



ORIGINAL CONTRIBUTION

Multimodal 3D Supports Improve Observational Drawing from Life: A Quasi-Experimental Study of First-Year Art Students

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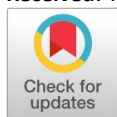
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Abstract— The persistent challenge of transferring Descriptive Geometry and Perspective (DGP) knowledge into practical control action in the Basics of Academic Drawing (BAD) arises within first-year art teacher education. Science has proven that students can learn geometric and perspectival principles conceptually, yet be unable to apply them consistently when creating observational drawings from life. To address this issue, this exploratory quasi-experimental study examined whether improved drawing process control and product quality, leading to reduced common structural errors, could be associated with an integrated instructional package comprising AutoCAD-based 3D supports, multimodal prompts, and the Integrated Control Operations Checklist (ICO_norm). A total of 46 first-year students from two art education programs completed a progression of three syllabus-oriented still-life modules with increasing complexity. Participants in the experimental group received the combined 3D multimodal support package, and those in the control group received standard BAD instruction. Three independent raters, blinded to condition, evaluated drawing outcomes using the IQD-5 rubric (Indicator of the Quality of Drawing), a binary error matrix, and ICO_norm coding for control operations during S1-S3. Across M1-M3, ICO_norm completion, IQD-5 scores, and error reduction, these same results showed larger gains in the experimental group than in the control group. Exploratory mediation analysis indicated that changes in integrated control operations were statistically consistent with a process-mediated improvement in drawing quality and error reduction. However, because this study used a non-randomized design, a relatively small sample size, and a bundled intervention, the findings should be considered preliminary evidence requiring replication and component-level analysis. Overall, the study conceptualizes multidimensional 3D scaffolding as a Self-Regulated Learning (SRL) mechanism, in which planning, monitoring, correction, and verification connect digital supports to drawing quality and error reduction.

Index Terms— Academic drawing, Descriptive geometry, Multimodal learning, 3D scaffolding, Error analysis, ICO_norm

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Introduction

Much contemporary thinking in higher education views the active learner less as a passive recipient of institutional pedagogy and more as an autonomous agent engaged in self-regulated learning within technology-enabled environments (Ahmadimoghaddam & Khaghani, 2025; Latour, 2017; Stiegler, 2018). International policy documents indicate that the nature of education is transforming in response to technology-mediated approaches, as knowledge has become accessible, controllable, and assessable (e.g., through big data). These documents further suggest that instructional designs should integrate content with learner monitoring and control features. Simultaneously, multimodal learning research by Kress (2009), Luo (2023) and Mayer (2002) indicates that learning productivity varies according to how well different modes interact to minimize

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cognitive load by coordinating the selection, organization, and integration of task-relevant information. Based on recent higher education studies, survey syntheses find that multimodal teaching strategies are associated with improved learning outcomes Khor et al., 2024. However, these studies also caution that the definitions of strategies and mechanisms of measuring outcomes vary considerably across sources (Harun & Singh, 2024; Rahmanu & Molnár, 2024). Similarly, art-technology research positions artistic tools as interventions for the generation of self-expression and cognitive development in a teacher preparation context.

However, in studio education, the value of multimodal learning cannot be reduced to simply multiple representational channels. Such channels are pedagogically significant when they enable the students to turn what is known to them into that which they can control as the drawing unfolds. This challenge is particularly evident among first-year art students, as observational drawing requires the real-time coordination of perception with construction, proportion, spatial depth, and whole-part relations. In a descriptive geometry class, a student might comprehend a geometric principle and still not apply it when the time comes to check the drawing, make corrections, and achieve structural unity. Consequently, the present study conceptualizes multimodal support not as an adjunctive embellishment but rather as a potential bridge between conceptual spatial knowledge and regulated studio practice.

This transfer problem is made visible in foundational studio education because students are required to derive perceptual, constructive, and corrective decisions from their spatial-geometric knowledge when drawing from life. Novices draw in art, design, and architecture often struggle with how to draw, especially in relation to composition, proportion, perspective, spatial depth, and whole-part relations. In the BAD course presented here, DGP is paired with observational drawing, but it repeatedly produces errors, suggesting that geometric knowledge is not routed through to operate as a checking operation during the drawing process.

Accordingly, the weak transfer from DGP knowledge to the control behavior required in BAD becomes the problem addressed in this study. This transfer problem emerges in typical studio practice when students start with an intent that seems correct but later produce conventional mistakes regarding placement, axes, proportions, perspective, and alignment along a Z-axis. Such errors do not merely reflect weaknesses in the final product; rather, they indicate that the early structural stages of the drawing were produced in a way that fails to activate planning, monitoring, verification, and corrective operations. Hence, the instructional problem is cognitive and behavioral - students must see spatial relations, comprehend their geometric logic, and then repeatedly apply the logic as a form of practical validation testing before tonal modeling obscures underlying structural inaccuracies.

Within the described framework, multimodal support acts as a regulatory scaffold. 3D Models based on AutoCAD clarify masses, axes, bounding relations, proportions, and perspectives; prompt students to plan, monitor, check, and correct these relations. In addition, ICO_norm records whether the operations are executed in S1-S3. Thus, it is proposed that repeated control operations would mediate the interaction among the support package, product quality, and error reduction. This is accomplished by investigating this novel process pathway whilst testing it using 3D/CAD scaffolds, structured prompts, ICO_norm process coding, and IQD-5 product scoring, as well as binary error diagnostics of authentic studio-based observational drawing from life.

Although prior multimodal and tech-enhanced approaches lay important groundwork for this study, they do not account for the precise transfer mechanism at hand. Numerous studies have demonstrated the potential of multimodal resources, learning analytics, CAD-environments, or 3D modeling to support understanding, engagement, spatial reasoning, and digital production (Gutiérrez de Ravé et al., 2025; Harun & Singh, 2024; Khor et al., 2024; Luo, 2023; Rahmanu & Molnár, 2024; Sosna et al., 2025). In contrast, less research shows how these forms of support manifest as a visible and observable sequence of drawing-correction behavior within authentic design studio practice. This is an important distinction because improvement in BAD cannot be attributed solely to access to a richer visual model. It also depends on whether the learner compares, adjusts, and corrects their drawing in relation to that model. The research gap is thus located along the crucial process pathway connecting multimodal geometric scaffolding with student practice control operations, and through them to drawing quality and error reduction.

This study fills this gap through an investigation of a cohesive instructional package in which DGP principles are used to inform observable actions associated with process-control behavior in BAD performance. The study assesses whether, instead of viewing multimodality as the addition of visual, verbal, and textual data, AutoCAD-based 3D supports, paired with structured prompts and the ICO_norm checklist, can help students activate control operations that are critical to their correct repetition in early observational drawing. The study is framed as exploratory because the intervention combines several instructional components and because the quasi-experimental design does not permit strong causal claims. Its contribution, therefore, lies in specifying and testing a plausible process-oriented pathway from digital scaffolding to drawing quality and error reduction, while acknowledging the need for further replication and component-level analysis.

Thus, the theoretical novelty of current research is discussed in terms of process mediation and behavioral regulation. The 3D supports based on AutoCAD aim to better clarify the definition of masses, axes, proportions, bounding relations, depth, and perspective; the multimodal prompts guide students into control actions; and the ICO_norm checklist exposes those control actions as a record of planning, monitoring, correction, and verification processes enacted during S1-S3. Framing the study this way permits it to go further than a blanket assertion that multimodality will enhance learning and allows us to start asking whether a coordinated support package correlates with more uniform process control, process innovation, or quality product generation, and fewer common structural errors. Thus, this study is distinctive in its integration of cognition and metacognition processes with observable drawing behavior, assessed through process-product and diagnostic-based indicators.

The study addresses the following research questions:

- (RQ1) Are first-year students exposed to the integrated AutoCAD-based 3D multimodal support package associated with greater improvements in BAD outcomes, drawing quality, and reduction of typical errors than students receiving standard instruction across M1-M3?
- (RQ2) Is exposure to the support package associated with higher completion of integrated control operations during S1-S3, as measured by ICO_norm?
- (RQ3) Are changes in ICO_norm statistically consistent with an exploratory process-mediated pathway linking group assignment with changes in drawing quality and error reduction?

Literature Review

Multimodal learning and self-regulation as a mechanism, not decoration

Multimodality has been described as the orchestrated deployment of semiotic and interactional resources to make sense and act within contexts (Jewitt, 2012; Kress, 2009; Van Leeuwen, 2008). A recurring implication is that “multiple modes” per se are not a good thing (because “effective” performance requires representation-task fit). Cognitively, multimedia learning theory anticipates enhancements when representations are distributed but do not overload mental operations and integrate them across verbal-visual channels (Belhaj, 2025; Mayer, 2002). Some of the more recent syntheses in higher education paint a general picture: Multimodal designs exhibit positive effects but also show substantial heterogeneity in what is considered a “multimodal strategy” and in how outcomes are assessed, challenging replication and mechanism inference (Harun & Singh, 2024; Rahmanu & Molnár, 2024). This constraint is problematic for BAD because the goal of both tasks is not just comprehension but execution: How novices verify and correct drawings in response to life setups.

Multimodal learning analytics has shifted its focus from final products to process indicators, e.g., attention, coordination, interaction, and regulation (Arifin et al., 2025; Ouyang et al., 2022). This shift is well aligned with Self-Regulated Learning (SRL) theory: Zimmerman’s cyclical model connects three phases - forethought, performance control, and reflection; Pintrich’s SRL framework underscores the regulation of cognition, motivation, behavior, and context; and Winne and Hadwin proposed a trace-based cycle encompassing task definition, goal setting, tactics, and adaptation to describe how students learn (Hacker et al., 1998; Panadero, 2017; Pintrich, 2004; Zimmerman, 2002). These phases relate to BAD as follows: Planning the format, observing axes and proportions, correcting spatial deviations, and checking overall work before tonal modeling.

Drawing research indicates that accuracy is directly tied to perceptual selection, visual measurement, eye-hand coordination, and object comparison as the drawing emerges. Potential sources of errors include misperception of the object itself, weak representational decisions, or insufficient monitoring of the drawing process (Chamberlain et al., 2013; D. J. Cohen & Bennett, 1997; Tchalenko & Chris Miall, 2009). Thus, BAD is an appropriate test bed for 3D scaffolds and prompts that may strengthen the processes by which novices observe, construct, check, and revise drawings.

The conceptual model of the present research establishes a sequential but reciprocal link between four constructs, building from these positions. First, the multimodal 3D scaffolds serve as external representations of the still-life structure, which allow for global inspection of massing, axes, proportion, depth, and constructive relations. Second, the representations are expected to affect drawing quality not from their qualitative visual presence alone but rather in a way that facilitates self-regulated learning processes like task definition, planning, monitoring, tactical correction, and verification. Third, these regulatory processes become visible in BAD using integrated control actions documented by ICO_norm in S1-S3. Fourth, when control operations are carried out with higher consistency, the resulting drawing is expected to exhibit greater IQD-5 scores and fewer diagnostic errors. Consequently, the framework views ICO_norm as a mediator of instruction packages and ultimate drawing results. This bridge is interesting because it explains not only why multimodal scaffolding may be effective through increased information exposition, but also how learners use this information for regulatory purposes to guide drawing construction while remaining open to correction.

3D/CAD and virtual wire-frame scaffolds for spatial reasoning and art education

Studies in Computer-Aided Design (CAD) and 3D modeling show how computational representations of spaces can offload projection, depth, and transformation tasks, making them more tangible by guiding spatial reasoning and procedural precision (Gutiérrez de Ravé et al., 2025; Ndububa, 2025; Sosna et al., 2025). Nevertheless, much research suggests that engagement, digital production, or the perceived value of learning itself is more important than actual improvement, as measured by hand-drawn observational products (e.g., this cannot be easily mapped into BAD, where the primary outcome is whether the student can control a drawing from life). Aidar et al. (2025) concentrated on curricular analysis and AutoCAD-based descriptive geometry.

Therefore, AutoCAD-based 3D support is considered as one part of a bundled instructional design. The scaffolding is therefore defined on stages of drawing operations: L1 supports global placement and massing in S1; L2 provides support for axes and proportional construction in S2; and L3 provides support for overlay, section, and verification in S3. Framing in this way separates representational support from potential novelty, motivation, and/or attentive-teacher effects.

At the same time, the literature on digital and technology-enhanced learning cautions against attributing performance gains solely to the instructional tool itself. Improvements may also reflect novelty effects, increased learner engagement, greater teacher attention, or the motivational value of working with digital representations. This caution is particularly important in studio-based art education, where affective engagement, confidence, and task persistence may influence the quality of drawing outcomes. Therefore, studies of 3D or CAD-based scaffolding should distinguish, as far as possible, between the representational value of the support, the regulatory value of the accompanying prompts, and the engagement effects produced by the introduction of new technology. The present study acknowledges this issue by interpreting the intervention as a combined instructional package rather than as evidence of the isolated effect of AutoCAD-based 3D modeling alone.

Process-oriented evaluation: Rubrics, checklists, and error coding with reliability

There is also an expectation that the assessment-for-learning literature, which supports explicit criteria and feedback loops assisting students in regulating performance across time (Black & Wiliam, 1998; Carney et al., 2022). Rubrics, when criteria are operationalized and transparent, can be used for learning purposes (Andrade, 2000; Brookhart, 2013). Due to the potential for studio assessment to be holistic and implicit, the need for well-defined coding rules and inter-rater reliability (J. Cohen, 1960; Krippendorff, 2011) on observational judgment is also essential.

That remaining gap is methodological and process-based: Multimodal/3D studies frequently benefit from multiple measures of gain but often do not specify what exactly changed in task-specific actions, while drawing assessments occasionally document the development of monitoring and correction without specifying the links with final products. This study bridges that gap by aligning three instruments: ICO_norm for process control, IQD-5 for product quality, and the binary error matrix for a reduction of diagnostic errors. Collectively, they address whether the observed effects reflect a process pathway, indicating that improvement reflects more than a tool or an engagement effect alone.

On this basis, the literature review resulted in three working hypotheses, which guided the empirical analysis. We hypothesize that students receiving the integrated AutoCAD-based 3D multimodal support package will demonstrate larger gains in drawing quality and more robust corrections of typical errors across M1-M3 than students who receive standard BAD instruction. Second, those students are expected to show higher frequencies of completion of integrated control operations during S1-S3 since the scaffolds and prompts should make planning, comparison, correction, and verification more obvious and systematic. Thirdly, a statistically significant improvement in ICO_norm is anticipated under a process-mediated pathway, whereby the instructional package leads to improved drawing outcomes through enhanced control behavior. These hypotheses do not assume AutoCAD-based models alone are responsible for the improvement; rather, they reflect the assumption that 3D supports, multimodal prompts, checklist-guided regulation, and studio feedback function as an integrated system of instruction.

Methodology

This study used a quantitative, quasi-experimental repeated-measures design with an experimental group and a control group over one semester. The design was quasi-experimental because students were not randomly assigned to conditions. The independent variable was exposure to an integrated instructional package consisting of AutoCAD-built 3D models of syllabus-aligned still-life setups, visual/audio/text prompts, and a normative Integrated Control Operations Checklist (ICO_norm). The control group followed standard BAD instruction within the same curriculum. The main outcomes were drawing quality, measured with the Indicator of the Quality of Drawing rubric (IQD-5; five criteria scored 0-3); frequency of typical drawing errors, coded through a binary error matrix; and process execution, operationalized as ICO_norm completion during S1-S3. Because the intervention combined multiple components, the study evaluates the effect of the package rather than the separate contribution of each component.

The study participants were first-year students enrolled in two programs at Abai Kazakh National Pedagogical University (Almaty, Kazakhstan): 6B02126 "Fine arts" ($n = 24$) and 6B01416 "Art education" ($n = 26$). This yielded an analytic sample of ($N = 46$: four students opted for standard training despite being willing to participate. Both groups were as mixed across programs as possible (the experimental group, EG; ($n = 23$; 6B02126, ($n = 11$; 6B01416, ($n = 12$; and the control group, CG; ($n = 23$; 6B02126, ($n = 12$; 6B01416, ($n = 11$), to minimize program-specific confounding. The inclusion criteria were a first-year enrolment in the basics of design (BAD) and Descriptive Geometry and Perspective (DGP) in the first semester. In contrast, exclusion criteria were (i) withdrawal, (ii) refusal, and (iii) missing artifact(s) that could not be compared across modules. Because of the lack of self-selection into standard training, baseline equivalence checks and sensitivity analyses were conducted to assess robustness.

Because group allocation was not randomized, several potential confounding variables may have influenced the results. These include prior drawing experience, initial motivation, individual confidence in academic drawing, familiarity with digital tools, and differences in self-regulated learning habits. Baseline equivalence was therefore examined using the available M1 outcome measures for process execution, drawing quality, and error frequency. However, unmeasured differences between groups cannot be fully excluded. For this reason, the results are interpreted as evidence of association within an authentic instructional context rather than as causal evidence.

The data were collected in an authentic instructional context in the first semester of the academic year 2024–2025 and followed the approved modules of the BAD syllabus, increasing in developmental complexity: M1 (still-life of mutually compositional geometric solids, = cylinder, sphere, pyramid on a dark background), M2 (composed still-life of plaster rosette/ornament "Flower" +1 fruit, e.g., apple), and M3 (Complex composed

still-life of plaster rosette “Flower” + 2-3 fruits/vegetables and vase/jug) All modules were conducted using a common, staged workflow indicative of the academic rules for drawing (the “from general to specific” principle, schematic wholeness through continuous comparison, and iterative verification from afar). The sessions were organized into S1 (Composition and Analysis), S2 (Constructive Build), S3 (Verification/Generalization), and S4 (Tonal Modeling), with S1–S3 contributing to structural accuracy.

Three tiers of multimodal 3D support were available to guide learners through each module. L1 supported understanding of global mass, sectional mass, and silhouettes, as well as how everything relates globally to begin making the initial layout decisions. L2 also axes-based object relations, household tools analogies, interacting with bounding structures, and proportional cues to support constructive and proportionally correct control. For tonal modeling, L3 provided section, overlay, and checking cues to assist with targeted correction. The supports were provided with visual, audio, and text cues that were synchronized with the ICO_norm control operations for S1-S3.

To delineate the structure of the intervention, operationally, instruction was divided into four components. Those components were included in the delivery (combined) and not experimentally separated in the current study (Table I).

Table I
Components of the integrated instructional package

Component	Operational role in BAD workflow	Isolated in this study?
Visual prompts	Directed attention to masses, axes, proportions, spatial depth, and constructive relations.	No
Audio/text prompts	Verbalized checking procedures and reminded students of the sequence of control actions.	No
ICO_norm check-list	Structured students’ process control during S1-S3 and provided a record of completed operations.	No

Hence, the intervention needs to be interpreted as a packaged instructional design. This study does not state that the AutoCAD models by themselves caused differences that were observed; it looks at whether stronger process control and drawing outcomes that were particularly good (not identified individually as through guided standards) were associated with using the combined package.

ICO_norm was a binary checklist of integrated control operations (i.e., complete process execution) during S1-S3. The operations were scored as 0 = not observed/performed, or 1 = observed/performed. The checklist recorded before tonal modeling if students executed key control actions such as checking overall placement, comparing major proportions, identifying axes and constructive relations in line, verifying perspective/spatial alignment, and correcting structure with errors. The binary format was chosen to enhance scoring consistency between raters as well as serve as a practical consideration of making the process easy to record in a real studio setting. Yet this format will log an operation but not its quality, granularity, or consistency. This limitation was recognized in the results interpretation, and conducting future studies with ordinal coding (e.g., 0 = not performed; 1 = partially performed; 2 = consistently and correctly performed) should be implemented.

Table II
IQD-5 scoring descriptors

Criterion	0	1	2	3
Composition	Objects are poorly placed; format is not organized.	Placement is unstable or partly accidental.	Composition is mostly balanced with minor weaknesses.	Composition is clear, balanced, and appropriate to the format.
Construction	Constructive structure is absent or incorrect.	Basic construction is attempted but unstable.	Main constructive relations are mostly correct.	Construction is accurate, coherent, and supports the whole drawing.
Proportions	Major proportional distortions dominate the drawing.	Some proportions are recognizable but inconsistent.	Proportions are generally correct with minor deviations.	Proportional relations are accurate and consistently controlled.
Perspective/space	Spatial relations and perspective are largely incorrect.	Spatial depth is attempted but contains major errors.	Perspective and spatial relations are mostly convincing.	Perspective, depth, and spatial organization are accurate and integrated.
Wholeness/ subordination	Drawing lacks unity; parts are disconnected.	Some relationships are visible but weakly coordinated.	Whole-part relations are mostly coordinated.	The drawing demonstrates strong unity, hierarchy, and subordination of details.

IQD-5, a five-criterion analytic rubric with indices from 0 to 3 for each criterion and a total score considered in the range of 0–15, was used to evaluate product quality. There were five: composition, construction, proportions, perspective/space, and wholeness/subordination. It was intended to represent fundamental priorities in BAD assessment and to aim for a direct relationship between elements of product quality and

process operations, as abstracted by ICO_norm. The most common errors were coded using a binary error matrix, assigning each predefined error code a value of 0 (absent) or 1 (present). The objective of the error matrix was to communicate diagnostic information regarding recurring structural, proportional, compositional, and spatial inaccuracies.

The IQD-5 scoring descriptors were operationalized as follows (Table II).

Instrument development and validation rationale

In this study, ICO_norm, IQD-5, and the binary error matrix functioned as context-specific criterion-referenced instruments rather than externally standardized tests. Hence, content validity was grounded in BAD workflow and DGP-related control actions as well as relevant quality dimensions of drawing, like composition, construction, proportions, perspective/space, and wholeness/subordination. This was accomplished through coding rules, scoring descriptors, anonymized drawings, three blinded raters, and separate estimates of reliability for the process analysis (coding & rating procedures), product analysis, and error coding. This study provides evidence of internal reliability and content validity alignment but requires further external psychometric validation in future studies.

Before beginning the rating process, raters were provided the IQD-5 descriptors, ICO_norm coding rules, and error-matrix definitions to improve scoring consistency. The scoring guide represented various descriptors corresponding to each criterion and the threshold required to assign a given score. Raters were blind to the students' group membership during all evaluations, and final ratings were conducted independently of each other. Inter-rater reliability was calculated to assess the consistency of scoring across raters. The current study provides evidence of reliability but does not claim external psychometric validation of the IQD-5 or ICO_norm beyond this context.

Raters (three independent instructors in the same department) were blinded and unaware of the identities of students. Drawings were anonymized, and all drawings were encoded prior to rating. Statistical methods: Data analysis consisted of descriptive statistics, equivalence checks for M1 baseline groups, estimates of inter-rater reliability for ordinal and binary measures, group-by-module mixed repeated-measures analyses, and exploratory bootstrap mediation analyses. Ethics procedures were compliant with university policies: (i) participation was voluntary, (ii) informed consent was secured, (iii) data anonymized, and (iv) research evaluation separated from routine grading.

Results

The results are presented in three steps. First, descriptive statistics are reported to show the pattern of change across modules. Second, inter-rater reliability is reported to evaluate the consistency of the assessment procedures. Third, group-by-module effects and exploratory mediation analyses are presented. Because of the quasi-experimental design and the small sample size, inferential results are interpreted cautiously and are not treated as definitive causal evidence.

In the three syllabus-aligned BAD modules (M1-M3), a total of 138 drawings were produced by first-year students: 46 in each module, with one drawing per student (EGs: ($n = 23$); CGs: ($n = 23$)). Using IQD-5 (five criteria, each rated 0-3 points; range: 0-15), a binary error matrix (20 codes; each coded as absent (0) or present (1); range: 0-20), and ICO_norm coding of integrated control operations during S1-S3, three blind raters independently reviewed the drawings.

Inter-rater reliability

All instruments demonstrated strong inter-rater agreement. For the overall combined IQD-5 total score, Krippendorff's alpha was $\alpha = .86$, 95% CI [.81, .90]. Across the five IQD-5 criteria, alphas themselves varied from .78 to .85. We used for ICO_norm coding, $\alpha = .89$, 95% CI [.85, .92]. For error-matrix coding, $\alpha = .84$, 95% CI [.79, .88] (Table IV).

Baseline comparisons (M1)

At M1, no significant differences were observed between the two groups. For ICO_norm total, the experimental group (EG) ($M = 7.4$, $SD = 1.9$) and the Control Group (CG) ($M = 7.2$, $SD = 1.8$) did not significantly differ, $t(44) = .36$, $p = .723$. For IQD-5 total, no difference between EG ($M = 6.7$, $SD = 1.4$) and CG ($M = 6.6$, $SD = 1.5$) was found, $t(44) = .24$, $p = .813$. Similarly, global errors, EG ($M = 9.1$, $SD = 2.0$) and CG ($M = 9.0$, $SD = 2.1$) did not statistically differ $t(44) = .17$, $p = .864$ (Table III).

Group differences across modules (M1–M3)

A mixed between-within-subjects Analysis of Variance (ANOVA) was conducted, with Group (experimental vs control) as a between-subjects factor and Module (M1, M2, M3) as the within-subjects factor. For ICO_norm total, the Group $\times$ Module interaction was significant, $F(2, 88) = 19.62$, $p < .001$, $\eta^2 = .31$ (Table V). Regarding IQD-5 total, the Group $\times$ Module interaction was significant, $F(2, 88) = 16.41$, $p < .001$, $\eta^2 = .27$. Regarding total errors, the Group $\times$ Module interaction was significant, $F(2, 88) = 14.08$, $p < .001$, $\eta^2 = .24$.

Descriptive statistics (Table III) revealed that from M1 to M3, ICO_norm increased by +7.6 operations in EG (from M = 7.4 to 15.0) compared with +4.8 in CG (M = 7.2 to 12.0). Over this same period, EG increased IQD-5 by 5.2 points (from M = 6.7 to 11.9) compared with CG, which increased by 2.9 points (from M = 6.6 to 9.5). Total errors diminished –5.0 codes in EG (M = 9.1 to 4.1) as opposed to –2.6 in CG (M = 9.0, 6.4).

Mediation analyses (M1→M3 change scores)

Exploratory mediation analyses were conducted using change scores from M1 to M3 (Δ ICO_norm, Δ IQD-5, and Δ Errors). Percentile bootstrap confidence intervals with 5,000 resamples were used to estimate indirect effects. The indirect effect of Group on Δ IQD-5 through Δ ICO_norm was positive, $ab = 0.88$, $SE = 0.33$, 95% CI [0.28, 1.55]. The indirect effect of Group on Δ Errors through Δ ICO_norm was negative, $ab = -0.73$, $SE = 0.29$, 95% CI [-1.33, -0.18]. The serial indirect pathway from Group to Δ Errors through Δ ICO_norm and Δ IQD-5 was also negative, $ab = -0.41$, $SE = 0.20$, 95% CI [-0.87, -0.09]. These findings are statistically consistent with the proposed process-mediated interpretation; however, they should be regarded as exploratory due to the limited sample size and the non-randomized study design.

Table III
Descriptive statistics for process (ICO_norm), product (IQD-5), and error outcomes by group and module

Outcome	Group	M1 Mean (SD)	M2 Mean (SD)	M3 Mean (SD)
ICO_norm total (0–18)	EG	7.4 (1.9)	11.6 (1.8)	15.0 (1.6)
	CG	7.2 (1.8)	9.8 (1.9)	12.0 (1.7)
IQD-5 total (0–15)	EG	6.7 (1.4)	9.7 (1.3)	11.9 (1.2)
	CG	6.6 (1.5)	8.1 (1.4)	9.5 (1.3)
Errors total (0–20)	EG	9.1 (2.0)	6.0 (1.8)	4.1 (1.6)
	CG	9.0 (2.1)	7.6 (1.9)	6.4 (1.7)

Note. ICO_norm total is the sum of completed integrated control operations (0/1) recorded during S1–S3. IQD-5 total is the sum across five criteria (0–3 each). The total is the sum of coded typical errors (0/1 per code)

As shown in Table III, although both groups demonstrated improvement from M1 to M3, the experimental group exhibited a more substantial positive change across all three outcome domains. The increase in ICO_norm was more pronounced in the experimental group, indicating that S1-S3 process-control operations were held significantly more profusely. The experimental conversed group had greater IQD-5 scores and thus higher product quality from the M3. Total errors also fell more steeply in the experimental group. Overall, this pattern is consistent with the combined support package being associated with more effective execution of creative processes and more precise drawing states.

Table IV
Inter-rater reliability (3 blinded raters)

Measure	Scale	Coefficient	Value	95% CI
IQD-5 total	Ordinal	Krippendorff's α	.86	[.81, .90]
IQD-5 criteria (range)	Ordinal	Krippendorff's α	.78–.85	—
ICO_norm coding	nominal/binary	Krippendorff's α	.89	[.85, .92]
Error matrix coding	nominal/binary	Krippendorff's α	.84	[.79, .88]

Acceptable to strong inter-rater reliability was observed across all three domain assessments (Table IV). The total score for the IQD-5 demonstrated very high agreement, while all individual IQD-5 criteria showed acceptable levels of inter-rater reliability. Good agreement was also noted for ICO_norm coding, indicating that raters could reliably determine whether key control operations were performed. Binary diagnostic coding showed strong reliability, as evidenced by the error matrix. Overall, these results support the internal consistency of the scoring procedures used in this study; however, they do not replace the need for further external validation of the assessment framework.

Table V
Group $\times$ module effects and mediation (M1→M3 change scores; bootstrap 5,000)

Analysis	Statistic	p	Effect size / CI
ICO_norm: Group $\times$ Module	$F(2, 88) = 19.62$	$< .001$	$\eta^2 = .31$
IQD-5: Group $\times$ Module	$F(2, 88) = 16.41$	$< .001$	$\eta^2 = .27$
Errors: Group $\times$ Module	$F(2, 88) = 14.08$	$< .001$	$\eta^2 = .24$
Group $\rightarrow \Delta$ ICO_norm $\rightarrow \Delta$ IQD-5	$ab = 0.88$ ($SE = 0.33$)	—	95% CI [0.28, 1.55]
Group $\rightarrow \Delta$ ICO_norm $\rightarrow \Delta$ Errors	$ab = -0.73$ ($SE = 0.29$)	—	95% CI [-1.33, -0.18]
Group $\rightarrow \Delta$ ICO_norm $\rightarrow \Delta$ IQD-5 $\rightarrow \Delta$ Errors	$ab = -0.41$ ($SE = 0.20$)	—	95% CI [-0.87, -0.09]

Note. Δ indicates M3 – M1 change. Indirect effects were evaluated using bias-corrected bootstrap confidence intervals.

Two-way ANOVA revealed significant Group $\times$ Module interactions on ICO_norm, IQD-5, and total errors (Table V), indicating that the pattern of change over modules M1-M3 was different for both groups. The effect size of the mean difference between groups suggests meaningful group-related differences with respect to Developing Process Execution, Defect Product Quality, and Decreasing Errors. The mediation results also indicate that increases in ICO_norm can mediate gains in drawing quality and reductions of errors. Like the indirect results, these should be taken as speculative associations rather than definitive evidence of causation.

Discussion

Results offer initial support for a process-based interpretation of multimodal 3D scaffolding in first-year BAD instruction. The experimental group scored over the control 3 times higher and 2.5 times higher in ICO_norm completion, IQD-5, and coded errors on M1-M3; mean differences of all the metrics were greater than a threshold score. Knowing this, these findings suggest that an integrated instructional package may have enabled students to convert their knowledge of DGP-related content into observable control operations from S1-S3. Because the study was quasi-experimental and not done by random assignment, the findings should be considered correlational, occurring in a true classroom environment and not causal. The mediation analysis adds plausibility to the hypothesized process pathway but remains exploratory and in need of replication in larger, randomized samples.

Its findings contribute to the broader claim that multimodal designs can enhance learning outcomes, but also further delineate specific mechanisms. Positive but heterogeneous effects of multimodal strategies in higher education are reported by systematic and review-based studies, since the term “multimodal” is used for very different instructional designs and outcome measures (Harun & Singh, 2024; Khor et al., 2024; Rahmanu & Molnár, 2024). The present results confirm that positive direction, but go beyond it to show that a key outcome in BAD is not just success after instruction, but the students’ ability to translate multimodal cues into repeated checking and correcting actions. So, this contribution is less an additional piece of evidence for the beneficial impact of multimodal learning but rather a process-level account of when it may become even more helpful in studio drawing. In this respect, the paper provides a wider art-technology rationale of Kozhagulov et al. (2026) a narrower process-control interpretation.

Alternative explanations should also be considered. The observed effects may indicate the presence of a structural value in the supports from 3D, although not only those should have driven the content structure, as it was probably a novelty effect by AutoCAD-based materials, more engaged students, greater attention to task, and hence better motivation in favor of the experimental condition. In this study, knowing digital tools and having prior experience with drawing could also influence how students responded to the intervention. However, these issues were not directly assessed in the current study, which weakens its internal validity. Future research should assess motivation, prior experience, engagement, and digital familiarity to differentiate the effects of 3D scaffolding from more general technology or motivational factors.

Theoretical implications

The findings relate to multimodal learning theory, but rather than augmenting the claims that multiple means translate into better learning outcomes. Overall, the results suggest that supporting issues with multimodal materials is most meaningful when those materials involve relatively concrete operations that students will be able to perform, check, and repeat as they work on their problem. This reading is corroborated by cognitive and social-semiotic accounts of multimodality, where coordination between representational forms and situated action is key. Unlike in previous research, the visual, audio, and textual prompts were not simply decoration but support for specific control operations (finding masses, checking axes, comparing proportions, verifying spatial relations). This brings me back to the key point that this interpretation is process-centric, and perhaps why multimodal learning may be particularly useful in observational drawing, where students have no time or opportunity to replace conceptual knowledge with action; instead, they must convert declarative knowledge into by-performance perceptual and constructive decisions.

This finding is also consistent with Self-Regulated Learning (SLR) theory. A cyclical model of forethought, performance control, and reflection by Zimmerman (2002), regulation of cognition and behavior by Pintrich (2004), and a trace-oriented model by Winne and Hadwin all support the argument that learning will be enhanced if students define the task, select tactics, monitor their progress, and adapt their actions (Hacker et al., 1998). In this study, one can interpret the increase in ICO_norm as an observable studio analogy for these SRL processes. The fact that the intervention did not just provide students with additional information about the object to be drawn, but prompted them to self-regulate how they constructed their drawing. Accordingly, the mediation results extend SRL theory into the context of observational drawing, suggesting that process-control operations may mediate the connection between instructional scaffolding and product-level improvement.

The current study extends this discussion into studio-based observational drawing from life, in contrast to studies on CAD and 3D modeling in engineering graphics or design education. Whereas most of the prior work has focused on spatial reasoning, digital production, or learner engagement, the present study explored the transfer of geometric-perspectival knowledge into hand-drawn construction in the presence of real observers. The findings, therefore, extend research on digital pedagogies by suggesting that the pedagogical value of 3D supports may be less contingent on their technological sophistication and more reliant on their integration with an individual learner’s drawing workflow. The study

also challenges the dominance of purely product-based evaluation in art education, revealing that better tracking than products may be possible via process indicators and diagnostic error coding -a more systematic way of making improvement visible and instructionally actionable.

With regard to scaffolding research focused on CAD-based practices and 3D scaffolding, results corroborate the importance of computational representations for rendering spatial structure more salient (An & Tao, 2024; Gutiérrez de Ravé et al., 2025; Sosna et al., 2025). Simultaneously, the current study adds to this line of research as the target performance was not purely digital modeling nor solely spatial-reasoning performance, but observational construction through hand drawing from life. This difference is important. The AutoCAD-based supports were utilized as a temporary scaffold for comparing, correcting, and verifying a physical drawing rather than final digital products. This suggests that CAD-based scaffolds may be more fruitful when integrated into a concrete, end-to-end workflow of studio control actions rather than being introduced as a separate technocentric engagement. It also advances the AutoCAD curriculum line of Aidar et al. (2025) research on process verification in BAD

The transfer DA gap between DGP knowledge and BAD performance also becomes more conspicuous from M1 to M3 as the task complexity increases. Proportional & spatial coordination requirements heightened when students progressed from geometric solids to mixed ornamental, organic, and vessel-based still-life arrangements. The stronger EG gains, as a general tendency, indicate that multiple repeats of ICO_norm may be particularly beneficial when early errors in tonal modeling through S1–S3 are likely to propagate into later construction.

The results also dovetail with contemporary and prior studies of observational drawing. Research on drawing accuracy highlights the importance of perceptual selection, visual measurement, hand-eye coordination, local-global comparison, and error monitoring during drawing (Abdullah et al., 2024; Chamberlain et al., 2013; D. J. Cohen & Bennett, 1997; Liu et al., 2025; Tchalenko & Chris Miall, 2009). The current results lend support to this idea because the largest gains were found in conditions where students performed operations of contrast, line check between axes, scale check on the right axis, and structure corrections most reliably. Meanwhile, the research enhances the field of observational drawing by describing how these moving parts can be taught and evaluated through an overlaid process-product-diagnostic model. The findings do not negate previous work but rather augment it by providing a curricular and instructional rationale: students may be better at line drawing when perceptual work is prominently linked to specific geometric reference points that are checked repeatedly by regulatory checking mechanisms.

From an assessment perspective, the study validates the efficacy of product, process, and diagnostic type measures in fundamental drawing education. The analytic estimate of drawing quality was derived from IQD-5, ICO_norm indicated whether student-controlled activities, and the error matrix identified structural & positional errors made repeatedly. This fusion addresses a widespread challenge of studio assessment, namely, the tendency for drawing evaluation to be global or embedded and hard to reproduce. The reliability coefficients in this study indicate that the trained raters can make consistent use of the instruments. However, these instruments are tools to be used within a particular context and need external validation for continuous use across cohorts, institutions, and drawing tasks.

These comparisons together clarify the contributions that have been made. The findings corroborate prior research on multimodal learning, CAD-based instruction, SRL, and observational drawing, while extending this literature toward a more holistic, process-oriented model of first-year BAD instruction. Although the pathway that comes out of this - 3D/multimodal scaffolding, inherent form-and-function-based SRL-related control operations embedded in drawing with better quality and fewer structural errors, etc — is still largely exploratory; it offers a much more systematic manner for how the improvement occurs than these narrowly drawn product or technology-centered points can deliver. This is why the study should be interpreted as an initial step toward a process-oriented approach to drawing pedagogy rather than an assertion that digital tools correlate with better academic drawing.

Practical implications

The results have several practical implications. DGP can be incorporated into BAD to provide explicit control operations instead of additional theoretical time, as the first option. Even more so, L1-L3 supports can be used diagnostically: L1 indicates layout and massing, L2 informs about axes and proportions, and then the third layer will check everything up and aid in repairing if necessary. Third, the error matrix with IQD-5 can link product feedback with process guidance. Fourth, ICO_norm can enhance the transparency of studio assessment by helping students understand which operations must be conducted in advance of tonal modeling.

Limitations and future research

The interpretation of the findings has several limitations. The study was conducted at a single institution with a modest sample size ($n=46$), which limits generalizability. Second, the lack of random assignment leaves unmeasured differences between groups free to contribute to the results, although there were no significant group differences for baseline outcome measures at M1. Third, the intervention was bundled: AutoCAD-based 3D supports combined with visual/audio/text prompts and ICO_norm structuring. Consequently, the study is not capable of determining which component was primarily responsible for the observed changes. Fourth, ICO_norm was a dichotomous code which simplified coding but did not reflect differences between students in terms of the degree to which or consistency with which they performed each control operation. Finally, novelty effects, engagement, prior drawing experience, motivation, and familiarity with digital tools were not measured in the study directly. Lastly, in S1-S3 analysis, focusing on tonal modeling was highlighted as opposed to later tonal modeling in S4, which may also be co-occurring and,

as such, have an impact on global ratings of drawing quality. The aforementioned limitations imply that the findings should be interpreted as preliminary and exploratory rather than conclusive.

To conclude, future studies should replicate the present research using larger samples, different institutions, and by randomly matched groups. In addition, component-level or dismantling studies are needed to isolate the relative contribution of AutoCAD-based 3D models, multimodal prompts, checklist-guided process control, and teacher feedback. Future work should also establish more variant forms of ICO_norm and implement ordinal or qualitative scoring systems instead of using binary coding in isolation. Lastly, studies should assess motivation, past drawing experience, effort, and digital competence to examine potential artifacts of improvement. Finally, transfer and retention effects should be examined by applying the support system to novel motifs, later-semester drawing tasks, and independent drawing conditions without direct scaffolding.

Conclusion

This exploratory quasi-experimental study examined whether an integrated AutoCAD-based 3D multimodal support package was associated with improvements in observational drawing from life among first-year art students. The study focused on the transfer of Descriptive Geometry and Perspective knowledge into practical control operations during the early stages of the Basics of Academic Drawing. A total of 46 students completed three syllabus-aligned still-life modules of increasing complexity, and their drawings were evaluated by three blinded independent raters using IQD-5, a binary error matrix, and ICO_norm coding for S1-S3 process operations.

Results indicated that the experimental group exhibited greater improvements in process-control completion, drawing quality, and reduction of typical errors compared to control students. Exploratory mediation analysis indicated that decreases in ICO_norm were statistically compatible with a process-mediated explanation of improvement: those students who more consistently completed control operations also tended to show greater drawing quality gains and error reductions. However, these findings should not be interpreted as quasi-causal evidence. The non-randomized design, the small sample size, the bundled intervention, and the binary outcome of ICO_norm are limitations in strengthening conclusions.

Thus, the primary contribution of this study is not a definitive validation of 3D scaffolding, but rather the development of a systematic and verifiable model to link DGP's knowledge with the process-control actions that must be performed to bring about desired BAD effects. The study indicates that digital 3D support can enhance pedagogy through alignment with concrete drawings, clear checking procedures, and highly visible assessment drivers. The practical implications of these findings may be realized through L1-L3 visual supports, ICO_norm-guided process monitoring, and criterion-referenced feedback with IQD-5 and error diagnostics. However, further research is required before fundamental generalizations can be made with randomized designs, larger samples, comparisons between components and process measures that are considerably better at detecting slight variations.

In summary, this interpretation situates the study within recent work in multimodal and CAD/3D learning, extends self-regulated theory from task processing to observable drawing-control behavior, pinpoints improvements in observational drawing to practice based on repeated diagnostic correction, iterative feedback, and process-oriented assessment rather than final product alone, so as to connect these findings with contemporary educational design and studio pedagogy.

Declarations

Conflict of interest

The authors declare that they have no known financial interests, personal relationships, institutional affiliations, or other competing interests that could have influenced the design, implementation, analysis, interpretation, or reporting of this study.

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Author contributions

All authors contributed to the conception and design of the study, research implementation, data collection, data analysis, interpretation of findings, and manuscript writing and revision. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for its content.

Informed consent

All participants took part in the study voluntarily, and informed consent was obtained prior to data collection. Participants were informed that their data and drawing artifacts would be anonymized and treated confidentially. The research evaluation was separated from routine academic grading.

Use of generative AI

Generative AI and AI-assisted language tools were used only for language editing, translation support, and improvement of the readability of the manuscript. These tools were not used to generate the study design, data, statistical analysis, results, or conclusions.

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