Basic Drawing Framework for Architecture Students Pursuing a Bachelor's Degree: A Case Study on Undergraduate student in Thailand

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Received: *Jul 17, 2024*
Revised: *Oct 2, 2025*
Accepted: *Nov 20, 2025*

Abstract

This study proposed a basic hand-drawn technical drawings skill (BHTDS) assessment framework to evaluate the BHTDSs of undergraduate students in terms of six indicators, namely (S1) cleanliness, (S2) line transparency, (S3) drawing weight, (S4) precision in drawing, (S5) completeness, and (S6) text. The relevance of the six indicators was evaluated by a random sample of 25 experts in structural design, architecture, engineering, and academia and a questionnaire was developed to collect data from the sample. This study employed a quantitative methodology using IOC analysis, confirmatory factor analysis (CFA), and structural equation modeling (SEM). Statistical analysis and structural equation modeling were performed to validate the indicators by using a random sample of 200 experts, architects, and engineers. All BHTDS indicators were acceptable, with factor loadings of 0.86–0.94 (R^2 = 0.74–0.88), a composite reliability of 0.96, and an average variance extracted of 0.81. The validated BHTDS framework was used to assess the skills of 39 undergraduate students. The purpose of this research was to develop and validate a Basic Hand-Drawn Technical Drawing Skills (BHTDS) assessment framework for undergraduate architecture students. The students achieved the highest average score for cleanliness (6.54), followed by perfection (6.49). According to the results of the assessment, the aspect that required the least effort to perfect was the correctness of the students' drawings, which had the lowest score (6.07).

Keywords: Assessment, Basic drawing skills, Hand-drawn, Technical drawing, Validation indicators

1. Introduction

Technical drawings are a cornerstone of professional practice in architecture, engineering, and technology, facilitating crucial communication between the creators of ideas and the producers who bring those ideas to life (Eckert & Boujut, 2003; Gao, Walters, Jaselskis, & Wipf, 2006; Stacey, Eckert, & McFadzean, 1999; Tai, 2022). These drawings function as a universal language, designed to be clearly understood by engineers, contractors, and architects alike. Given their essential role, professionals in these fields must master technical drawing skills, beginning with the fundamental competence of Basic Hand-Drawn Technical Drawing Skills (BHTDS) (Oakley, 2019; Sharma, Murugadoss, & Rambabu, 2020).

In higher education systems globally—including those in Thailand, Malaysia, Indonesia, Japan, the United Kingdom, and the United States—BHTDS is recognized as the foundational basis for a wide range of skills related to architecture, engineering, and industrial operations (Triyono, Trianingsih, & Nurhadi, 2018). Even with the increasing prevalence of digital drawing tools, the practice of manual sketching has retained its importance, and in countries like Thailand, BHTDS-related courses remain a mandatory component for all technician programs, from vocational certificates and diplomas to university degrees. The enduring value of BHTDS is also seen in its ability to help students engage more deeply with technical subjects they might otherwise find unappealing (Ware, 1896). In higher education, including Thailand, Malaysia, Indonesia, Japan, the United Kingdom, and the United States, BHTDS serves as the basis for the vast majority of basic skill related to architecture, engineering, and industrial operations (Triyono, Trianingsih, & Nurhadi, 2018).

Within the specific context of architecture, students are required to learn construction technical drawing alongside a broad curriculum that includes design, history, commerce, and law. Technical drawing is an indispensable skill for architects, allowing them to effectively communicate their design concepts to the builders, contractors, and other professionals involved in the construction process. This involves using specialized tools like rulers, compasses, and protractors to create precise drawings that convey critical details such as dimensions, materials, and construction techniques, ensuring a project is built correctly and safely. Coursework typically begins with basic techniques like sketching and shading, progressing to more advanced topics such as perspective drawing, rendering, and 3D modeling (Ching, 2019; Yee, 2012). Students learn to produce a full range of technical documents, including plans, elevations, sections, and details (Robbins & Cullinan, 1994). While traditional drafting techniques are central, many architecture programs now integrate computer-aided design (CAD) software, enabling students to create adaptable digital models. Ultimately, the goal is to equip students with the skills needed to communicate their design ideas effectively to all industry stakeholders, from clients to building officials (Iulo, Weinreb, Aviles, & Ling, 2017; Meyer & Norman, 2020).

The quality of hand-drawn technical work is determined by several crucial factors, including line weight, correctness, and the consistency of text type and font (Ching, 2019; Fakhry, Kamel, & Abdelaal, 2021; Herbert, 1993; Mahmoud, Kamel, & Hamza, 2020; Peters, 2020; Ware, 1896; Xu, 2020). Assessing these qualities is vital, as assessment results can reveal the strengths and limitations of students, which in turn informs their growth and the ongoing development of educational curricula (Henderson & Phillips, 2014; Lew & Nelson, 2016). By analyzing these results, educators can identify areas where students are excelling or struggling, allowing for tailored instruction to meet individual needs (Bates, Konkin, Suddards, Dobson, & Pratt, 2013). Furthermore, if a significant number of students consistently face difficulties with a particular concept, it may signal a need to revise teaching methods or the curriculum itself (Sundberg, 2002).

To create a standardized and effective method for this evaluation, a recent study was conducted to identify and validate key indicators of BHTDS. These indicators are designed to assess the skills of architectural, engineering, and technical students at all educational levels and ensure they meet the needs of employers. The six proposed BHTDS indicators are:

(S1) Cleanliness

(S2) Line transparency

(S3) Drawing weight

(S4) Precision

(S5) Completeness

(S6) Text

These indicators underwent a rigorous validation process. First, they were subjected to expert validation using item–objective congruence (IOC) analysis. Following this, their applicability and relevance were evaluated through questionnaires distributed to a sample of entrepreneurs (in structural design and architecture), architects, and engineers. The data from these questionnaires were then statistically analyzed using confirmatory factor analysis (CFA) to identify the factor loadings of each indicator. In structural equation modelling (SEM), a factor loading of 0.6 or higher suggests a strong effect. This analysis was performed using the Analysis of Moment Structures (AMOS) statistical program, a module of SPSS. The results of the analysis verified the proposed indicators, providing a powerful, validated tool for assessing BHTDS. The findings of this study can be directly incorporated into the evaluation process for architecture students and others in technical fields, promoting student growth and improving the overall quality of education by aligning academic skills with professional necessities (Ware, 1896).

The contextual "problems" of BHTDS skills assessment in Thailand have been clarified by elucidating the discrepancy between teaching and assessment. The theoretical aspects of hand-drawing are still emphasised in Thai architecture curricula, but the assessment process lacks standardised and validated criteria. Consequently, there is a discrepancy between the curriculum and the assessment of student performance. This research endeavours to resolve this issue by creating and verifying a systematic assessment framework that will serve as a bridge.

2. Indicator Review and Research Framework

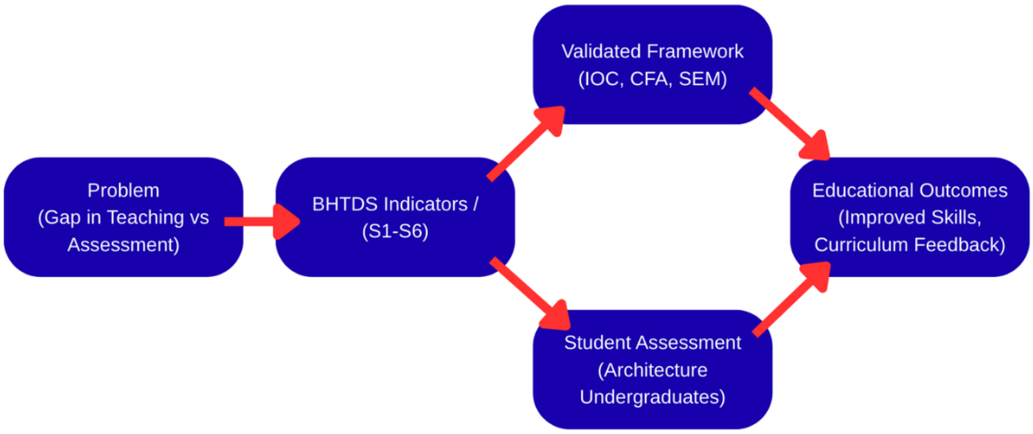

Figure 1 Conceptual framework of the study

Figure 1 demonstrates the connection between the identified issue (the divide between instruction and assessment), the six BHTDS indicators (S1–S6), the validation process (IOC, CFA, SEM), and their implementation in student assessment. The results emphasise enhanced drawing abilities and feedback on curriculum development for architectural education.

The BHTDS (Building and Housing Technical Drawing Standards) holds immense importance for architectural students as it serves as a valuable benchmark for evaluating their technical drawing skills in the context of building and housing projects. Each indicator within the BHTDS provides specific insights and benefits for architectural students:

(S1) Cleanliness:

For architectural students, cleanliness holds significant importance as it directly reflects their professionalism and attention to detail. Technical drawings serve as essential tools for communicating and visualizing architectural concepts, making their clarity and neatness paramount (Ceylan, Şahin, Seçmen, Somer, & Süher, 2021; Charitonidou, 2023). By following standards for legible lettering, pristine paper, and correct pagination, students develop the discipline needed to produce work that meets industry expectations. Clean, well-organized drawings facilitate effective communication with clients, contractors, and other stakeholders, which is critical during the construction phase. The precision and accuracy demonstrated through cleanliness minimize the risk of misunderstandings and errors, contributing to successful project outcomes. This practice nurtures an architect's ability to be meticulous, a fundamental skill for ensuring design accuracy and functionality (Liu, Castronovo, Messner, & Leicht, 2020; Milo, 2020). Furthermore, the habit of cleanliness translates into visually appealing drawings that enhance a student's professional portfolio, showcasing their skills to potential employers and boosting career prospects in a competitive industry (Ostime, 2019). This principle also extends to comprehensive project documentation. Properly organized drawings with correct pagination streamline reviews and revisions, demonstrating a student's capacity to manage complex projects effectively (Baduge et al., 2022). Ultimately, an emphasis on cleanliness equips architectural students with the foundational habits for professional excellence, positively impacting their future projects and contributions to the built environment.

(S2) Line Transparency:

Line Transparency (S2) is a crucial indicator for architectural students, directly influencing the clarity and visual impact of technical drawings (Rosales, 2022; Charitonidou, 2023). By focusing on creating crisp, well-defined lines, students learn to precisely convey design elements, spatial relationships, and construction details, which fosters a high degree of precision and consistency in their work (Ching, 2019). This clarity is vital for delineating different architectural components, ensuring drawings are coherent and organized. By avoiding overlapping or indistinct lines, students enhance the legibility of complex designs, which helps prevent potential misunderstandings and errors during the construction phase (Charitonidou, 2023). Furthermore, this practice develops an eye for aesthetically pleasing presentations, as drawings with sharp, uninterrupted lines evoke a sense of professionalism and visual appeal. Effective line transparency also underpins successful collaboration. When technical drawings have well-defined lines, they facilitate seamless communication among design teams and stakeholders, creating an efficient working environment essential for any project's success. Mastering line clarity equips students with the skills to produce drawings that are technically accurate, visually engaging, and easily understandable, laying a strong foundation for a career where precision and effective communication are paramount.

(S3) Drawing Weight:

For architectural students, the indicator of Drawing Weight (S3) is of significant importance, as it involves the skillful use of varying line thicknesses to convey depth, dimension, and visual hierarchy in technical drawings (Charitonidou, 2023). The ability to control line weight is fundamental to shaping the visual representation of a design and enhancing its overall clarity and impact (Ching, 2019). By employing different line weights purposefully, students learn to create a clear visual distinction between elements. Heavier lines can represent objects closer to the viewer or define primary structural forms, while lighter lines can indicate finer details or background elements. This technique imbues flat drawings with a sense of three-dimensionality, making them more comprehensible and visually engaging. This nuanced precision elevates the quality of architectural representations and fosters a keen understanding of visual priority. Furthermore, astering drawing weight is crucial for effective communication throughout the design and construction process. Clear line weights help articulate materiality and spatial relationships, enabling clients and construction teams to accurately visualize the final project. Adherence to industry standards for drawing weight ensures that technical documents are professional and unambiguous, facilitating seamless collaboration among all stakeholders in the architectural field (Sharifjanovna, 2022). Ultimately, this skill combines technical proficiency with aesthetic sensibility, empowering students to produce drawings that are not only accurate but also communicate design ideas with depth and finesse, laying the groundwork for a successful career.

(S4) Precision in Drawing:

The indicator of Precision in Drawing (S4) is immensely important for architectural students, evaluating their ability to produce accurate and meticulously detailed technical drawings (Charitonidou, 2023; Ching, 2019). Precision is a cornerstone of architectural documentation, ensuring that drawings reliably convey design intent through the correct use of line weights and standard symbols for floors, doorways, levels, and directional arrows. When executed with precision, these drawings become dependable references for construction teams, enabling them to accurately translate concepts into tangible structures (Adilov, 2022; Bianconi, Filippucci, & Buffi, 2019). A focus on precision enhances a student's ability to create documents that are readily interpretable, reducing the likelihood of costly misunderstandings and errors during project implementation. The correct application of annotations and symbols ensures that drawings provide a comprehensive and accurate representation of the design (Adilov, 2022). This practice instills a professional mindset of meticulousness and attention to detail, which is critical for adhering to building codes, regulations, and safety standards in professional practice (Alnusairat, Al Maani, & Al-Jokhadar, 2021; Sharifjanovna, 2022). Moreover, this indicator teaches students to critically review their work, identify errors, and continuously refine their skills (Al-Malah, Hamed, & Alrikabi, 2020). By mastering precision, architectural students enhance their ability to communicate effectively with all stakeholders and develop the foundational skills necessary for a successful career where accuracy is essential for turning architectural visions into reality.

(S5) Completeness:

The indicator of Completeness (S5) is vital for architectural students, assessing their ability to deliver well-organized, comprehensive, and timely technical drawings (Charitonidou, 2023). This extends beyond including all essential plans, sections, and elevations; it also encompasses meeting project deadlines, a critical aspect of professional practice (Alnusairat et al., 2021; Ching, 2019). By delivering complete drawings on time, students demonstrate professionalism and reliability, traits highly valued in the industry (Al-Malah et al., 2020). Comprehensive documentation is crucial for effective collaboration. When drawings are complete, they enhance communication and coordination between project teams and stakeholders, minimizing the risk of misunderstandings or delays during construction (Alnusairat et al., 2021; Bianconi et al., 2019). This indicator fosters a meticulous, detail-oriented approach, encouraging students to review their work thoroughly to ensure no critical information is omitted. Ultimately, completeness is essential for building a strong professional portfolio that showcases a student's capability to manage and document projects thoroughly. Adhering to standards of completeness prepares students to meet industry expectations, where comprehensive technical drawings are fundamental to successful project execution and clear communication among all parties involved.

(S6) Text: The Text (S6)

The effective use of text in technical drawings is a critical indicator of an architectural student's communication skills, providing essential context that drawings alone cannot convey (Charitonidou, 2023). This skill involves more than just legible penmanship; it requires thoughtful text organization and font selection to ensure all annotations, captions, and specifications are clear and concise. By mastering written communication within their drawings, students produce documents that are easily understood by clients, contractors, and other stakeholders. Aesthetically organized text not only enhances the professionalism of a presentation but also streamlines the construction process by providing unambiguous information on materials, dimensions, and other critical elements. This attention to detail reflects a student's commitment to precision and helps build a cohesive narrative that effectively explains the design intent. Ultimately, proficiency in textual communication extends beyond technical drawings into professional reports and proposals, making it a foundational skill for a successful career (Veza, 2021). Evaluating this and other manual skills requires a standardized approach, which is why a Basic Hand-drawn Technical Drawing Skill (BHTDS) assessment framework is indispensable in architectural education. While digital tools are prevalent, fundamental hand-drawing remains essential for conceptual development and rapid ideation (Al-Malah et al., 2020; Khodeir & Nessim, 2020). The BHTDS framework provides an objective method for assessing a student's mastery of core principles like line weight, scale, proportion, and spatial relationships. This structured evaluation allows instructors to provide targeted feedback, helping students improve specific weaknesses (Al-Malah et al., 2020). By implementing a consistent assessment framework, architectural institutions uphold academic rigor and ensure their graduates possess the competencies required to meet demanding industry standards (Al-Malah et al., 2020; Veza, 2021). Furthermore, the framework serves as a valuable tool for curriculum development, enabling educators to identify and address common deficiencies in their instructional approach. It fosters a culture of continuous improvement, encouraging students to actively refine their hand-drawing abilities throughout their education (Veza, 2021). In essence, the BHTDS framework is crucial for empowering students with the foundational skills needed to excel in the dynamic field of architecture, ensuring they can communicate their visions with clarity, precision, and confidence.

The six indicators of Basic Hand-Drawn Technical Drawing Skills (BHTDS)—(S1) purity, (S2) line transparency, (S3) drawing weight, (S4) precision in drawing, (S5) completeness, and (S6) text—were determined through a methodical approach. Initially, a comprehensive examination of the literature on architectural and engineering drawing standards revealed recurring criteria for evaluating the quality of technical drawings. Secondly, these criteria were further refined through consultation with professionals and academicians in the fields of architecture and engineering, thereby guaranteeing that the indicators accurately represented both academic requirements and industry practices. Lastly, the indicators were validated using the Item–Objective Congruence (IOC) method and subsequently confirmed through confirmatory factor analysis (CFA) and structural equation modelling (SEM).

The six indicators are interconnected and collectively function to establish a comprehensive framework for evaluation. Visual precision is crucial for the interpretation of technical drawings, and cleanliness (S1) and line transparency (S2) underscore this importance. The accuracy and effective representation of design intent are ensured by the drawing weight (S3) and precision (S4), which ensure that technical details are communicated reliably. By guaranteeing that the drawings are not only technically accurate but also exhaustive and readily comprehensible to stakeholders, the documentation is fortified by completeness (S5) and text (S6). Collectively, these indicators establish a comprehensive framework that ensures that academic training is in accordance with professional standards, thereby facilitating the consistent and dependable assessment of student performance.

3. Research Methodology

This study developed Basic Hand-drawn Technical Drawing Skills (BHTDS) indicators for Thai university curricula based on surveys of architectural and engineering businesses. Six key skills were identified: (S1) cleanliness, (S2) line transparency, (S3) drawing weight, (S4) precision, (S5) completeness, and (S6) text. To validate these skills, a questionnaire using IOC analysis was sent to 100 experts from the Association of Siamese Architects and the Engineering Institute of Thailand, from which 25 replies were received. This sample size was deemed statistically sufficient, as the relevancy score was >0.86, exceeding the minimum 0.60 threshold cited for smaller expert groups (Chaisanit and Suksakulchai, 2009; Thanvisitthpon et al., 2020; Turner and Carlson, 2003). All six BHTDS indicators proved valid, achieving high relevancy scores of 0.86–0.96. Based on this expert validation, a subsequent questionnaire using a 10-point Likert scale was created. This was distributed to a random sample of entrepreneurs, architects, and engineers to further verify the indicators' relevance in professional practice.

Table 1 Basic Hand-Drawn Technical Drawings Skill Indicators

BHTDS indicators				
Dimension	**ID**	**Indicator**	**Definition**	**IOC**
BHTDS	S1	Cleanliness	No tears on the paper and legible penmanship; no folds or stains and correct pagination	0.88
	S2	Line transparency	Sharp and distinct linework; elegant and meticulous structuring with no indication that the collision line has been crossed	0.91
	S3	Drawing weight	Awareness of line weight; deep understanding of dimension	0.96
	S4	Precision in drawing	Understanding of line weights and symbols such as floor symbols, doors, level signals, directions, and sales patterns	0.89
	S5	Completeness	Clean and detailed composition, on-time delivery	0.86
	S6	Text	Correct spelling; neat and organized layout; appropriate font size	0.89

The BHTDS indicators were the basis for a six-item questionnaire (Supplementary S2). According to Dawson, Peppe, and Wang (2011); Thanvisitthpon (2023), an appropriate sample size is at least 10 times the total number of items and >200. Because the present study developed six questionnaire items for each BHTDS indicator, the sample size was 200 respondents. Prior to SEM analysis, the data from the 200 responses were subjected to a Kolmogorov–Smirnov test, with the null hypothesis (H_0) being that the data would be normally distributed. If the observed value is larger than the crucial value (>0.05), H_0 is supported, and the data are normally distributed (Bayraktar, Tatoglu, & Zaim, 2008; Thanvisitthpon, 2021). The six BHTDS indicators were verified using CFA, and SEM analysis was used to evaluate their factor loadings and reliability. The relevance of the BHTDS indicators was determined using factor loadings (0–1). The reliability (R^2) of the BHTDS indicators was used to assess the factors' composite reliability

(CR). SEM-based CFA was conducted using means and variance–covariance matrices rather than a correlation matrix (**Table 2**).

Table 2 Correlation Matric of BHTDS Indicators

Indicator	A	B	C	D	E	F
A	1					
B	0.81**	1				
C	0.8**	0.81**	1			
D	0.82**	0.79**	0.86**	1		
E	0.77**	0.72**	0.84**	0.9**	1	
F	0.8**	0.82**	0.78**	0.82**	0.81**	1

The correlation coefficients of 15 pairs were substantially different from 0 at the 0.05 level, indicating that the correlation coefficients were statistically significant. These results are displayed in TABLE I with the significance of the correlation coefficients. The association between D and E and the variable with the greatest correlation coefficient had values ranging from 0.77 to 0.90, with the highest correlation coefficient being 0.90. The smallest value was 0.77, representing the correlation between A and E. The results of the investigation of the BHTDS indicators were developed into grading criteria with five levels, namely distinction, medium, pass, resubmit, and fail (**Table 3**). The BHTDS indicators were applied to a group of 39 students studying architecture at a tertiary institution.

Table 3 Scoring Criteria for BHTDS Exam Based on BHTDS Indicators

Indicator	Scoring criteria				
	Distinction 10–8	Medium 7–6	Pass 5–4	Resubmit 3–2	Fail 1–0
(S1) Cleanliness	Lettering is legible, paper is not ripped or wrinkled, and no erasure is visible; pagination is correct	Lettering is legible, paper is a bit ripped or wrinkled, and some erasure is visible; pagination is correct	Numerous messy and unclean areas	Messy and careless work in general; improvement required	Messy work requiring improvement
(S2) Line transparency	Lines are crisp and distinct; beautiful; no disruption of the line	Most lines are clean	Some overlapping lines that are not crisp	Black lines used to soften lines and prevent them from seeming messy and angular	Lines incredibly sloppy and lacking sharpness
(S3) Drawing weight	Able to discriminate between line weights, which indicates a solid grasp of drawing proportions	Strong line weight but a lack of clarity; able to properly divide the load	Draft lines adding bulk and negatively affecting already poor work	Line weights not separated and proportions and significance of lines incomprehensible	Lack of separation of the weight of the lines; proportions and significance of the lines incomprehensible

Indicator	Scoring criteria				
	Distinction 10–8	Medium 7–6	Pass 5–4	Resubmit 3–2	Fail 1–0
(S4) Precision in drawing	Ability to draw accurately using the right line weights and symbols for, for example, floors, doorways, levels, and directional arrows	Text written properly; application of line weights, but symbolic representations of, for example, floor symbols, doorways, level indicators, and extended directions have minor errors	Incorrect writing in places, indicating improper use of symbols and incomplete measurements	Written on several occasions; no model display sign and missing measurements	Incomprehensible shapes and inability to accurately convey size or appearance
(S5) Completeness	Written in full; comprehensive; delivered on time	Full attention to task yet disregard for some details; organized overall and comprehensive; delivered on time	Insufficiently polished in many ways; some crucial aspects not included, causing the work to seem unfinished and preventing it from being delivered on time	Lack of attention to detail and refinement; requiring more time to complete; work submitted late	Failure to focus, resulting in a lack of quality in many areas and failure to submit work on time
(S6) Text	Proper spelling; letters well-organized and clean; appropriate font use	Aesthetically pleasing; well-organized; correct spelling	Poorly written in many respects; not aesthetically pleasing; correct spelling	Further work required to develop characters; characters not visually appealing or well-written	Several places impossible to read; inelegant; immediate correction required; numerous misspelled words

Table III presents the Scoring Criteria for the BHTDS (Building and Housing Technical Drawing Standards), a comprehensive framework designed to evaluate technical drawings. This system utilizes a five-level grading scheme to ensure a detailed and nuanced assessment of a candidate's skills and competencies. Adopting a five-level scoring system is essential for moving beyond simple binary classifications to achieve a more thorough evaluation of quality. This multi-level approach allows evaluators to distinguish subtle differences in skill, knowledge, and outcomes, facilitating a more precise and objective assessment process.

Furthermore, this detailed scale enables the provision of specific, constructive feedback. By pinpointing exact strengths and weaknesses, individuals gain valuable insights into their performance, empowering them to target areas for improvement effectively. This fosters a culture of continuous learning and professional development. The standardized framework also promotes objectivity and impartiality, reducing subjectivity and ensuring consistent evaluation across different contexts. This aligns with the principles of academic integrity and meritocracy. Additionally, the nuanced scale facilitates effective benchmarking and the establishment of clear performance standards, making comparisons between individuals or projects more meaningful. In summary, the five-level scoring system enhances the precision, fairness, and clarity of assessments. By offering detailed insights and promoting objectivity, the BHTDS framework contributes significantly to the advancement of academic excellence and professional growth in architecture and engineering.

4. Results and Discussion

A. *CFA of BHTDS indicators*

CFA was used to evaluate the first-order factor loadings and reliability of the six BHTDS indicators. The associations between the BHTDS indicators were analyzed using SEM. **Figure 2** presents the structural equation model and factor loadings of the BHTDS indicators, where χ^2 = 2.49, degrees of freedom (df) = 4, p = 0.65, root mean squared residual = 0.05, root mean square error of approximation = 0.038, goodness of fit index (GFI) = 0.995, adjusted GFI (AGFI) = 0.945, normed fit index = 0.997, and confirmatory fit index = 0.999. GFI, AGFI, normed fit index, and confirmatory fit index values should be close to 1, and root mean square error of approximation and root mean squared residual values should be less than 0.05.

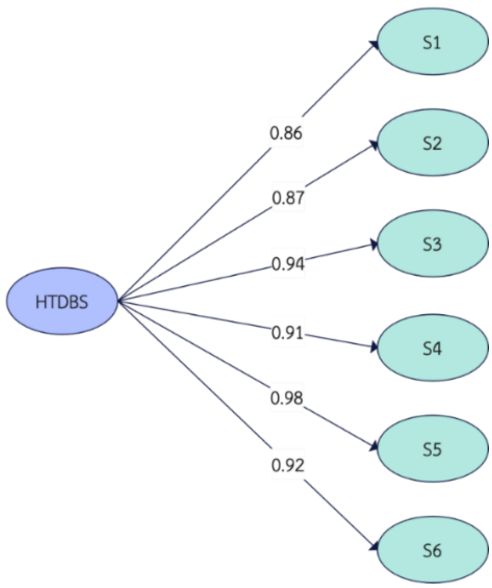

Figure 2 Structural equation model and factor loadings of BHTDS indicators.

The indicators' first-order factor loadings are presented in **Table 4**. The factor loadings for S1–S6 ranged from 0.86 to 0.94 (R^2 = 0.74 to 0.88). According to Kim and Mueller (1978), a factor loading of >0.3 is statistically significant. The CR of the BHTDS indicators was 0.96, with average variance extracted values of 0.81. According to Fornell and Larcker (1981), a CFA construct is legitimate if the CR value is greater than 0.6 or the AVE is greater than 0.5.

Table 4 First-order factor loadings of BHTDS Indicators

Latent factor	CFA construct validity		BHTDS indicator	Factor loading	R^2
	CR	Average variance extracted			
BHTDS	0.96	0.81	S1	0.86	0.74
			S2	0.87	0.77
			S3	0.94	0.88
			S4	0.91	0.82
			S5	0.89	0.79
			S6	0.92	0.84

B. *Implementing Scoring Criteria for BHTDS*

Architectural drawing was analyzed through an evaluation of the 39 students' BHTDSs, each of which was scored using criteria derived from an analysis of the indicators. The BHTDS evaluation was completed over the course of a semester (4 months, July to October 2022). Each student completed 13 tasks that were scored using the BHTDS criteria.

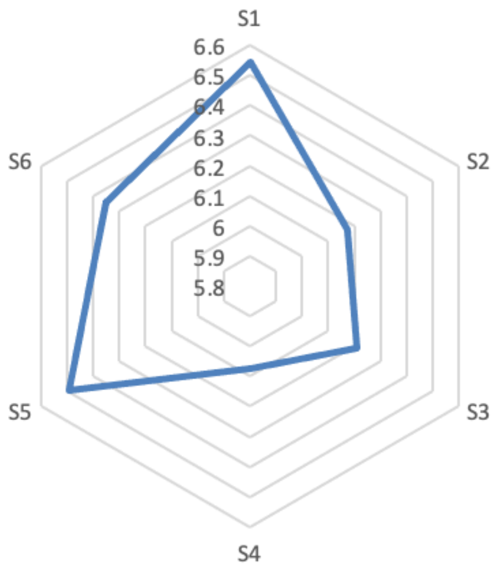

Figure 3 presents the BHTDS evaluation outcomes for each task related to architectural drawing

Figure 3 presents the evaluation results across six key indicators, providing a granular look at the strengths and weaknesses of architectural drawing students. The average scores were as follows: (S1) Cleanliness at 6.54, (S2) Line Transparency at 6.13, (S3) Drawing Weight at 6.21, (S4) Precision in Drawing at 6.07, (S5) Completeness at 6.49, and (S6) Text at 6.35. The data indicates that students performed best in Cleanliness (S1), achieving the highest average score of 6.54. The second-highest score was for Completeness (S5) at 6.49. However, a nuanced look at this category reveals a specific issue: while students demonstrated a good understanding of how to use line weight, they frequently erred in the presentation of standard symbols for floors, doorways, level indications, and other forms. The most significant finding is the lowest average score in Precision in Drawing (S4) at 6.07. This identifies a clear and critical skill gap, suggesting that students struggle with accuracy in their work. This lack of precision may be attributable to traditional teaching methods that overemphasize theory at the expense of applied practice.

To address these identified deficiencies, a shift in pedagogy is warranted. Methodologies such as Active Learning can significantly improve students' comprehension and application of theory. This approach facilitates content analysis, synthesis, and evaluation through dynamic activities like reading, writing, conversation, and collaborative problem-solving, while also providing students with valuable informal feedback (Freeman et al., 2014; Kozanitis & Nenciovici, 2022). Complementing this, Project-Based Learning (PBL) offers a powerful hands-on solution. By engaging in planning, developing, and creating practical solutions to complex, unstructured problems within small teams, students can directly improve their BHTDS (Bilgin, Karakuyu, & Ay, 2015; Mahasneh & Alwan, 2018; Zen & Ariani, 2022).

Beyond its diagnostic capabilities, the implementation of the BHTDS framework has had a demonstrably positive effect on the learning environment itself. Student satisfaction with the assessment process significantly increased from an average of 3.82 in previous years to 4.21 after the tool was introduced. This improvement can be attributed to several factors. Primarily, the six indicators provide a transparent, objective, and standardized method for evaluation, which minimizes ambiguity and subjective judgment. Students appreciate a fair process with clear performance criteria that align with industry standards. As research indicates, effective teaching and learning models paired with robust evaluation tools are proven to enhance student abilities (Dow, DiazGranados, Mazmanian, & Retchin, 2014; Dunn & Mulvenon, 2009; Kimball, White, Milanowski, & Borman, 2004).

Furthermore, the BHTDS framework fosters more constructive and individualized feedback. Instructors can pinpoint specific areas of strength and weakness, allowing students to better understand their progress and focus their efforts. This targeted feedback loop enhances the learning experience and empowers students to take ownership of their skill development. Consequently, this has led to increased student motivation and engagement. Knowing that their work will be assessed against well-defined criteria encourages students to invest more time and effort in refining their hand-drawing skills. Finally, by reflecting real-world architectural conventions, the BHTDS framework better prepares students for the challenges of their future careers, smoothing the transition from academia to professional practice.

In conclusion, the development and implementation of reliable skill evaluation instruments are essential for enhancing student abilities. A consistent and objective tool like the BHTDS framework allows educators to identify areas where students need additional support and to personalize instruction accordingly (Idris, Talib, & Razali, 2022; Nieminen & Carless, 2023). This data-driven insight into student performance is crucial for validating the effectiveness of teaching models. For instance, strong student performance on assessments following hands-on activities provides evidence for the efficacy of those techniques (Najah Ahmed et al., 2019; Patel, Shukla, Huang, Ussery, & Wang, 2020). Ultimately, the synergy between a dependable evaluation framework like BHTDS and effective teaching strategies is fundamental to providing high-quality instruction and preparing students for success in their future endeavors.

5. Conclusion

This study proposed and validated a set of Basic Hand-drawn Technical Drawing Skills (BHTDS) indicators for evaluating university-level architecture and engineering students. The six indicators are: (S1) cleanliness, (S2) line transparency, (S3) drawing weight, (S4) precision in drawing, (S5) completeness, and (S6) text. The indicators underwent a rigorous validation process, beginning with IOC expert validation and followed by a questionnaire administered to 200 industry professionals. A Confirmatory Factor Analysis (CFA) of the data confirmed the model's robustness. The Structural Equation Modeling (SEM) validation was successful, with all indicators demonstrating high factor loadings of 0.86–0.94 (R^2= 0.74–0.88), a composite reliability of 0.96, and an average variance extracted of 0.81. In a practical application, these indicators were used to assess architecture students in a fundamental sketching course. The results identified specific areas for improvement, with "precision in drawing" (S4) receiving the lowest average score (6.07), while "cleanliness" (S1) scored the highest (6.54). This study concludes that the validated BHTDS indicators are a reliable evaluation instrument. They provide educators with a tool to identify student weaknesses and offer targeted feedback. Developing and implementing such effective evaluation tools, which are aligned with learning objectives, is crucial for ensuring students acquire the essential technical competencies necessary for future success in professions like architecture.

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