Validation of a diagnostic instrument on the prerequisites for the subject of technical drawing in higher education

Validación de un instrumento de diagnóstico sobre los prerrequisitos de la asignatura de dibujo técnico en educación superior

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Abstract

The importance of prerequisites—that is, essential prior knowledge—in the constructivist approach lies in that they constitute the foundation upon which new learning is built. However, in the context of technical drawing in higher education, this process is limited by the lack of these prior competencies, which hinders both the approach to related subjects and the development of specialized skills. Given this situation, this research aimed to validate a diagnostic instrument designed to assess the necessary prerequisites in the subject of technical drawing. To this end, a methodology was adopted that integrated a deductive and mixed approach, with a descriptive-explanatory scope and a non-experimental cross-sectional design. The Delphi method was also used for expert selection and the Lawshe model to ensure the instrument's content validity. Among the main results, the identification of 35 prerequisites, classified as fundamental and attitudinal, stands out, as well as the development of the "Technical Drawing Prerequisites Questionnaire for Higher Education," composed of 30 items distributed across three dimensions: conceptual, procedural, and attitudinal. The statistical validation of the instrument yielded solid results, with a correlation of 0.9, a Cronbach's alpha of 0.93, and a Kappa index of 1. Ultimately, this instrument is presented as a key tool for diagnosing training gaps, allowing educational institutions to implement

effective remediation strategies that contribute to strengthening the teaching-learning process in this technical discipline.

Keywords: higher education, Delphi method, technical drawing prerequisites, instrument validation.

Resumen

La importancia de los prerrequisitos -es decir, los conocimientos previos esenciales- en el enfoque constructivista radica en que constituyen la base sobre la cual se construyen nuevos aprendizajes. Sin embargo, en el contexto del dibujo técnico en la educación superior, este proceso se ve limitado por la falta de dichas competencias previas, lo que dificulta tanto el abordaje de asignaturas relacionadas como el desarrollo de habilidades especializadas. Ante esta situación, la presente investigación se propuso validar un instrumento diagnóstico diseñado para evaluar los prerrequisitos necesarios en la asignatura de dibujo técnico. Para ello, se adoptó una metodología que integró un enfoque deductivo y mixto, con un alcance descriptivo-explicativo y un diseño transversal no experimental. Asimismo, se empleó el método Delphi para la selección de expertos y el modelo Lawshe para asegurar la validez de contenido del instrumento. Entre los principales resultados, se destaca la identificación de 35 prerrequisitos, clasificados en fundamentales y actitudinales, así como la elaboración del "Cuestionario de Prerrequisitos de Dibujo Técnico para Educación Superior", compuesto por 30 ítems distribuidos en tres dimensiones: conceptual, procedimental y actitudinal. La validación estadística del instrumento arrojó resultados sólidos, con una correlación de 0,9, un alfa de Cronbach de 0,93 y un índice Kappa de 1. En definitiva, este instrumento se presenta como una herramienta clave para diagnosticar brechas formativas, permitiendo a las instituciones educativas implementar estrategias de nivelación efectivas que contribuyan a fortalecer el proceso de enseñanza-aprendizaje en esta disciplina técnica.

Palabras clave: educación superior, método Delphi, prerrequisitos de dibujo técnico, validación de instrumento.

Introduction

The significance of prerequisites or prior knowledge, acquired through a constructivist approach, lies in their fundamental role as a foundation for constructing new learning. According to Piaget (1970) and Vygotsky (1978), learning is conceived as a process of progressive accumulation, in which individuals integrate new information with preexisting knowledge, thereby facilitating the understanding of complex concepts.

In the context of higher education, the ability to connect experiences and prior knowledge with new content is essential for promoting meaningful learning in professional training. As noted by Trujillo (2024), the complexity of content at this level requires skills in critical analysis, synthesis, and practical application of knowledge to achieve comprehensive training.

It is important to highlight that prior knowledge in specific areas, both in the humanities such as sociology and in exact sciences like mathematics, is crucial for academic success in higher education. This knowledge acts as a cognitive scaffold that facilitates understanding and learning (Riveros, 2023). However, the lack of specific prior knowledge upon entering higher education hampers the comprehension of abstract concepts and obstructs the development of specialized competencies.

Particularly, this deficiency represents a significant challenge, as Alcívar (2024) warns that the absence of basic foundations, combined with the complexity of the content, negatively impacts students' academic performance, generating cognitive overload that hinders the effective assimilation of new material and limits the development of essential competencies in the field. Thus, gaps in prerequisites adversely affect academic performance and have repercussions on the study of complementary subjects.

In this regard, both international and national studies show low performance in technical areas of higher education, attributable to deficiencies in pre-university training. At the international level, UNESCO (2022) reports that 58% of engineering students in developing countries face difficulties in basic subjects due to the disconnection between secondary curricula and university demands. In Ecuador, the INEC (2023) reports that 42% of higher education students fail at least one basic course in the first cycle, with integral calculus (35%) and technical drawing (28%) being the most critical.

Regarding the most relevant background on the validation of diagnostic instruments in higher education, various recent studies underscore their importance. Among them, the work of Gómez (2020), titled “Design and validation of an analytical rubric for evaluating skills in technical drawing for mechanical engineering students,” highlights the need to employ standardized tools to measure graphic accuracy and the interpretation of international technical standards, concluding that rigorous validation of assessment instruments is essential to ensure the reliability of results and the development of technical competencies.

Complementarily, the research conducted by Fernández (2021), focused on validating a digital test for special skills in architecture, demonstrated that early identification of deficits through psychometrically sound tools allows for personalized teaching and reduces dropout rates. Thus, it concludes that the validation of instruments is fundamental to guarantee the accuracy and effectiveness of diagnostics, optimizing pedagogical strategies.

It should be noted that the absence of standardized instruments to evaluate prerequisites in technical drawing among university students complicates the creation of effective leveling courses and contributes to dropout, especially among vulnerable students (Demarchi, 2020). Therefore, it is imperative to develop comprehensive diagnostic tools that ensure a fair and successful transition to higher education.

Ultimately, the background presented justifies the need for this study, whose main objective is to fill the existing gap regarding the lack of validated instruments and systematic studies to diagnose the basic knowledge of technical drawing among engineering students, considering the diversity in their prior training.

In this context, it is essential to carry out the evaluation or diagnosis of prerequisites to identify potential educational gaps and design strategies that facilitate the transition and adaptation of students. As Espinoza (2022) points out, the application of diagnostic assessments to detect areas for improvement lays the groundwork for strengthening key competencies.

Consequently, this study focuses on validating a diagnostic instrument called “Technical Drawing Prerequisites for Higher Education,” with the following specific objectives: to identify the prerequisites for the technical drawing course and to construct the corresponding diagnostic instrument for application in higher education.

Methodology

The research was conducted using a deductive method with a mixed approach, allowing for a comprehensive address of the validation process of the diagnostic instrument regarding technical drawing prerequisites for higher education. According to Creswell (2018), the mixed approach, by combining qualitative and quantitative elements, facilitates a constructive understanding of the studied phenomenon through methodological triangulation and data analysis. This approach also favored the identification of key factors for the design of the instrument, which was subsequently subjected to a validation process grounded in empirical evidence and the criteria of specialized experts.

Moreover, the study adopted a descriptive-explanatory scope, as it identified the fundamental elements (prerequisites) that constituted the diagnostic instrument, specifically designed to evaluate the level of knowledge and skills in technical drawing within the context of higher education. Complementarily, the explanatory component allowed for the analysis of the stability, internal consistency, and relationships among the instrument's items. This dual methodological approach is based on Hernández et al. (2021), who state that the descriptive scope enables systematic characterization of a phenomenon, while the explanatory scope, supported by statistical techniques, delves into construct validity and instrument reliability.

Finally, a non-experimental cross-sectional design was employed, as the information was collected at a single point in time without manipulating variables, ensuring that the results reflect a real criterion from the experts. According to Taherdoost (2023), this design ensures the future applicability of the validated instrument in similar educational contexts.

Study sample

In the context of this research, the selection of the expert panel was conducted using the Delphi method. This procedure, by applying rigorous selection criteria, allows for the formation of groups of professionals highly specialized in a specific area. Such specialization is essential for implementing strategies that ensure the validity and reliability of the designed instrument. As noted by Rincón & Ramírez (2024), careful selection of experts contributes to integrating solid arguments that facilitate the identification of both the strengths and limitations of the evaluated instrument, thereby supporting objective decision-making regarding the modification or elimination of items.

The study sample consisted of 25 professionals linked to engineering, education, and technical drawing, who are affiliated with both public and private higher education institutions. From this initial group, a sample of 5 specialized experts was selected through a process based on the competency index (K), adapted from Rincón & Ramírez (2024). To this end, information was gathered related to the level of education (NF), years of experience (AE), area of professional expertise (AEP), and research experience (EI). A minimum requirement was established, stating that participants must hold at least a master's degree in fields related to engineering, education, exact sciences, innovation, among others.

Subsequently, three coefficients were calculated: the knowledge coefficient (KC), related to years of experience and professional area; the argumentation coefficient (KA), determined from the evaluation of the impact of their research contributions; and the competency index (K), obtained by summing the KC and KA coefficients and dividing the result by two. To interpret this index, the following categories were used: Excellent ($0.8 < K \leq 1$), Good ($0.5 < K \leq 0.8$), and Poor ($K \leq 0.5$). The results corresponding to the selected sample are presented in Table 1.

Table 1
Expert selection

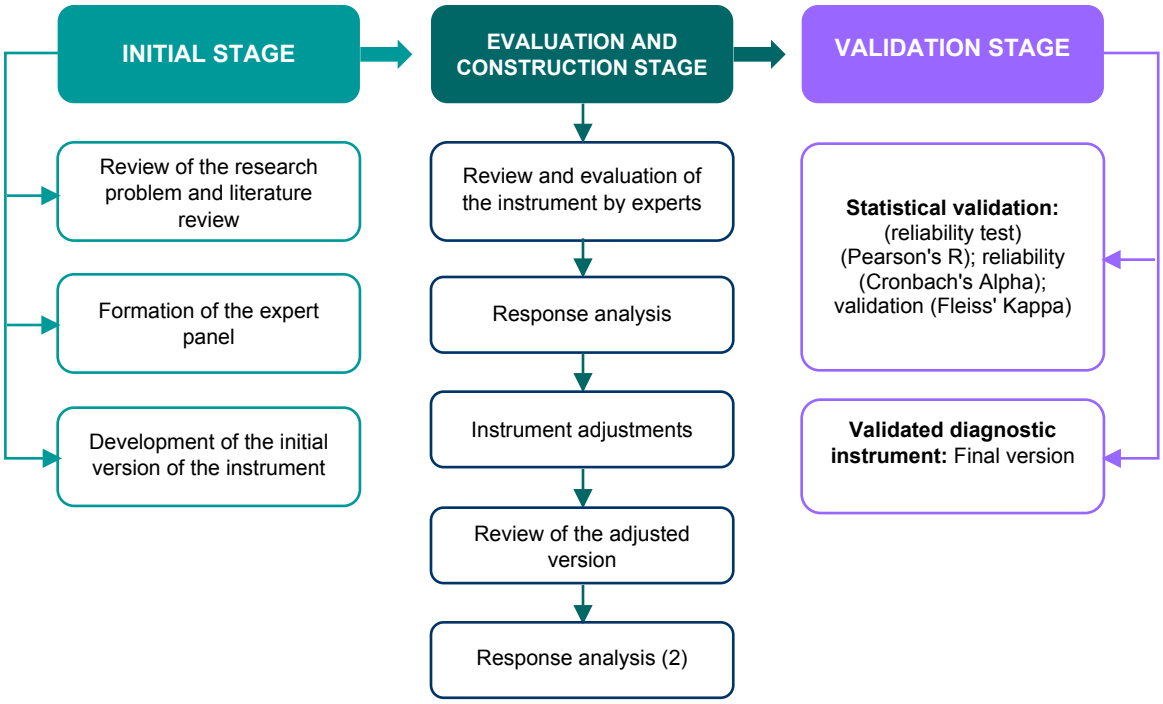
Expert No.	NF	AE	AEP	EI	KC	KA	K	Competency coefficient
1	Doctorate	23	Mathematical Education and Technical Drawing	Author of 20 articles in Education, research group director, and coordinator of Research and Innovation projects	0.9	0.9	1	EXCELLENT
6	Doctorate	24	Water Resources	Author of books, book chapters, scientific research articles, Senecyt certifications	0.9	0.9	1	EXCELLENT
12	Doctorate	20	IT Tools in Hydraulics, WaterGems, Epanet, SWMM, GIS, AutoCAD, BIM modeling	Author in research lines: Hydraulic Engineering, sanitation, irrigation, using optimization algorithms for comprehensive system management	0.9	0.9	1	EXCELLENT
19	Doctorate	20	Use of Matlab in innovative projects (number tracing and high-level model creation)	Research project with CEDIA. Democratization of Artificial Intelligence from an early age	0.9	0.9	1	EXCELLENT
24	Doctorate	17	Modeling in water supply and sewage systems	Publications in computational hydraulics, conferences, theses	0.9	0.9	1	EXCELLENT

Note. Data obtained through the application of the Delphi method

Thus, the expert panel consisted of five professionals with advanced degrees and extensive experience in technical drawing. These specialists were selected to evaluate and validate the designed diagnostic instrument, using survey techniques and applying the Lawshe method. It is important to highlight that the instrument to be validated was developed based on the “Technical High School Curriculum” proposed by the Ministry of Education (MINEDUC, 2017), as well as recent contributions from Veintimilla (2024), with the purpose of measuring students' prior knowledge in the technical drawing subject for higher education.

In summary, the procedure implemented in this research, focused on the validation of the diagnostic instrument, was structured in three carefully designed stages to ensure its technical rigor and applicability. These stages are summarized in Figure 1.

Figure 1
Research procedure



Note. Summary of the process applied to the research

Figure 1 summarizes each of the actions taken during the validation process of the diagnostic instrument, from the thorough literature review to the final validation and the attainment of a robust and reliable version. This dynamic process allowed for the development of a tool that effectively addresses the identified educational need.

It is important to note that for data analysis, principles of descriptive statistics were applied, using tools such as Microsoft Excel for the organization, processing, and clear representation of results.

Results and discussion

The analysis presents the results obtained during the validation process of the diagnostic instrument designed to assess the prerequisites for the technical drawing course in higher education. The Delphi methodology and the Lawshe content validity index were employed to establish the pertinence and relevance of the items. This process was complemented by statistical tests that ensured the reliability and consistency of the instrument.

Thus, the results are presented based on the research objectives, organized sequentially to facilitate clear and coherent interpretation.

First, the specific objective aimed at identifying the prerequisites for the technical drawing course in higher education was addressed. To achieve this, an exhaustive search and analysis of available literature in academic repositories, as well as official documentation from the Ministry of Education of Ecuador (MINEDUC) and other higher education institutions, were conducted. Among the main references, the “Technical High School Curriculum” from MINEDUC (2017) and contributions from Veintimilla (2024) were considered, which allowed for structuring the variables, dimensions, and prerequisites related to technical drawing.

The results obtained are presented in Table 2.

Table 2
Prerequisites for technical drawing in higher education

Variable	Dimensions	Prerequisites/Items	Author
Fundamental Prerequisites	Conceptual	• Possesses basic fundamentals of technical drawing and its projections. • Identifies the characteristics and materials specific to technical drawing. • Accurately manages scales in graphical representations. • Knows and uses different graphical perspectives (isometric, orthogonal, and central). • Interprets the process for making graphical representations of cuts and axonometric projections. • Recognizes measurement units, scales, and conventional signs in topography. • Uses paper formats, lines, polylines, letters, and diagrams for graphical representation. • Applies concepts of descriptive geometry in graphical representations. • Identifies basic symbols used in technical diagrams.	Ministerio de Educación del Ecuador (2017). Veintimilla (2024).
	Procedural	• Measures distances and angles of a terrain for graphical representation at scale. • Uses appropriate instruments to measure distances and angles. • Records and organizes field data using the corresponding measurement units. • Manages geographic information systems for data representation. • Draws and interprets technical plans, applying drawing standards or conventions. • Uses technical design software like CAD, Arview, or similar to create graphical representations. • Processes field data to represent it graphically with precision. • Organizes and prints plans according to specific scales and formats. • Applies measurement units, scales, and conventional signs in graphical representations and topographic profiles. • Considers international standards such as ISO or DNI in the preparation of technical drawings.	Ministerio de Educación del Ecuador (2017). Veintimilla (2024).

Attitudinal Prerequisites	Attitudinal	• Respects international graphic representation and technical symbolism standards (e.g., ISO) when creating plans. • Uses technical drawing tools and software ethically. • Respects copyright or intellectual property rights in the development of graphics. • Ensures quality and precision in the preparation of technical drawings. • Implements new methods to improve the representation of drawings or graphics. • Presents graphics following established standards or norms to ensure clarity and precision. • Demonstrates a proactive attitude towards learning about new design technologies. • Incorporates constructive feedback in the development of technical representations. • Actively participates in group technical projects, fostering knowledge exchange. • Recognizes the ethical use of technological and natural resources. • Recognizes the importance of sustainability and environmental respect in proposals or project development. • Produces clear and organized representations to facilitate interpretation. • Identifies areas for improvement and applies strategies to refine technical work. • Creates technical designs that combine creativity and functionality. • Stays updated on new trends in technical design. • Evaluates their work to ensure compliance with objectives.	Veintimilla (2024).

Note. Data corresponding to the theoretical construct

In this context, two main variables were identified: “fundamental prerequisites” and “attitudinal prerequisites,” encompassing a total of 35 prerequisites (items) that coherently align with the curriculum framework established by MINEDUC (2017). This supports the assertion by Castillo & Hernández (2022), who emphasize that prior knowledge should include theoretical, practical, and attitudinal aspects, thereby ensuring a comprehensive, contextualized approach aligned with the training demands of higher education.

Based on the identified prerequisites, the initial version of the instrument was developed, which was then evaluated by the expert panel to analyze its content validity using the model proposed by Lawshe (1975). During this process, experts assessed each item using a three-point scale: 3 = Essential, 2 = Useful but not essential, and 1 = Not necessary. Of the 35 proposed items, 30 were deemed valid.

The results obtained in the first round are outlined in Table 3.

Table 3

Results from expert evaluation – First round

Dimension	Items	NE	IVC	Interpretation
Conceptual	**I.1**	5	1	Valid item
	I.2	5	1	Valid item
	I.3	5	1	Valid item
	I.4	5	1	Valid item
	I.5	5	1	Valid item
	I.7	5	1	Valid item
	I.8	5	1	Valid item
	I.9	5	1	Valid item
Procedural	**I.10**	3	0.2	Item to be removed
	I.11	5	1	Valid item

	I.12	5	1	Valid item
	I.13	5	1	Valid item
	I.14	3	0.2	Item to be removed
	I.15	5	1	Valid item
	I.16	5	1	Valid item
	I.17	5	1	Valid item
	I.18	5	1	Valid item
	I.19	5	1	Valid item
Attitudinal	**I.20**	5	1	Valid item
	I.21	5	1	Valid item
	I.22	5	1	Valid item
	I.23	3	0.2	Item to be removed
	I.24	3	0.2	Item to be removed
	I.25	3	0.2	Item to be removed
	I.26	5	1	Valid item
	I.27	5	1	Valid item
	I.28	5	1	Valid item
	I.29	5	1	Valid item
	I.30	5	1	Valid item
	I.31	5	1	Valid item
	I.32	3	0.2	Item to be removed
	I.33	5	1	Valid item
	I.34	5	1	Valid item
	I.35	5	1	Valid item

Note. Results obtained using Lawshe's method in the first round of evaluation

To determine the content validity of the items (IVC), Lawshe's formula was applied (IVC = (Ne - N/2) / (N/2)), where Ne represents the number of experts who considered the item as “essential” or “useful but not essential,” and N is the total number of experts. According to this method, items with an IVC equal to or greater than 0.78 are considered valid, while those with a lower value must be revised or eliminated.

In this context, Table 4 shows that out of the 35 evaluated items, 30 were considered “essential” and validated by consensus. Conversely, the remaining 5 items (10, 14, 23, 25, and 32) were classified as “useful but not essential” by three experts; however, since they obtained an IVC below the established threshold, these items were discarded.

Based on the results from this first round of evaluation, the corresponding adjustments were made to the instrument, leading to a second version that was sent back to the expert panel for review. On this occasion, the 30 adjusted items were deemed valid, achieving total consensus among the specialists.

Table 4 presents a summary of the validated items.

Table 4

Summary of results from the second round of evaluation

Dimension	Items	NE	IVC	Interpretation
Conceptual	1 to 9	5	1	Valid item
Procedural	10 to 17	5	1	Valid item
Attitudinal	18 to 30	5	1	Valid item
Total valid items: 30				

Note. Results obtained in the second round of evaluation

The results from the second round of evaluation reveal that all 30 items (prerequisites) were validated with a content validity index (IVC) equal to 1 across all three evaluated dimensions. The items corresponding to the conceptual dimension (1 to 9), procedural dimension (10 to 17), and attitudinal dimension (18 to 30) were unanimously considered valid by the five experts, thus meeting the criteria established by the Lawshe's method.

Consequently, a diagnostic instrument was constructed to measure the level of prerequisites (prior knowledge) of students in the subject of technical drawing within the realm of higher education. This instrument

was structured taking into account the previously defined variables, dimensions, and items, grounded in solid technical and pedagogical criteria.

Table shows a summary of the diagnostic instrument structure and its theoretical foundation.

Table 5

Summary of the diagnostic instrument structure

Name of research instrument	**Technical Drawing Prerequisites Questionnaire for Higher Education**		
Theoretical foundation	**Prerequisites:** Academic conditions, knowledge, skills, experience, and values.		**Author:** Vaca et al. (2024)
	Technical Drawing: A system of graphic representation using standardized norms and conventions to accurately communicate the geometric, structural, and functional characteristics of an object.		**Author:** Saenz (2022)
Variables	**Dimensions**	**No. of Items**	**Author**
Fundamental Prerequisites: encompasses theoretical knowledge and practical skills	Conceptual	**9**	Ministerio de Educación del Ecuador (2017) Veintimilla (2024)
	Procedural	**8**	Ministerio de Educación del Ecuador (2017) Veintimilla (2024)
Attitudinal Prerequisites	Attitudinal	**13**	Veintimilla (2024)
Interpretation Scale: adapted from DIGCOMP (2022)	Basic: 0-22 Intermediate: 23-45 Advanced: 46-68 Highly specialized: 69-90		

Nota. General structure of the constructed instrument

The instrument designed to measure the prerequisites of technical drawing in higher education comprises three dimensions: conceptual, procedural, and attitudinal. Additionally, it integrates an interpretation scale adapted from DIGCOMP (2022), which classifies mastery into four levels: Basic, Intermediate, Advanced, and Highly Specialized. This scale allows for standardized interpretation of results and identification of improvement opportunities in students' technical and academic competencies.

In this regard, the multidimensional structure of the instrument aligns with Fernández (2021), who emphasizes the importance of incorporating multiple dimensions in diagnostic instruments to ensure the precision and effectiveness of results, thus facilitating a comprehensive evaluation that supports the design of relevant educational strategies.

Ultimately, the general objective of validating the diagnostic instrument concerning the prerequisites of the technical drawing subject for higher education was achieved. Statistical tests were applied to ensure the reliability, consistency, and validity of the instrument, referred to as the “Technical Drawing Prerequisites Questionnaire for Higher Education,” using the Test-Retest method. The questionnaire was sent to 25 experts, of whom 10 responded, to analyze the relationship between the instrument's variables and assess the stability of responses over time.

As a result of the analysis, a Pearson correlation coefficient (R = 0.9) was obtained, indicating a strong correlation and supporting the metric reliability of the instrument. The results are summarized in Table 6.

Table 6
Reliability test results

Test	Retest	Coefficient of Temporal Stability
300 responses	Variation, 7 of 300 responses (293)	**0.90**

Note. Data obtained through the application of the instrument to a sample of 10 participants

The internal consistency of the instrument was then evaluated by calculating the "Cronbach's Alpha" coefficient. For this, the total number of items, the sum of the individual variances, and the total variance of the instrument were considered. The result obtained was a coefficient of 0.93, corresponding to an "excellent" level of measurement. The detailed values are presented in Table 7 below.

Table 7
Internal consistency test results

Number of Items =	30
Sum of variances =	6.89
Total variance =	70.61
Cronbach's Alpha Coefficient =	**0.93**

Note. Data obtained from the reliability test

Finally, the definitive version of the questionnaire was evaluated by the expert panel, who assessed general aspects such as the theoretical foundation, sufficiency, clarity, coherence, quality, and relevance of the instrument. After collecting the individual results, the data were tabulated, and the statistical method "Fleiss Kappa" was applied, yielding a concordance index of "Kappa 1," indicating "almost perfect agreement" among the evaluators.

The results obtained are presented in Table 8 below.

Table 8
Expert judgment – Fleiss Kappa statistic

Element	Rating					Total general
	1	2	3	4	5	
Theoretical Foundation					5	**5**
Sufficiency					5	**5**
Clarity					5	**5**
Coherence					5	**5**
Quality					5	**5**
Relevance					5	**5**
Po = 1	**Pe =** 0					**Po-Pe =** 1
Random Theoretical Concordance: 1						
KAPPA: 1						
Median:					**Mode:**	
5					5	

Nota. Results obtained from expert validation

In conclusion, the method applied allowed for an accurate and detailed evaluation of the relevance of each item. The active participation of experts, combined with rigorous statistical analyses, ensured the validity of the selected items. Therefore, the results provide solid support for the quality of the instrument, confirming the assertion by Gómez (2020) that rigorous validation, supported by collaborative work with experts and statistical testing, is essential to ensure the reliability, validity, quality, and precision of the instrument, thus enabling adequate measurement of the concepts or variables for which it was designed.

Conclusions

The study identified 35 prerequisites for learning technical drawing in higher education, classified into two categories: fundamental prerequisites and attitudinal prerequisites. These serve as the foundation for constructing appropriate diagnostic instruments.

The diagnostic instrument, termed the "Technical Drawing Prerequisites Questionnaire for Higher Education," is structured across three dimensions: conceptual, procedural, and attitudinal. It comprises a total of 30 items and includes an interpretation scale that categorizes the mastery of prerequisites into four levels: Basic, Intermediate, Advanced, and Highly Specialized.

Finally, the validation of the instrument was conducted using the Delphi method across two evaluation rounds, employing the Lawshe model. Additionally, statistical analyses were performed, including the Test-Retest method and assessments using Pearson correlation coefficient, Cronbach's Alpha, and Fleiss Kappa. These results support the validity, reliability, high internal consistency, and an almost perfect level of agreement among the evaluators.

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