

Divergent Thinking in University Students: Design, Validation and Proposal of a Measurement Instrument with Global Applicability

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ABSTRACT:

Divergent thinking (DT) is a fundamental competency for innovation and problem-solving in higher education. However, there is a marked need for psychometrically validated instruments, especially in Spanish-speaking environments like Ecuador, that allow for the comprehensive and holistic measurement of this construct. This study aimed to design, validate, and verify a questionnaire to assess divergent thinking in university students. A quantitative, instrumental, and cross-sectional methodology was employed. The total sample consisted of 1,033 students from Engineering Science programs at the State University of Milagro. Exploratory and confirmatory factor analyses (EFA and CFA) validated the theoretical structure of four dimensions of divergent thinking: Fluency, Flexibility, Originality, and Elaboration. The psychometric results demonstrated an excellent fit for the proposed model ($KMO=0.982$; $\chi^2/df=2.70$; $CFI=0.950$; $RMSEA=0.0442$) and high internal consistency at both the overall ($\alpha=0.974$) and dimensional (range $\alpha=0.904-0.936$) levels. This validated instrument offers a robust and relevant tool for assessing divergent thinking in higher education, facilitating informed pedagogical decisions in the training of future engineers.

Keywords: Divergent Thinking; Creativity; Psychometric Validation; Measurement Instrument; Engineering; Higher Education.

1. INTRODUCTION

Divergent thinking has been established as a crucial competency in university education, where students are expected not only to acquire theoretical knowledge but also to develop the ability to reason creatively and solve complex problems (Akdemir-Beveridge, Akdemir, & Yildirim, 2025). This competency is essential in a work environment that values innovation and adaptability (Kozbelt, Beghetto, & Runco, 2020). However, valid and reliable tools for assessing

this competency in university students are essential (Guilford, 1956). The lack of appropriate instruments restricts teachers' ability to assess and promote divergent thinking in their classes (Luna-Bazaldúa, Velázquez, & Robles, 2024).

In the academic context, the development of divergent thinking is linked to cognitive and emotional advantages (Ramírez & López, 2023). Recent studies indicate that students with higher divergent thinking skills tend to exhibit better

deductive reasoning abilities and greater resilience to anxiety, as they promote open-mindedness toward multiple opportunities (Hilongos, 2024). In STEM fields, for example, Narvaza & Manla (2024) found that, although university students may exhibit fluency and flexibility, they frequently show low levels of originality and elaboration, which limits their effective creative potential.

The importance of divergent thinking lies in its strong link to creativity, problem-solving, and innovation in academia (Haase, Cagan, & Beaty, 2025). According to Torrance (1974), divergent thinking enables individuals to generate diverse solutions to a problem, which is crucial in a world that is constantly changing and transforming. In this context, promoting divergent thinking in university students not only fosters their personal growth but also equips future professionals to face complex challenges in their respective disciplines (Plucker, Beghetto, & Dow, 2021). Furthermore, divergent thinking has been associated with academic performance and student satisfaction, thus highlighting its importance in education (Sternberg & Lubart, 2020).

Despite its importance, there is a noticeable lack of validated surveys that assess divergent thinking in the Spanish-speaking or local context (Bernal & Aguilar, 2021). Many of the available tools were created in Anglo-Saxon environments and may not be relevant or appropriate for the cultural and educational situation of Spanish-speaking countries (Márquez, Ríos, & Calderón, 2021). This lack of adaptation and validation of tools restricts the ability of researchers and teachers to accurately assess divergent thinking in their students, which impacts the application of effective pedagogical strategies (Fernández, Martínez, & Torres, 2022).

The assessment of divergent thinking faces technical obstacles: aspects such as originality and fluency tend to have low reliability, particularly when frequent scoring techniques are used. Forthmann et al. (2020) showed that the accuracy of initial scores tends to be low (marginal confidence .62–.67; even .50 for single

responses), which requires improvements in methodology.

Therefore, the purpose of this research is to develop and validate a questionnaire that assesses divergent thinking in university students, ensuring its usefulness and relevance in Spanish-speaking environments. This resource will not only offer a useful tool for evaluating divergent thinking but will also support the implementation of educational strategies that promote creativity and innovation in higher education. Validating this questionnaire will enable teachers and administrators to make informed decisions about how to incorporate divergent thinking into their educational programs, thereby fostering a more active and effective learning environment (González et al., 2023).

2. THEORETICAL FRAMEWORK

2.1. Definition

Divergent thinking is an essential mental process in the field of creativity, which involves generating a variety of ideas, perspectives, or responses to a circumstance, problem, or stimulus, without initially expressing concern about their feasibility, relevance, or immediate usefulness (Morales & Ríos, 2022). This type of thinking is based on the freedom to explore different possibilities, enabling people to challenge conventional frameworks, break with established logic, and promote innovation (Fernández-Toro et al., 2021).

One of its most prominent characteristics is the generation of novel and unusual responses that deviate from the traditional, as well as the ability to produce diverse options instead of a single correct answer (Ramírez & Londoño, 2023). In this context, divergent thinking is opposed to convergent thinking, which seeks to recognize a single valid answer or definitive resolution based on logic and deductive analysis (Villalobos, Gómez, & Paredes, 2020). Although convergent thinking is beneficial for activities that demand precision and accuracy, divergent thinking is essential in situations that require creativity, adaptability, and critical analysis skills (Runco & Acar, 2020).

Within the academic context, fostering divergent thinking helps students manage open-ended situations or problems that are not clearly defined, such as those that arise in research, innovation, or entrepreneurship. Furthermore, it promotes skills such as intellectual independence, flexibility in decision-making, and the ability to navigate uncertainty (Ramírez & Londoño, 2023). For this reason, numerous higher education institutions have begun to implement teaching strategies based on active methodologies, such as problem-based or project-based learning, which reinforce this capacity (Silva & Carranza, 2022).

2.1.1. Components of divergent thinking

Divergent thinking consists of several fundamental components that work together to produce creative and innovative solutions. The following are the key elements:

2.1.1.1. Fluency

Fluency refers to the ability to generate numerous ideas within a limited timeframe toward a specific goal. This dimension has been repeatedly confirmed in tests such as the Torrance Tests of Creative Thinking (TTCT), which record the total number of responses provided by participants (Pasarín-Lavín, García, Rodríguez, & Núñez, 2024). Current studies have shown that fluency is one of the most stable indicators of creative thinking and maintains a positive correlation with overall creative performance (Acar, 2022). In academic settings, high fluency has been linked to academic writing skills, logical reasoning, and project development abilities (Hilongos, 2024).

2.1.1.2. Flexibility

Flexibility refers to the ability to modify one's approach or mental tactics when trying to solve a problem or generate ideas. It involves not only generating numerous responses but also diversifying the categories or classes of responses provided. Current research, such as that by Groeneveld et al. (2022), has highlighted that flexibility is linked to the ability to adapt in academic settings, particularly among computer science and engineering students who need to move between diverse conceptual and

methodological frameworks. Factor analysis of tests such as the ECAT (Engineering Creativity Assessment) also recognizes flexibility as a distinct dimension of problem-solving (Akdemir-Beveridge et al., 2025).

2.1.1.3. Originality

Originality refers to the scarcity or uniqueness of ideas generated in relation to responses to established norms. It is usually assessed from a statistical or qualitative perspective (e.g., frequency of occurrence within a standard sample). Forthmann et al. (2020) identified limitations in the reliability of originality scores when based solely on frequency without considering conceptual quality. However, recent advances such as the S-DAT instrument (Haase et al., 2025) employ artificial intelligence and semantic distance analysis to assess originality impartially, suppressing inter-rater bias. This innovation represents significant progress toward the automated assessment of original thinking in global contexts.

2.1.1.4. Elaboration

Elaboration refers to the ability to detail, develop, or enhance an original idea. Despite being the least analyzed dimension, it is perceived as an indicator of the student's cognitive engagement with creative work (Runco, 2021). In educational design studies, such as those conducted by Tzeng and Liu (2023), it has been shown that students with high elaboration also exhibit higher levels of metacognitive thinking and the ability to transfer concepts. Similarly, in the validation of the TransDis instrument (Yang et al., 2023), elaboration was considered a relevant characteristic of creative writing performance in Chinese university students.

The analysis of these dimensions has allowed various authors and disciplines to develop creativity models applicable to higher education. For example, in developing the C-SCA (Comprehensive Scientific Creativity Assessment) instrument, Wu, Liu, and He (2024) used confirmatory factor analysis to confirm that the four dimensions of creative thinking can be

consistently assessed in science-oriented secondary and university students.

In teaching practice, promoting these dimensions requires active teaching strategies such as project-based learning, divergent questioning, formative assessment, and collaborative work (Haase, Hanel, & Pokutta, 2025). Recent studies demonstrate that teachers who integrate development-oriented activities observe improvements in their students' intrinsic motivation, self-efficacy, and academic performance (Said -Metwaly, Fernández-Castilla, & Barbot, 2022).

Therefore, understanding divergent thinking as a multidimensional construct allows for both a more accurate assessment of the creative abilities of university students and the development of more effective and equitable educational interventions.

2.2. Previous instruments

2.2.1. Torrance Tests of Creative Thinking (TTCT)

The TTCT (verbal and figural) remains the most widely used instrument worldwide for assessing the classic dimensions of divergent thinking: fluency, flexibility, originality, and elaboration. Several studies confirm its high inter-rater reliability (greater than 90%) and its temporal stability (test-retest scores between 0.59 and 0.93), positioning it as a robust instrument in educational contexts (Runco & Jaeger, 2020; Warne, Golightly, & Black, 2022). However, recent research shows that the fluency dimension can distort the scores for originality and elaboration, leading to an overestimation of creativity when using total scores (Acar, 2022).

However, Acar et al. (2023) have suggested an automated scoring system for the verbal TTCT using natural language processing, showing correlations of .60 to .72 with human ratings. This innovation represents significant progress toward standardizing the instrument and reducing inter-rater bias. Nevertheless, Forthmann et al. (2020) suggest avoiding the use of overall scores on the TTCT and instead analyzing each dimension

independently to ensure a more accurate assessment of divergent thinking.

2.2.2. Remote Association Testing (RAT)

The Remote Associates Test (RAT), created by Mednick and Mednick (1962), was initially designed to assess convergent thinking, but it has often been used as an additional indicator in studies on creativity and divergent thinking. Current versions of the RAT have demonstrated high reliability (α between .91 and .92) across various languages and groups of people (Kenett et al., 2020). However, its validity as a sole indicator of creative thinking remains a subject of debate, as it requires specific verbal skills and operates under a single-solution logic.

Recent research has attempted to increase its usefulness through computational methods. For example, Kenett et al. (2020) used semantic networks and computer models to investigate the cognitive processes underlying RAT, which has facilitated a better understanding of the interrelationships between convergent and divergent thinking. However, its application as the main indicator of creative thinking still needs to be complemented with other tools (Warne et al., 2022).

2.2.3. Self-reports

Self-report measures have become established as complementary and alternative tools for assessing divergent thinking in university settings, particularly by encompassing the emotional, motivational, and contextual aspects of creativity. For this reason, Groeneveld, Dierick, and Van der Meijden (2022) created a self-assessment scale for computer science students, based on seven dimensions of creative thinking. This scale demonstrated excellent internal consistency ($\alpha = .91$) and a factor structure suitable for the university-level population.

In another study, Tzeng and Liu (2023) modified a design thinking instrument for nursing students in Taiwan, focusing on creativity as a transversal competency. The validation process included expert review, exploratory factor analysis, and shaping, achieving adequate fit indices (CFI = .95; RMSEA = .06). These studies demonstrate

that properly designed and validated self-report measures can complement direct performance tests such as the TTCT, providing a more comprehensive perspective on divergent thinking.

2.3. Content validity, construct validity, and reliability: psychometric foundations (AERA, APA, NCME, 2014)

Reliability and validity are crucial factors in the development and evaluation of psychological and educational tools. According to the Standards for Educational and Psychological Testing issued by the AERA, APA, and NCME (2014), any instrument should be evaluated based on its content validity, construct validity, and reliability.

2.3.1. Content validity

Content validity refers to the degree to which the elements of an exam or tool accurately and completely reflect the entire theoretical construct being analyzed (Muñiz & Fonseca-Pedrero, 2019). This type of validity is particularly significant in the early stages of instrument design, as it ensures that the incorporated questions or items align with the key elements of the phenomenon being analyzed and do not overlook essential aspects or include insignificant components.

For divergent thinking, content validity takes on particular relevance, as this construct comprises several dimensions: fluency, originality, flexibility, and elaboration (Forthmann et al., 2020; Morales & Ríos, 2022). To ensure an accurate representation of the construct, it is essential that the components of the designed instrument address each of these dimensions in a balanced way. Fluency refers to the quantity of ideas generated; originality, to their novelty or exceptionality; flexibility, to the variety of categories used; and elaboration, to the degree of thoroughness and development of the ideas (Silvia et al., 2022).

Hilongos (2024) developed a method to assess creative thinking in science students, employing a panel of internationally recognized experts. The findings showed CVI coefficients exceeding 0.80 and CVR coefficients exceeding 0.60, indicating appropriate content representation. Similarly,

Akdemir-Beveridge et al. (2025) used rigorous content standards in developing the Engineering Creativity Assessment Tool (ECAT), incorporating expert judges in engineering, education, and psychometrics to confirm that the suggested tasks adequately reflected the construct of divergent thinking in technical contexts.

Furthermore, several authors indicate that achieving high content validity requires the intervention of specialists in the specific field, who, through technical judgment, evaluate the relevance, clarity, and representativeness of the items (Escobar-Pérez & Cuervo-Martínez, 2008). This facilitates the identification of possible cultural or linguistic biases, particularly relevant in tests adapted to Spanish-speaking contexts.

2.3.2. Construct validity

Construct validity refers to the degree to which an instrument effectively assesses the theoretical construct it seeks to examine, and is determined by verifying that the empirical structure resulting from the data coincides with the previously established theoretical structure (Muñiz & Fonseca-Pedrero, 2019). This validation is primarily carried out through statistical methods such as exploratory and confirmatory factor analysis, which facilitate the identification of the instrument's dimensionality and the verification of consistency between the elements and dimensions of the construct.

For the Torrance Test of Creative Thinking (TTCT), frequently used to assess divergent thinking, several recent studies have indicated inconsistencies in its factor structure. Forthmann et al. (2020) and Acar (2022) found that when managing for the impact of fluency—one of the most prominent dimensions of divergent thinking—the TTCT's structure often shrinks to two-factor or even one-factor models. This has raised questions about the legitimacy of using composite scores without considering the unequal weighting of its components. These findings have prompted a critical analysis of the use of aggregated scores in the assessment of innovative thinking.

In contrast, more recent instruments such as the Evaluation of Creative and Analytical Thinking (ECAT) have demonstrated empirical results more consistent with the theoretical model of divergent thinking. In a recent study, Akdemir-Beveridge et al. (2025) detected a four-element structure that aligns with the theoretical dimensions of the construct (fluency, originality, flexibility, and elaboration), corroborated through a confirmatory factor analysis with solid fit indices ($CFI = .96$; $TLI = .94$; $RMSEA = .05$). Similarly, Tzeng and Liu (2023) confirmed the validity of a modified version of the ECAT in the context of nursing education, where significant factor loadings and a consistent structure were detected, which strengthens the construct validity of the instrument in various pedagogical contexts.

These findings highlight the importance of empirically verifying the connection between the collected data and the intended conceptual structure, particularly in tools designed to assess complex competencies such as divergent thinking, where reliable assessment is crucial for diagnostic, educational, and research uses.

2.3.3. Reliability

The reliability of a psychometric instrument refers to its ability to provide consistent and stable results over time, across different uses or evaluators, which is crucial for ensuring accuracy in measuring a construct (Muñiz & Fonseca-Pedrero, 2019). According to international standards for educational and psychological examinations, established by the AERA, APA, and NCME (2014), a Cronbach's alpha coefficient exceeding .70 is considered acceptable, and an omega coefficient exceeding .80 is advisable, particularly in applied research or personal assessment settings.

In the context of divergent thinking, the Torrance Test of Creative Thinking (TTCT) remains a frequently used instrument, demonstrating reliability coefficients above .85 in

various international samples, corroborating its internal robustness (Runco & Jaeger, 2020). However, several authors have indicated that this reliability could be affected by the high correlation with the fluency dimension, highlighting the importance of examining the dimensions individually.

Regarding self-reports, the scale proposed by Groeneveld et al. (2022) obtained a total reliability of $\alpha = .91$, with values for dimensions greater than .85. In research in Spanish, instruments with similar characteristics have been developed; for example, the creative thinking questionnaire of Luna-Bazaldúa et al. (2024), applied to university students in Mexico, showed reliability coefficients between .82 and .89, demonstrating adequate internal consistency.

The ECAT (Evaluation of Creative and Analytical Thinking) instrument, recently validated in engineering and applied sciences, showed reliability coefficients between .86 and .94 (Akdemir-Beveridge et al., 2025). This evidence has been supported by research in Spanish-speaking countries that highlights the importance of adapting instruments to the sociocultural context (Silva & Carranza, 2022; Bernal & Aguilar, 2021).

In recent years, technological advances have enabled the incorporation of automated scoring systems, based on artificial intelligence, to assess open-ended creativity tasks. Acar et al. (2023) and Haase, Hanel, and Pokutta (2025) developed computational tools such as the S-DAT (Semantics-based Divergent Association Task), which show correlations between .60 and .81 with human scores, supporting both their inter-rater reliability and concurrent validity. These innovations offer a viable and scalable alternative for the automated measurement of divergent thinking, especially in educational settings with large student populations.

The following table details the instrument's name, objective, dimensions, and main characteristics:

Table 1: Instruments for assessing divergent thinking

Name of instrument	Aim	Dimensions evaluated	Main features
Torrance Tests of Creative Thinking (TTCT)	Measuring divergent thinking in children and adolescents.	Fluency, Flexibility, Originality, Elaboration	Verbal and figurative version; includes tasks of completing drawings and stories; validated mainly in children.
Remote Associates Test (RAT)	Evaluate the ability to make remote semantic associations.	Conceptual associations (originality and flexibility)	Brief verbal test; it requires finding a word that relates to three others; it is more linked to convergent thinking.
Alternate Uses Test (AUT)	Measure fluency, flexibility, and originality in creative responses.	Fluency, Flexibility, Originality	Open task that asks for unusual uses of common objects; dependent on the cultural and verbal context of the participant.
Creative Achievement Questionnaire (CAQ)	Evaluate creative achievements in different artistic or scientific areas.	It does not directly measure dimensions (self-reporting)	Retrospective questionnaire on personal achievements; useful as a complement to other instruments.
Figural Creativity Test (FCT)	Measuring graphic creativity in school-aged children.	Fluency, Originality, Elaboration	Based on drawings and graphic compositions; suitable for elementary and secondary school students.
Design Creativity Assessment (DeCA)	Evaluate creativity in design and engineering students.	Originality, Elaboration, Quality, Viability	Technical design scenarios; aimed at adults; includes evaluation rubrics.
Engineering Creativity Assessment Tool (ECAT)	Measuring creative thinking in engineering contexts.	Fluency, Flexibility, Originality	Scenarios applied with expert evaluation; validated in university engineering students.
Self-Report Creative Problem Solving Scale	Measuring perception of creative thinking skills in students.	Fluency, Flexibility, Persistence, Motivation	Likert-type questionnaire; designed for university students (computer science); good internal reliability.
Comprehensive Scientific Creativity Assessment (C-SCA)	Measuring creative thinking in science and problem solving.	Fluency, Originality, Flexibility	It includes open-ended problems, verbal and visual tasks; designed for teenagers and university students.

TransDis (Automatic DT Assessment)	Evaluate divergent thinking automatically using AI.	Fluency, Originality, Flexibility	Based on computational semantic distance; automated evaluations; useful in multilingual and global contexts.
S-DAT (Semantic- Distance Assessment Tool)	Measuring verbal creativity through semantic processing.	Originality (semantics), Flexibility	Uses natural language models to score open-ended responses; validates automatically using AI; useful in adults.

As can be seen in Table 1, most conventional instruments such as the TTCT, FCT, or AUT were created for children, adolescents, or educational settings, and rely heavily on human interpretation or graphic tasks that are not always compatible with university education. Furthermore, many of these instruments have not been widely validated for use with university-educated adults, or they exhibit cultural and linguistic limitations (Runco & Jaeger, 2020; Forthmann et al., 2020).

On the other hand, the most modern instruments, such as the ECAT, the C-SCA or the S-DAT, although they advance in technological and psychometric validity, do not always integrate the four classic dimensions (fluency, flexibility, originality and elaboration) into a single theoretical-practical framework applicable globally (Acar et al., 2023; Haase et al., 2025).

Therefore, the creation and validation of an instrument specifically designed for older university students, focusing on the four dimensions and its intercultural application, represents an evident empirical and methodological requirement in the field of divergent thinking assessment.

Methodology

The following study is a quantitative, non-experimental, cross-sectional, descriptive and instrumental approach.

Participants

The sample consisted of 1,033 higher education students. A non-probability convenience

sampling method was used for the study (Martínez et al., 2022), selecting students from the various degree programs within the Faculty of Engineering Sciences at the State University of Milagro. Participants were recruited voluntarily. The distribution of the total sample by degree program is detailed in the Results section (Frequency Table).

Procedure

In this process for the design of the instrument, it was carried out in four different stages with the objective of explaining the execution process, which was divided into: instrument design, creation of the form, expert judgment, pilot study, application of the final test and statistical analysis.

Instrument design

The questionnaire was designed and structured based on the classic psychometric model of divergent thinking, which defines it through its four fundamental dimensions: Fluency, Flexibility, Originality, and Elaboration (**Guilford, 1956; Torrance, 1974**). A preliminary set of 40 items, formulated as statements using a Likert-type scale, was developed to measure engineering students' ability to generate novel and varied solutions in academic and professional contexts. The item formulation intentionally sought to minimize cultural and linguistic bias, following the global applicability criteria discussed in the literature to ensure its relevance in the university setting.

Expert judgment

The content validity of the instrument was verified through expert judgment by ten experts (ten was the number required for consensus), all of whom had recognized expertise in psychometrics, educational assessment, and creativity, with specific experience in higher education contexts. This process is essential to align the instrument with the theoretical construct and avoid bias (Escobar-Pérez & Cuervo-Martínez, 2008; Akdemir-Beveridge et al., 2025). These professionals evaluated the relevance, semantic clarity, and theoretical representativeness of the initial 40 items with respect to the four dimensions of divergent thinking. The experts agreed on the coherence of the proposed dimensions and suggested minor wording adjustments to improve item clarity, which strengthened the instrument's content validity before the pilot phase (Hilongos, 2024).

Form

The instrument was designed and implemented on a Google Forms digital platform to automate the data collection process. Before adding the questions, informed consent was obtained to protect participants' rights in accordance with the ethical principles of Helsinki.

Pilot study

The objective of this study was to design and validate an instrument. Before its final application, a pilot study was conducted to examine the clarity of the items and ensure they were easy for participants to read. Additionally, the internal consistency of the items and their feasibility for use in the instrument were analyzed.

In this case, a pilot test was administered to 166 higher education students, selected from a sample using non-probability convenience sampling. The instrument was administered synchronously on a

digital platform, under the same conditions planned for the final implementation.

The participants completed the form without any comprehension difficulties; the average response time was XX minutes. The overall internal consistency of the data was assessed using Cronbach's alpha, and the following result was obtained.

The instrument's questions were not modified after the pilot study, and similar or equivalent conditions were used in the general sample. Therefore, the 166 observations were added to the total data set. This decision was based on Muñiz's guidelines or recommendation, which states that the pilot study can be included in factor analyses if the instrument's content is altered.

Final application.

After completing the pilot phase and finding no further adjustments or modifications to the questions necessary, the questionnaire was implemented in its final form. During this process, data was collected for the study's exploratory and confirmatory statistical analyses.

The final test was administered to 867 university students, using a digital format similar to the pilot study, maintaining the same conditions, scales, and information. The number of data collected in the pilot study ($n=166$) and the final sample size ($n=867$) were also affected.

Statistical analysis

This study was conducted in Jamovi for the statistical analysis process used to validate the questionnaire. Before proceeding, it was necessary to determine if there were any missing or incomplete data. An exploratory factor analysis was applied to identify latent variables, and a confirmatory factor analysis was used to verify the questionnaire's structure.

Results

	Frequency	Percentage
Food (1)	119	11.5
Environmental (2)	112	10.8
Architecture (3)	32	3.1
Biotechnology (4)	226	21.9
Software Engineering (5)	220	21.3
Industrial Engineering (6)	319	30.9
Information technology (7)	5	0.5
Total	1033	100.0

exploratory factor analysis

In any statistical process, it is important to verify the dataset to ensure no information is lost; therefore, the aforementioned process was carried out. An exploratory factor analysis is primarily based on detecting the latent variables

that are to be identified within the set of items being formed.

To conduct the exploratory factor analysis, it was necessary to perform the KMO test and Bartlett's test of sphericity, both of which assess the suitability of the data. Table 1 below presents the results of the KMO and Bartlett tests.

Table 1. Kaiser-Meyer-Olkin (KMO) and Bartlett tests

KMO and Bartlett Test		
Kaiser-Meyer-Olkin measure of sampling adequacy		
		0.982
Bartlett's sphericity test	Approx. Chi-square	22719
	Gl	780
	Next.	,000

The exploratory factor analysis was conducted with a total of 40 questions, which were distributed across four factors. The factor analysis revealed four latent factors. Item 1 showed a loading of less than 0.30, and item 31 loaded onto another factor, so these items were removed. After the removal process, the four factors were retained, with 38 items in total: 10

items in the first factor, 9 items in the second, 10 items in the third, and 10 items in the fourth.

Table 2 presents the factor loadings for each item, showing loadings greater than 0.3, as established by Mavrou (2015), where four factors have been identified, as indicated by the questionnaire author. It should be noted that the items have been modified and are now as follows.

Table 2

Factor Loads

	Factor				Uniqueness
	1	2	3	4	
PDOR28	0.881				0.408
PDOR27	0.771				0.427
PDOR29	0.761				0.381
PDOR26	0.692				0.393
PDOR25	0.669				0.432
PDOR22	0.662				0.482
PDOR21	0.627				0.422
PDOR30	0.546				0.451
PDOR24	0.545				0.451
PDOR23	0.504				0.426
PDEL36		0.794			0.392
PDEL37		0.763			0.347
PDEL35		0.751			0.376
PDEL39		0.740			0.357
PDEL38		0.717			0.444
PDEL34		0.671			0.384
PDEL40		0.625			0.332
PDEL33		0.565			0.387
PDEL32		0.518			0.437
PDFX15			0.724		0.405
PDFX16			0.714		0.375
PDFX13			0.661		0.391
PDFX19			0.659		0.432
PDFX11			0.659		0.412
PDFX14			0.585		0.377
PDFX20			0.583		0.381
PDFX12			0.535		0.426
PDFX18			0.479		0.444
PDFX17			0.335		0.478
PDFZ7				0.768	0.388
PDFZ8				0.743	0.404

Factor Loads

	Factor				Uniqueness
	1	2	3	4	
PDFZ4				0.723	0.443
PDFZ5				0.646	0.472
PDFZ9				0.596	0.576
PDFZ3				0.576	0.533
PDFZ2				0.556	0.508
PDFZ10				0.430	0.565
PDFZ6			0.313	0.387	0.522

Note. The 'Main axis factoring' extraction method was used in combination with a 'promax' rotation.

The table shows the results of the variance extraction of the four latent factors that have been formed, where factor 1 collects 15.6% of the information, while the second factor has 14.7%,

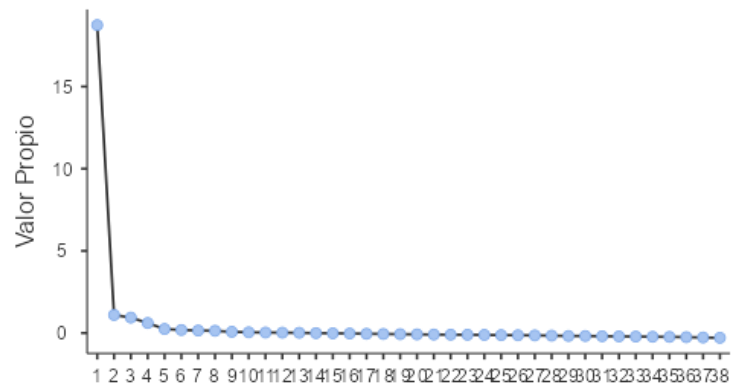
the third factor 14.4% and finally the fourth factor 12.6%, the total of the four factors that have been formed with a total of 57.2%.

Table 1 Sedimentation Graph

Summary

Factor	SC Loads	% of the Variance	% Cumulative
1	5.91	15.6	15.6
2	5.58	14.7	30.2
3	5.46	14.4	44.6
4	4.79	12.6	57.2

Board Percentage of variance explained



In the next step, confirmatory factor analysis is performed. This type of analysis aims to corroborate the proposed factor structure of the model. To determine if a model is optimal or adequate, it is necessary to consult the fit indices according to the study. The table shows the results of the model fit indices. The factor model

confirmatory factor analysis

was obtained with the following values: $\chi^2 = 1777$, $df = 659$, $p = .001$, Comparative Fit Index (CFI = 0.950), Tucker-Lewis Index (TLI = 0.947), Root Mean Square Error of Approximation (RMSEA = 0.0442), and Standardized Root Mean Square Error (SRMR = 0.0304).

Board

Adjustment Measures

90% CI of RMSEA							
CFI	TLI	SRMR	RMSEA	Lower	Superior	AIC	BIC
0.950	0.947	0.0304	0.0442	0.0418	0.0467	76457	77029

The results of the internal consistency, as shown in the table using Cronbach's alpha coefficient, indicate and demonstrate that the designed and validated instrument has adequate reliability for assessing the divergent thinking variable. Specifically, the coefficients are described in both

dimensional and general terms, ranging from $\alpha = 0.904$ to 0.974 . The first factor has $\alpha = 0.928$, the second factor $\alpha = 0.936$, the third factor $\alpha = 0.933$, and the fourth factor $\alpha = 0.904$. These values reflect very good internal consistency.

Board Internal consistency of the data.

Items	Cronbach's alpha
Factor 1	0.928
Factor 2	0.936
Factor 3	0.933
Factor 4	0.904
General	0.974

Discussion

The main objective of this research was to design and validate a psychometric instrument for assessing divergent thinking (DT) in university engineering students. The results of content validation, exploratory factor analysis (EFA), and confirmatory factor analysis (CFA) demonstrate that the proposed questionnaire is a robust,

reliable, and relevant instrument that meets the rigorous psychometric standards required in the educational field.

Theoretical Convergence and Dimensional Structure

The empirical findings confirm the multidimensional structure of the construct, representing one of the fundamental

contributions of this study. Confirmatory factor analysis verified a latent four-factor model, which aligns perfectly with the classic dimensions of writing competence: Fluency, Flexibility, Originality, and Elaboration.

This structure reaffirms the validity of the traditional theoretical framework established by pioneers such as (Guilford, 1956) and (Torrance, 1974). Obtaining excellent fit indices in the AFC (CFI=0.950, TLI=0.947, RMSEA=0.0442) corroborates that the empirical structure of the instrument agrees with the theoretical conceptualization of the PD, similar to that reported in successful validations of modern instruments in technical contexts, such as the ECAT. (Akdemir-Beveridge, Akdemir, & Yildirim, 2025)

Our results contrast with the psychometric limitations identified in the assessment of creative potential. The literature has cautioned that traditional instruments often exhibit a "fluency bias" that distorts the scores for the Originality and Elaboration dimensions, frequently leading to simpler or unifactorial factor models (Acar, y otros, 2023). The success of our instrument in clearly distinguishing the four factors suggests that the wording and conceptualization of the items effectively isolate these dimensions, overcoming the problem of excessive correlation between Fluency and the other measures—a crucial aspect for obtaining a more accurate assessment of creative potential, as emphasized by the authors (Runco & Jaeger, On the nature of divergent thinking, 2020).

Measurement Reliability and Accuracy

The internal consistency demonstrated by the questionnaire is a noteworthy finding. The Cronbach's alpha coefficients obtained were extremely high, both overall ($\alpha=0.974$) and for each of the factors (range $\alpha=0.904$ – 0.936). This high reliability ensures that the instrument provides stable and consistent results, which is fundamental for its use in contexts where decision-making (diagnostic, educational, or research-related) depends on the accuracy of the measurement (Muñiz & Fonseca Pedrero, 2019).

This consistency is comparable to or better than that reported in validated self-report questionnaires for university populations, such as the one developed by [author's name missing]. (Groeneveld, Dierick, & Van der Meijden, 2022)

Contextual Relevance and Global Applicability

The validation of the instrument in engineering students at the State University of Milagro addresses a critical need identified by several authors: the lack of validated psychometric tools relevant to Spanish-speaking cultures (Bernal & Aguilar, 2021). Content validation, supported by expert judgment (Escobar Pérez & Cuervo Martínez, 2008), ensured that the language and concepts were appropriate for this context, mitigating the cultural and linguistic barriers that often affect the measurement of creative thinking in Spanish-speaking students (Ramírez & López, 2023).

The choice of the Engineering population underscores the importance of evaluating the PD in STEM fields, where innovation is a key competency (Hilongos, 2024) (Narvaza & Manla, 2024). By providing a specific tool for this group, the study supports the promotion of active educational strategies (Ramírez & Londoño, 2023) that seek to cultivate the ability of future professionals to generate novel and varied solutions (Morales & Ríos, 2022), thus contributing to the training of competent professionals to face the challenges of the 21st century (Plucker, Beghetto, & Dow, 2021).

Future and Technological Implications

While the study is based on a rigorous and traditional methodology, the context of PD assessment is rapidly evolving. The use of the digital platform (QuestionPro) facilitated massive and synchronous data collection. However, future research should consider integrating technological advancements for scoring, such as AI-assisted systems for evaluating open-ended tasks (Acar, y otros, 2023). These developments promise a scalable and objective alternative, improving inter-rater reliability, although our instrument, being a validated self-report, already

offers a practical and immediately applicable solution.

Limitations

Despite strong validity and reliability indicators, the main limitation lies in the local nature of the sample, confined to a single university and engineering programs. Although content validation aimed for global applicability, cross-validation studies in other Spanish-speaking regions are recommended to confirm construct invariance.

Conclusions

Initially, content validation through expert judgment allowed for determining the relevance and semantic clarity of the questions used to assess divergent thinking in undergraduate engineering students. The professionals who evaluated the instrument agreed that the proposed dimensions were coherent and requested minor adjustments to the wording. This strengthened the semantic aspect of the content for the subsequent process, thus supporting or reinforcing the instrument's content validity.

Secondly, the pilot study was conducted with a sample of 166 participants matching the characteristics of the target population, yielding favorable results. Internal consistency of the instrument was determined using Cronbach's alpha, within the established range of 0.882–0.976. Overall, the instrument obtained an alpha score of 0.976, with factors 1 at 0.950, 2 at 0.894, 3 at 0.924, and 4 at 0.882. This demonstrates the stability and reliability of the instrument in the pilot study, thus fulfilling the requirements for its subsequent mass implementation.

Thirdly, the exploratory factor analysis (EFA) was relevant, because it confirmed between the proposed theoretical model with the empirical structure of four components, so the KMO tests were used with a value of 0.982 and the Bartlett's sphericity ,000, both values allowed us to know

that the data are adequate to carry out the EFA, it should be mentioned that two items were removed because one of them was less than 0.30 and loaded on another factor.

Following the analysis of the EFA, the structure of the model was verified through confirmatory factor analysis (CFA). The fit structure was verified using appropriate validity indices. Therefore, it was appropriate to apply a CFA, which aims to corroborate the factors proposed in the model. According to the model, the following results were obtained: CFI=0.950, TLI=0.947, SRMR=0.0304, RMSEA=0.0442. Therefore, the indices are adequate according to the scientific literature.

Similarly, internal consistency was determined by applying Cronbach's alpha, which aims to determine the reliability of the designed instrument. A score of α was obtained in the final application of the instrument, confirming its internal consistency across the dimensions. At a global level, it has a range between $\alpha=0.904$ –0.974, thus demonstrating stability in its reliability analysis. This indicates that the instrument is reliable in the higher academic context of the Engineering program.

This study is relevant because it explores new empirical horizons that evaluate divergent thinking at the higher level of the Engineering degree. This proposed tool aims to guide pedagogical improvements and how these, in turn, can help future professionals develop new ideas in the professional field, as well as analyze them from a critical point of view based on fluency, flexibility, originality, and elaboration.

Finally, this study has limitations and proposes new lines of research; therefore, it is recommended that it be applied in other degree programs, taking into consideration gender and semester level, in order to understand its application in other academic contexts that allow for the evaluation of divergent thinking.

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