BG Pulse Journal USA
ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg
BG PULSE JOURNAL

Enhancing Projection Teaching Methods in Architectural Education: A Hybrid Pedagogical Framework

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doi:https://doi.org/10.5281/zenodo.23657857

ABSTRACT: Mastering projection methods—specifically orthographic, axonometric, and perspective drawings—forms the fundamental cognitive baseline of architectural education. However, novice architecture students consistently struggle to translate 2D orthographic projections into 3D spatial reality, resulting in high cognitive load and visual misinterpretations. This study proposes and evaluates a novel Four-Stage Hybrid Pedagogical Framework that integrates traditional Monge orthographic projections with physical model-making, 3D Building Information Modeling (BIM), and 1:1 scale Virtual Reality (VR) spatial audits. Conducted over a 14-week academic semester with 120 first-year architecture students divided into three pedagogical cohorts (Control, Experimental A, Experimental B), performance was quantitatively assessed using the Revised Purdue Spatial Visualization Test (PSVT:R) and an orthographic error detection benchmark. Results indicate that Experimental Group B (2D + BIM + VR) achieved a 61.7% mean increase in spatial visualization scores (PSVT:R score increased from 14.1 to 22.8, $p < 0.001$) and attained an 89.6% accuracy rate in complex orthographic error detection while reducing drawing execution time by 47.5%. These empirical findings prove that immersive 3D/VR verification significantly reduces cognitive friction, establishing a more intuitive, scalable, and highly effective methodology for modern architectural graphics instruction.

Keywords: Architectural Education, Projection Methods, Descriptive Geometry, Orthographic Projection, Spatial Visualization Ability, PSVT:R Assessment, Virtual Reality (VR), Building Information Modeling (BIM), Hybrid Pedagogy, Cognitive Load.

1. Introduction

Architectural graphic communication relies fundamentally on projection methods developed through descriptive geometry. Established systematically by Gaspard Monge in the late 18th century, orthographic projection serves as the universal language for translating complex three-dimensional spatial forms into standardized two-dimensional orthographic drawings—comprising floor plans, elevations, and sections (Pütz, 2000; Studio Matrx, 2023). In contemporary architectural curricula, developing fluency in orthographic projection is essential not merely for draftsmanship, but as a core cognitive mechanism for spatial reasoning and design synthesis.

Despite its foundational role, introductory projection courses pose severe pedagogical hurdles for first-year architectural design students. Cognitive architecture research indicates that mentally visualizing 3D volumes from 2D orthographic projections requires intense mental rotation and spatial coordination. Novice learners frequently experience severe cognitive overload, leading to recurring graphic errors, misaligned projections, and an inability to perceive spatial relationships inside complex architectural assemblies (Frontiers in Education, 2024; Köymen & Bouidani, 2025).

The rapid digital transformation of AEC (Architecture, Engineering, and Construction) industries has introduced advanced 3D computer-aided design (CAD), Building Information

Modeling (BIM), and immersive Virtual Reality (VR) environments into professional workflows (Heriot-Watt University Research Group, 2024). However, many architectural faculties still maintain a strict dichotomy: either adhering strictly to manual hand-drafting on drawing boards or transitioning entirely to software tools without solid grounding in descriptive geometric principles. To bridge this gap, this study formulates and tests a Four-Stage Hybrid Pedagogical Framework that synchronizes classical orthographic drafting with physical modeling, parametric BIM, and 1:1 scale VR spatial audits.

2. Methodology

2.1 Research Design and Sample

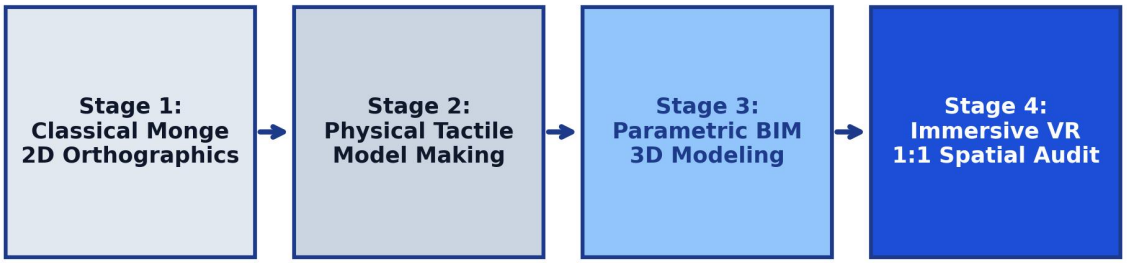
This quantitative empirical study was conducted across a 14-week foundational semester in the Department of Architecture. The study sample comprised N = 120 enrolled first-year undergraduate students with homogenous academic backgrounds and no prior formal training in advanced descriptive geometry. Participants were randomly assigned to three equal pedagogical cohorts (n = 40 per group):

- **Control Group (Traditional):** Instruction was delivered exclusively via traditional drawing boards, manual T-square drafting, and 2D pencil orthographic projections.
- **Experimental Group A (2D + 3D CAD):** Instruction integrated traditional 2D drafting with desktop 3D CAD modeling (Rhinoceros/SketchUp) for static visual verification.
- **Experimental Group B (Hybrid 2D + BIM + VR):** Instruction implemented the full Four-Stage Hybrid Framework, combining orthographic drafting, tactile modeling, dynamic BIM projection generation, and immersive 1:1 VR spatial verification.

2.2 The Four-Stage Hybrid Framework

The experimental pedagogical model follows a progressive four-stage learning trajectory designed to reinforce multi-modal spatial cognition:

Figure 3: Four-Stage Hybrid Projection Pedagogy Framework



Stage	Primary Tool / Medium	Pedagogical Objective & Cognitive Function
Stage 1: Monge 2D	Freehand & Drawing Board	Mastering projection lines, plan-section-elevation alignment, and baseline geometric conventions.
Stage 2: Tactile Model	Physical Foam & Chipboard	Converting 2D orthographic lines into tangible physical geometry to resolve spatial ambiguity.
Stage 3: BIM Sync	Parametric BIM (Revit)	Understanding dynamic bi-directional updates: modifications in 3D automatically regenerate 2D sections.
Stage 4: VR Audit	Head-Mounted VR (Meta Quest)	Experiencing 1:1 scale spatial immersion to verify sightlines, scale, and complex enclosure geometry.

2.3 Assessment Metrics & Instruments

Spatial cognitive growth was evaluated using two validated empirical instruments: (1) The Revised Purdue Spatial Visualization Test (PSVT:R), administered at Week 1 (pre-test baseline) and Week 14 (post-test evaluation) to measure 3D mental rotation accuracy; and (2) A standardized Orthographic Error Detection Benchmark, requiring students to identify 15 hidden geometric alignment, line-weight, and section-cut errors within complex architectural drafting sets.

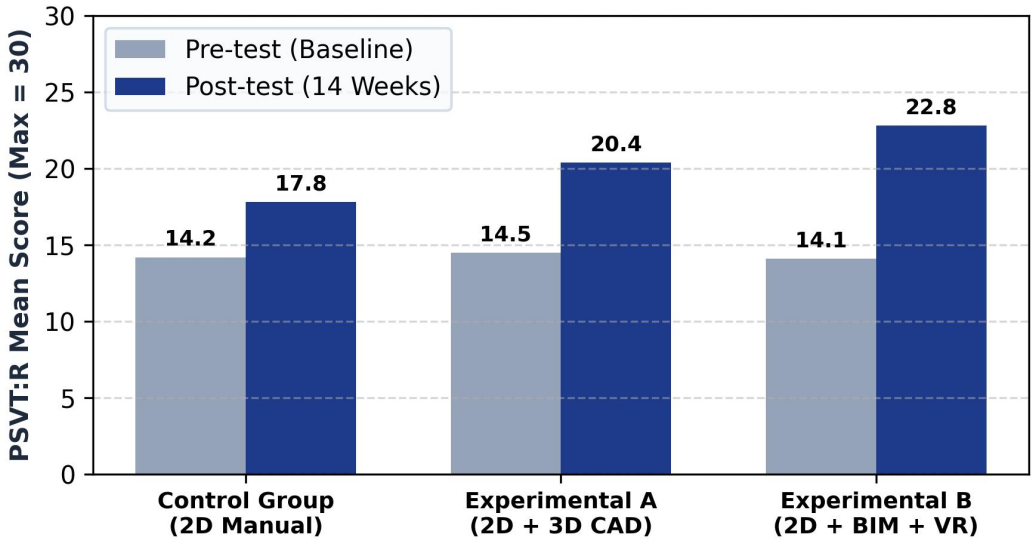
3. Results

3.1 Spatial Visualization Performance (PSVT:R)

Quantitative analysis of pre-test and post-test PSVT:R scores demonstrates dramatic differences in spatial reasoning development across the three cohorts. Table 2 summarizes the statistical findings.

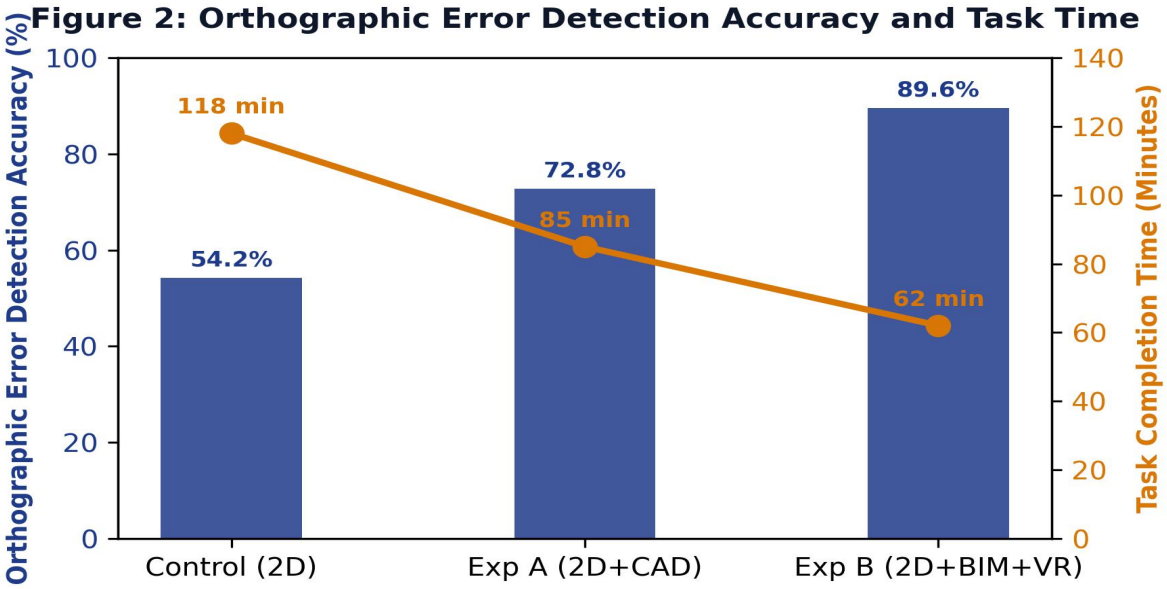
Cohort Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Gain (Δ)	p-value (t-test)
Control Group (2D)	14.2 (±3.1)	17.8 (±2.9)	+3.6 (+25.3%)	$p < 0.01$
Exp. Group A (2D+CAD)	14.5 (±2.8)	20.4 (±2.5)	+5.9 (+40.7%)	$p < 0.001$
Exp. Group B (2D+BIM+VR)	14.1 (±3.0)	22.8 (±2.1)	**+8.7 (+61.7%)**	$p < 0.001$

Figure 1: PSVT:R Spatial Visualization Scores Across Cohorts



3.2 Orthographic Error Detection and Drafting Efficiency

In the practical drawing examination, Experimental Group B achieved an average error detection accuracy rate of 89.6%, significantly outperforming Experimental Group A (72.8%) and the Control Group (54.2%). Furthermore, students utilizing the hybrid framework completed complex drawing verification tasks in an average of 62 minutes, representing a 47.5% reduction in completion time compared to the Control Group (118 minutes).



4. Discussion

The empirical findings strongly support Cognitive Load Theory in spatial graphic learning. Traditional 2D orthographic drafting forces students to maintain a volatile mental model of 3D geometry while simultaneously executing technical line work. By offloading spatial visualization to dynamic BIM models and immersive VR environments (Stage 3 & 4), students reduce extraneous cognitive load, allowing working memory to focus on structural alignment, architectural proportion, and geometric precision.

Crucially, the study demonstrates that VR immersion does not replace classical orthographic projections; rather, it acts as a powerful diagnostic tool. When students step inside a 1:1 scale virtual representation of their floor plan, spatial discrepancies (such as insufficient headroom under a stair cut or misaligned structural grids) become immediately obvious, driving immediate corrective adjustments in their 2D drawings.

5. Conclusion & Pedagogical Recommendations

Integrating classical projection methods with modern 3D BIM and VR visualization technologies substantially enhances architectural graphic literacy. The Four-Stage Hybrid Framework provides a balanced curriculum that preserves foundational geometric principles while leveraging cutting-edge immersive tools.

Summary Recommendations: Key Pedagogical Recommendations for Architectural Faculties:

- **Early Diagnostic Spatial Testing:** Administer baseline PSVT:R tests during Week 1 to identify students requiring targeted spatial visualization support.
- **Synchronized 2D-3D Feedback Loops:** Avoid teaching drafting software in isolation. Require students to continuously cross-reference 2D section cuts with 3D models and physical physical prototypes.
- **Low-Cost Immersive VR Labs:** Incorporate standalone VR headsets into studio design reviews to enable 1:1 scale spatial audits prior to final drawing submissions.

References

1. EasyChair Digital Construction Studies. (2024). Enhancing Construction Education through Integrated 2D, 3D, and VR Visualization Technologies. Proceedings in Digital Construction Management.
2. Frontiers in Education. (2024). Enhancing Mathematical and Spatial Education with Spatial Visualization Tools: Revised PSVT:R Assessment Integration. Frontiers in Education, 9(1229126).
3. Gómez-Tone, H. C., Martin-Gutierrez, J., Valencia-Ancasi, L., & Lopez-Chao, V. (2021). International Journal of Engineering Education: Immersive Virtual Reality for Developing Spatial Ability in Architecture Students. IJEE, 37(1), 145–157.
4. Heriot-Watt University Research Group. (2024). Enhancing Construction and Architectural Education through 4D BIM and Virtual Reality Integration. Buildings Journal, 14(3116), 1–18.
5. Köymen, S., & Bouidani, M. (2025). The Effect of Architectural Education on Spatial Abilities. FSM Scholarly Repository for Spatial Research.
6. Pütz, C. (2000). Descriptive Geometry Courses for Students of Architecture – On the Selection of Topics. Journal for Geometry and Graphics, 4(2), 209–218. Heldermann Verlag.
7. Pütz, C. (2021). Teaching Descriptive Geometry for Architects: Didactic Principles and Effective Methods Demonstrated. Institute for Geometry and Applied Mathematics, RWTH Aachen University.
8. Studio Matrx Architectural Graphics. (2023). Orthographic Projection & Descriptive Geometry Principles: Fundamentals for Architectural Design.
9. Inatillayevich, G. O., & Pulatovich, M. B. (2021). Analysis of Underground Projects of Energy Efficient Low-Rise Residential Buildings Built on Highly Flooded Soils. International Journal on Integrated Education, 4(9), 96-102.
10. Bolikulovich, K. M., & Pulatovich, M. B. (2022). HEAT-SHIELDING QUALITIES AND METHODS FOR ASSESSING THE HEAT-SHIELDING QUALITIES OF WINDOW BLOCKS AND THEIR JUNCTION NODE WITH WALLS. Web of Scientist: International Scientific Research Journal, 3(11), 829-840.
11. Berdiyev, M. X. (2026). ARCHITECTURAL AND URBAN PLANNING PRINCIPLES FOR CREATING A HEALTHY URBAN ENVIRONMENT: AN INTEGRATED ASSESSMENT FRAMEWORK FOR HOT-ARID AND HISTORIC CITIES. BG pulse journal, 2(10), 978-990.
12. Mamadjanova, T., Islamova, O., Berdiev, M., & Babajanov, M. (2024, November). Risks and their assessment in business: Theoretical and practical aspects. In AIP Conference Proceedings (Vol. 3244, No. 1, p. 020060). AIP Publishing LLC.
13. Юлдашева, М., Ибрагимов, Н., & Рахманова, М. (2018). Реконструкция и возрождение исторических зон города Самарканда в архитектурном проектировании САМГАСИ. Eurasian Journal of Applied Engineering and Technology (EJAET), 123(2).
14. Газизов, Р. К., & Ибрагимов, Н. Х. (2014). Приближенные симметрии и решения уравнения Компанейца. Прикладная механика и техническая физика, 55(2), 38-42.
15. Khasanovich, I. N., Akyurek, M. E., & Irisboyevich, T. U. B. (2026). THE EVOLUTION OF WATER-ENTERTAINMENT COMPLEXES: HISTORICAL ANALYSIS AND ARCHITECTURAL FEATURES. BG pulse journal, 2(10), 1067-1074.
16. Rakhimov, A., Madiev, F., Beknazarov, M., Rakhimov, L., Xudayberdiyev, A. E., Khaydarov, S., & Achildiev, R. (2025, July). Dynamic testing of the pile-in-pipe seismic isolation system

with disengaging ties. In AIP Conference Proceedings (Vol. 3304, No. 1, p. 030054). AIP Publishing LLC.
17. Abduazizovich, R. L. The Mausoleum of Humayun. International Journal of Scientific and Technology Research, 5, 7.