it is possible to maintain them. The item shown with an asterisk in the table, *Managing resilience,* has a factor loading of only 0.403 and can

therefore be eliminated, since its conceptual content is included in the item *Reflective function of human development.* In this way, the latent variables *Teaching understanding and the human condition* and *Social and environmental responsibility* are unified into a single latent variable called *Formation of the Human development and social responsibility* , with five observable variables. Finally, it should be noted that in all dimensionality reduction processes, communality index values above 0.600 were obtained, which is considered appropriate to give construct validity to the theoretical model.

Objective 4: Confirmatory factor analysis

For this purpose, it is important to consider that the main function of the CFA is to verify whether the theoretical structure of the assessment instrument fits the data and to determine the construct validity. Table 13 shows that a value of χ^2 equal to 2.059 was obtained, indicating an acceptable fit, given that values less than 3.0 are considered adequate (Kline, 2016). For the parsimony values, a value of 0.056, which suggests a reasonable fit, since values less than 0.08 are acceptable and values less than 0.05 are ideal (Brown, 2006).

Table 13. Fit indices of confirmatory factor analysis

Model χ^2 (CMIN/DF)	Error distribution	Comparison indices			Parsimony adjustment				Hoelter Index
	RMSEA	CFI	TLI	NFI	PRatio	PCFI	PNFI	AIC	Sample
2.059	0.056	0.914	0.908	0.845	0.940	0.858	0.794	2819.37	0.05 = 175 0.01 = 180

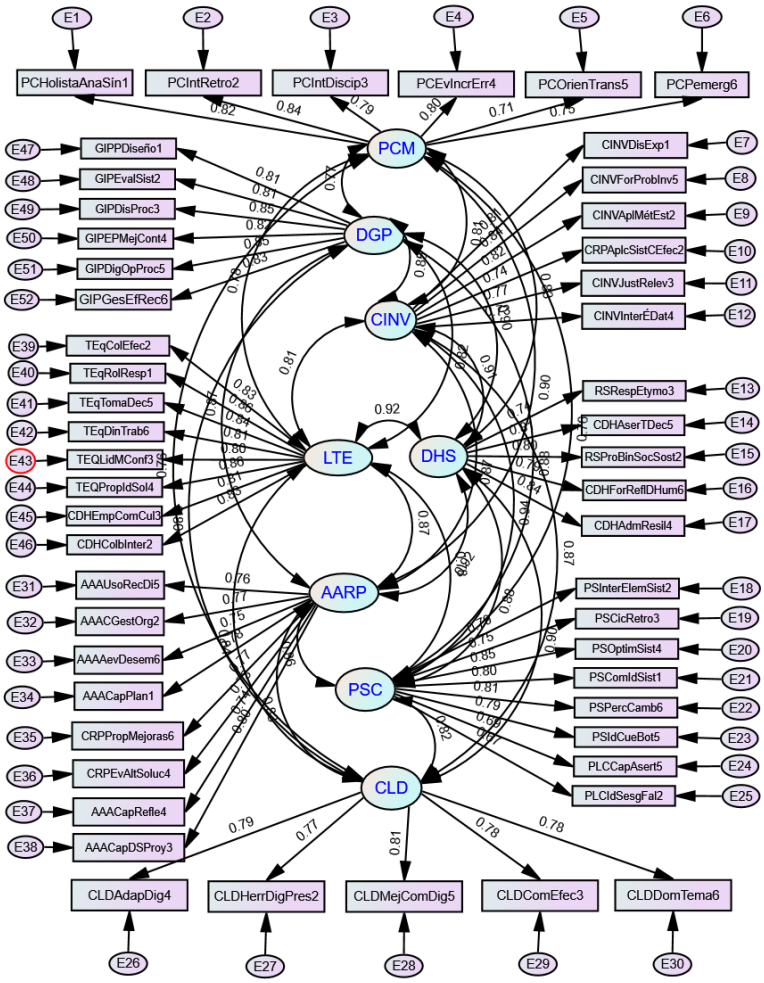
Note: Prepared by the authors based on the results.

For the Comparative Fit Indices (CFI, TLI, NFI), the values obtained are CFI = 0.914, TLI = 0.908, and NFI = 0.845. Values above 0.90 indicate a good model fit, confirming that the observable variables, written as learning outcomes, are well aligned with their latent factors. For the Parsimony Index, which refers to the simplicity of the theoretical model with which the data are explained, the following indices were obtained: PRatio = 0.940; PCFI = 0.858; PNFI = 0.794. If these values are close to 1, they suggest that the model is efficient and tends to avoid complexity. Regarding the index that supports the stability of the model based on the sample size, the value of the Hoelter Index, it is reported that for a significance

level of 0.05, the minimum sample size required to obtain a good fit is 175, while for 0.01 it is 180. A sample size of 337 individuals was used in the study.

The path diagram results in Figure 2. This represents the structure of the SEM model; it highlights the following key elements, based on the table of standardized factor loadings provided in the AMOS results sheet.

Figure 2. Path diagram of the covariances of the latent variables and their observable variables



Note: Prepared with AMOS 29, based on the results

In it we can observe the following data provided by the AFC:

- Latent variables and their relationships with observable variables: It shows how each latent variable (construct) is related to its observable indicators, with standardized factor loadings.

- Factor loadings: Most factor loadings exceed the threshold of 0.50, indicating a good relationship between each item and its corresponding theoretical factor. Some observed variables show factor loadings above 0.70, which is excellent.
- Covariances/Correlations: Correlations are found between latent variables with factor loadings above 0.85 and others above 0.90. The interpretation of covariances or correlations between factors must be correct. High values (≥ 0.85 or 0.90) do not support discriminant validity, but rather threaten it, since they suggest a conceptual overlap between constructs that should be distinct (Kline, 2016). In other words, very high correlations indicate that the factors may be measuring practically the same thing, which compromises the evidence of discriminant validity (Hair, et al., 2019). To guarantee this form of validity, correlations must be kept at moderate levels, so that there is a relationship between the constructs, but without losing their conceptual distinction.
- Measurement errors: Each observable variable has an associated error term, reflecting the variance not explained by the model.

Discussion

The overall objective of this study was to design and statistically standardize a professional competency assessment instrument for engineering training. In accordance with the methodological guidelines, the scope of this study is limited to evaluating content and construct validity and does not address criterion-related validity. In this regard, the results support the four hypotheses.

Initially, it was found that the items of the evaluation instrument, *measured as learning outcomes,* are reliable and valid, as stated in the first hypothesis. Various authors such as Hair et al. (2019) and George and Mallery (2003) point out that a value of the factor loadings above 0.5 is considered adequate, because its measurement determines the degree to which the items are related to their factors. For the eleven latent variables of the theoretical model, Cronbach's alpha values close to or greater than 0.9 were obtained, with an average of 0.9077, as shown in Table 3, which indicates that the instrument complies very well with the internal consistency index.

On the other hand, the second hypothesis allowed operationalizing the *Competency Achievement variable* through a graphic model of didactic intention and sequence, as a way to develop professional competencies in students. The output elements of the cycle in Figure

1 are the learning outcomes, so the standardized assessment instrument used in this study regulates not only the quality of student training in an academic program, but also its recognition by accrediting bodies.

In line with hypothesis three, a reduced latent factor structure was identified using an EFA. This exploratory factor analysis allowed us to reduce the dimensionality of the theoretical model from eleven latent variables to eight, using the following criteria:

- Low factor loadings: For their elimination, variables with loadings lower than 0.4 in the first analysis and 0.5 for the second were considered.
- Cross-loadings: Variables that loaded significantly on multiple factors indicated redundancy and were considered for elimination.
- Conceptual similarity: Variables with similar meanings across different latent factors were also considered for reduction (Brown, 2006; Kline, 2016).

To interpret the results of the EFA, the values obtained for the Kaiser-Meyer-Olkin (KMO) sampling adequacy index and the Bartlett sphericity test are compared with the values recommended by Byrne (2010) and Kline (2016).

- KMO: A value greater than 0.80 is considered excellent, while values between 0.70 and 0.79 are acceptable. In Tables 5, Table 8, and Table 11, KMO values range from 0.956 to 0.974, indicating very high sampling adequacy for the eleven latent variables in the three dimensions. This supports the applicability of factor analysis.
- Chi-square ($\chi 2$): In CFA, a high chi-square value may indicate an imperfect fit, but it is important to consider this situation in relation to the sample size. With 337 students, the reported chi-square values are significant, suggesting a discrepancy between the model and the observed data. However, due to the sensitivity of $\chi 2$ to sample size, it is recommended that other fit indices such as CFI (>0.90) and RMSEA (<0.08) be evaluated in conjunction to determine the quality of the theoretical model.

A Bartlett's test with a *p- value* less than 0.05 indicates that the correlations between the variables are strong enough to justify the EFA. In the study, all the values obtained for the three dimensions are significant ($p < 0.001$), which supports the viability of factor analysis. Similarly, the explained variance as a measure of the quality of an instrument, according to Kline (2016), is desirable to have a value greater than 60% in factorial models. The values obtained in the dimensions of the study (63.75%, 66.73%, 72.69%) indicate that the factor structure is appropriate and that the identified factors explain a large part of the percentage of the variance in the data. Additionally, Byrne (2010) suggests that factor

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loadings greater than 0.50 are acceptable and greater than 0.70 are excellent. In the assessment instrument, most factor loadings exceed the threshold of 0.70, suggesting that the items are well related to their respective factors.

Finally, to assess the construct validity of the theoretical model of the assessment instrument, hypothesis four was tested. Confirmatory factor analysis was used to evaluate the construct and discriminant validity of the final model with eight latent variables.

- Construct validity: Refers to the degree to which the instrument measures the theoretical constructs it purports to measure. The CFA confirmed construct validity by demonstrating a good fit between the theoretical model and the data, using indices such as CFI, TLI, and RMSEA.
- Discriminant validity: Indicates the degree to which the latent factors are distinct from each other.

The results of the CFA, including several covariance/correlation values above 0.85, suggest that actions such as the following should be taken in the final instrument, in order to improve discriminant validity.

- Conceptual review: Analyze whether the constructs are truly distinct. If they are almost identical in theory, it may be appropriate to merge them into a single construct.
- Item Refinement: Check whether some items are semantically duplicated. One item from each redundant pair could be eliminated, keeping the one that best represents the construct.
- Evaluate alternative discriminant indices: Use criteria such as Fornell-Larcker (average variance extracted, AVE) or the HTMT (Heterotrait-Monotrait) ratio. If these indices also show problems, the lack of discriminant indices is confirmed (Kline, 2016) and Hair et al., 2019).

Since the theoretical model was confirmed after dimensionality reduction, the justification for merging *Critical and Systemic Thinking* into a single factor is due to the concurrent relationship between both types of thinking. This is in accordance with the TecNM educational model, *Humanism for Social Justice* , in its Critical Thinking Model for Technological Education, from the systemic circular perspective of analysis and synthesis, the contrast and confrontation of ideas, feedback, and the construction of new knowledge (TecNM, 2024, pp. 60-69).

In this sense, critical thinking is enhanced by systemic thinking. For Senge (1996) , systemic and critical thinking are related. According to the author, systemic thinking allows

for the interconnection of elements within a system, favoring a more systematic and in-depth critical analysis of information. Likewise, its consequences can be evaluated to enable decision-making based on the analysis and synthesis of information. In contrast, Cabrera and Cabrera (2015) argue that the integration of systemic and critical thinking is fundamental in problem-solving due to the close relationship they provide for processing information. The authors point out that systemic thinking enhances critical thinking by considering interrelationships and diverse perspectives to address a problem. Critical thinking, through analysis and inference, is essential for systematically building and evaluating systemic models. Thus, this comprehensive model of *Critical and Systemic Thinking* allows us to question information and assumptions, identify biases, and evaluate the validity of arguments and their connections within a system (Cabrera and Cabrera, 2015).

Regarding the fusion between *autonomous and self-regulated learning* with the ability *to solve problems* in a single factor called *Self-regulated learning in complex problem solving* , various authors such as Intriago et al. (2024) and Zimmerman (2002) agree on the close relationship between both skills in terms of intrinsic motivation and commitment, self-regulation in the problem-solving strategy and its transfer to learning. In this sense, Zimmerman states that students who learn independently develop self-regulation skills, such as planning, monitoring and evaluating their own learning. These skills are crucial for problem solving. For their part, Intriago et al. (2024) report that students who learn independently develop self-regulation skills, such as planning, monitoring and evaluating their own learning.

Similarly, the CFA highlights the connection between the variables *Teaching Human Understanding* and *Social and Environmental Responsibility* . In this way, the CFA explains that there are conceptual similarities between its observable variables, in addition to the fact that their factor loadings overlap. Therefore, the union of these two latent variables in the variable *Formation of Human Development and Social Responsibility* is part of a broader approach that integrates the teaching of understanding and the human condition, a fundamental pillar for the education of the future, according to Edgar Morin (1999), concepts that are also included in the new educational model of the National Technological Institute of Mexico. In this model, Morin bases the understanding of the human condition by arguing that education must transcend the transmission of technical and scientific knowledge, to address the complexity of human existence and foster a global awareness that allows

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individuals to understand themselves and others in a context of social, environmental and cultural interdependence.

Similarly, Coelho and Menezes (2021) assert that social and environmental responsibility in higher education is a key component in the training of citizens committed to collective well-being and social equity. This vision aligns with the perspective of Morin (1999), who proposes that education must integrate the need to understand human development, fostering a holistic vision that relates individual development with responsibility towards others and the planet. Likewise, Yohan et al. (2023) emphasize that the teaching of sustainability must go beyond the simple management of natural resources, incorporating ethical and social dimensions that allow the training of professionals capable of generating innovative and responsible solutions.

Conclusions

Confirmatory factor analysis validated the theoretical structure of the assessment instrument model, aligning the performance indicators with their respective professional competencies. The model achieved an acceptable fit, with adequate values for the fit indices (CFI > 0.90, RMSEA < 0.08, TLI = 0.908), which supports the construct validity of the assessment instrument.

The results obtained are consistent with previous literature on the validation of assessment instruments in education and psychometrics. The percentage of explained variance is greater than 60%, suggesting that latent factors explain a significant proportion of the variability in the data. The professional competency assessment instrument is also consistent with the new educational model of the TecNM, as it integrates the components of critical thinking, communication, collaborative work, digital skills, social responsibility and environmental awareness, innovation processes, interdisciplinarity, the perception of change, continuous improvement, self-regulation of learning, among other concepts included in this standardized assessment instrument through items written as learning outcomes.

The integration of the latent variables *Critical Thinking and Literacy* (sense and significance of verbal information) and *Systemic Thinking* generates a single variable called *Critical and Systemic Thinking* . In the same sense as the fusion of the variables *Social and environmental responsibility* and the *Teaching of understanding and the human condition* , results in the latent variable called *Formation of human development and social responsibility.* Regarding the integration between the latent variable *Autonomous and self-*

regulated learning with the variable *Problem-solving ability* , the factor analysis produces a single variable identified as *Self-regulated learning in the resolution of complex problems.* This allows us to conclude that the theoretical model is simplified from eleven latent variables to eight, without losing theoretical support. Furthermore, in each latent variable, alignment is perceived with the new educational model of the TecNM, such as the case of *Autonomous and self-regulated learning* , which allows the creation of a scaffolding system "as a state of greater awareness of oneself" (TecNM, 2024, p. 89) and its skills. The other variables also They are implicit in the new educational model of TecNM, since these concepts seek to train students who not only process information to solve problems, but also the formation of a conscious individual "about the social and technological responsibility that frames their professional work (TecNM, 2024, p.131)".

Communication and Digital Literacy variable also aligns with the dialogic capacity promoted by the TecNM Educational Model, strengthening the interaction between the individual, their environment, and digital technologies—aspects that are critical to the teaching role. For higher education professors, measuring this capacity is useful because it not only enables the expression and understanding of ideas in virtual environments but also fosters the development of sociotechnological competencies, especially those related to inclusion, ethics, and the transformation of the environment through science and technology.

Regarding the training of teachers to implement the new educational model, it is necessary to include in teacher training the design and statistical validation of learning assessment instruments, since this correlates with the evaluation of professional competencies, which can activate the evaluation of the curricular design, with educational research projects, evaluating their impact on the formative categories of the published educational model: *Psychopedagogical training of educational research and Educational management and leadership* .

As a key guideline for this research project, we can point out that the competency assessment instrument obtained, composed of eight latent variables and 52 items, can be used as a basis for the assessment of professional competencies in the context of higher education. That is, the eight latent variables can be related to professional competencies in engineering training, and the 52 items can be used as observable variables written as learning outcomes. Figure 3 schematically shows an example of the application of observable variables as performance indicators for the assessment of professional competencies: *design and operation of research projects* .

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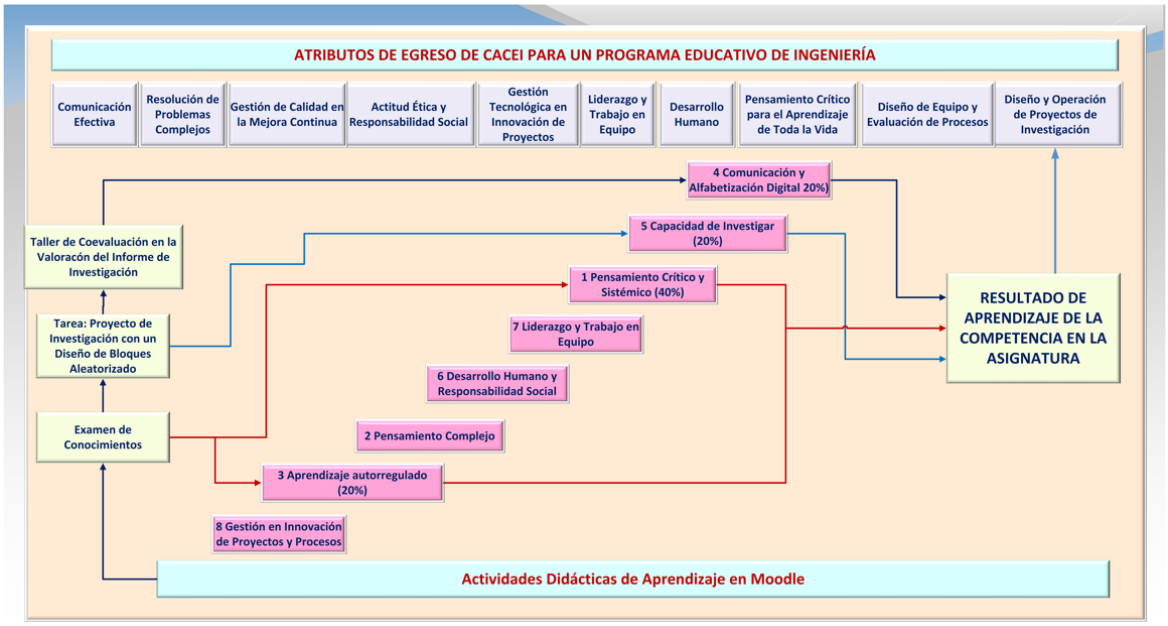
Figure 3. Application of the observed variables as indicators for measuring competence



Note : Prepared by the authors based on the results of the factor analysis.

As detailed in Figure 3, to assess the competency *Design and operation of research projects,* three learning activities can be programmed in Moodle (shown in the figure on the left), associated with various indicators written as learning outcomes and assigned a weighting as formative or summative assessment, thus assessing professional competence, in accordance with the competencies recommended by CACEI.

In conclusion, this research project achieved a rigorous methodological proposal for the standardized assessment of professional competencies, using an instrument validated in both its content and factorial structure, which provides construct validity. By articulating solid theoretical frameworks with the structural equation model, empirical evidence was obtained that supports the relevance, coherence, and applicability of an instrument for the assessment of competencies in higher education. This contributes not only to strengthening competency-based assessment processes but also to aligning assessment practices with the principles of the TecNM institutional educational model and international professional training standards.

Future lines of research

Although the theoretical model of the evaluation instrument presents a good fit in its measurement of content and construct validity, it is advisable to carry out another exploratory

and confirmatory factor analysis research, but now with oblique rotation (allowing correlation between constructs), which can further reduce the dimensionality of the evaluation instrument, since *Critical and Systemic Thinking,* together with *Complex Thinking* , can be the axis that groups other performance indicators, in accordance with the current educational model of TecNM, which establishes that the Critical Thinking Model for Technological Education:

> Its fundamental principle is the permanent construction and reconstruction of knowledge, considering that both thought, not only scientific and technological but also everyday thought, considering that both human thought and all objects, phenomena and processes of nature and society are in constant change, transformation and movement (TecNM, 2024, p. 60).

The results of this new research would allow for the integration of scientific and technological thinking, which utilize literal, logical, and inferential thinking, all of which are involved in the ability to solve problems, as well as design and develop research projects.

On the other hand, the results of this study open the opportunity to conduct another investigation that includes a factorial invariance analysis. This would allow evaluating the stability of the model *in different comparison groups* , since in this research the majority of participants were basic science students. Likewise, this research would determine which latent variables are most relevant in the evaluation of the professional competencies established in the different academic programs offered by TecNM. Furthermore, in updating this instrument to define socio-technological competencies, it is necessary to evaluate the covariances between latent factors to guarantee the conceptual independence of each evaluated competency. In parallel with this new line of research, predictive validity tests can be applied to confirm that performance measured with this instrument correlates with measures external to competency evaluation, such as employer satisfaction, which means evaluating criterion validity (Leyva, 2010).

The scope of this study focused on statistically standardizing the competency assessment instrument in terms of its content and construct validity. Using standardized instruments generates reliable results related to the teaching-learning process, which enables informed decisions regarding curriculum redesign, the development of continuous improvement projects at the institutional level, and educational programs, which contributes to the measurement and improvement of the institutional quality management system indicators.

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Therefore, it is necessary to implement another line of research to evaluate *the criterion-related validity of the developed assessment instrument* , through the determination of correlations, regressions, and scales differentiated by academic groups or educational programs. This research would allow for the establishment of normative performance standards that allow for the interpretation of student results based on their professional competencies and the graduate profile. Through comparative studies by cohort, program, or educational modality, the psychometric indices obtained in the measurement of criterion-related validity could generate cutoff points, percentiles, and normative scales that function as external criteria for validating the learning assessment instrument and the level of achievement of professional competencies.

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