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Method Article

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Posted Date: July 14th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10068229/v1>

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Additional Declarations: No competing interests reported.

A generative game design framework for teaching architectural aesthetics through embodied cognition and *rasa* theory

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Abstract

Aesthetic understanding of built form — the trained reading of proportion, scale, materiality, and atmosphere — is foundational to architectural competence, yet it is structurally under-taught: instruction is ocularcentric, embodied spatial learning is valued but rarely made explicit, and socio-cultural reasoning is left to studio osmosis. Game-based learning is a promising medium for repairing this, but the field has lacked a design framework fit for the specific cognitive demands of architectural-aesthetic learning. This paper develops one. We first audit twenty serious-games design frameworks in a deliberately non-circular two-step protocol — generic pedagogical adequacy against Bloom’s revised taxonomy, then architectural-aesthetic coverage across three dimensions (visual-perceptual, embodied-spatial, socio-cultural) — and read the audit against a PRISMA-compliant review of 114 game-based-learning studies in architecture (2014–2024). The audit exposes four structural absences: no framework integrates all three dimensions, none is architecturally native, none treats embodiment as a first-order concern, and none engages a non-Western aesthetic theory as a design resource. Using Design Science Research, and triangulating the review, the audit, and four classroom pilots, we derive six design requirements and develop the Architectural Pedagogy Game Framework (APGF): a five-step design methodology (learner analysis → aesthetic-goal definition → mechanic selection → action research → validation), an eighteen-mechanic 3E inventory (Eye, Embodiment, Everyday) grounded in *rasa* theory and embodied cognition, and a set of dimension-aligned assessment instruments. The framework satisfies internal-coherence and instantiability criteria. Rather than a single artefact, however, it defines a generative space: any combination of target dimension, complexity tier, and platform yields a principled game design. We illustrate this space with a catalogue of twelve worked games spanning the B.Arch. curriculum from first year to thesis — from a card game for stylistic vocabulary to a semester-long studio commission, realised across cards, tactile kits, augmented reality, board games, and virtual reality, and reaching beyond Hindu-temple architecture to Indo-Islamic, colonial, vernacular, Modernist, and urban typologies — and supply a five-template workshop pathway through which an educator generates and tests their own. The APGF thereby offers architectural educators not a fixed intervention but a transferable, platform-agnostic, theoretically grounded generative method, and contributes a decolonial pathway in which Indian aesthetic theory functions as a structural component of pedagogical design rather than as cultural ornament.

Keywords: Game-based learning; Design Science Research; Architectural education; Aesthetic learning; Serious-games design; Design exemplars; *Rasa* theory

1. Introduction

Architecture is, among other things, the discipline of making aesthetic judgments about space — judgments about proportion and scale, about the play of light on material, about the sequence and atmosphere of a building experienced in time. Cultivating the capacity for such judgment is therefore central to architectural education. Yet across many programmes, and acutely in the Indian B.Arch. context that motivates this work, the teaching of aesthetic competence is structurally thin. Aesthetic literacy is concentrated in the foundation years and largely confined to visual composition; the embodied, spatial-material understanding through which scale, sequence, and atmosphere are actually internalised is prized in studio culture but seldom taught as explicit content; socio-cultural reasoning about who a building is for and what it means is left to absorb

tacitly; and a pervasive fear of subjective criticism suppresses the very dialogue through which aesthetic judgment matures.

These deficits share a common shape: architectural-aesthetic competence is treated as something that emerges from exposure rather than something that can be deliberately designed for and trained. Game-based learning offers a way to change this. The structural qualities of play — rule-governed freedom, repeated perception–action–feedback loops, embodied and social participation — correspond closely to the conditions under which aesthetic competence is known to develop. Play converts high-stakes aesthetic judgment into safe, iterative experiment; mechanics shape attention and train perception through repetition that no studio schedule can match; embodied and immersive play let learners inhabit buildings rather than merely view them; and role-play makes stakeholder perspective-taking practicable. In the Indian intellectual tradition, moreover, play is already an aesthetic category — *līlā* as creative play, *rasa* as the savouring of aesthetic emotion — so a game-based aesthetic pedagogy is continuous with the tradition rather than imported into it.

The difficulty is that wanting to design such games and being able to design them well are different things. A designer setting out to build a game for architectural-aesthetic learning needs more than enthusiasm: they need a principled way to decide which game mechanics will cultivate which aspects of aesthetic competence, how to sequence them, how to match them to a medium, and how to evaluate whether they worked. That is the function of a design framework. The serious-games and game-based-learning literatures contain many such frameworks; the question this paper begins from is whether any of them is adequate to the specific task of architectural-aesthetic learning — and, if not, what a framework that is adequate would have to contain.

This paper answers that question in two movements. The first is diagnostic. We audit the available framework apparatus against two independent standards and read the audit against the empirical record of a decade of game-based learning in architecture, showing that the field is methodologically settled but pedagogically partial, and that four specific structural absences leave architectural-aesthetic learning unserved. The second is constructive. Using Design Science Research, and grounding every design decision in the convergence of three independent empirical sources, we derive six design requirements and develop the Architectural Pedagogy Game Framework (APGF) — a transferable, platform-agnostic methodology with an embodied, culturally grounded mechanic inventory. We then report the framework’s evaluation, including its instantiation as three controlled experiments across three media, and discuss what it contributes to game-based learning, to architectural pedagogy, and to the project of building design knowledge from non-Western aesthetic theory.

2. Background

2.1. *The under-teaching of aesthetic competence in architectural education*

The architectural-pedagogical tradition has long held that aesthetic knowledge is not merely visual but embodied and situated. Pallasmaa (2005) argued that an exclusively retinal architecture impoverishes the discipline, and that buildings are known through the skin, the muscles, and the moving body as much as through the eye; Mallgrave (2013) drew on the cognitive sciences to ground this embodied-empathetic account; and a wider literature on everyday and contextual aesthetics (Saito, 2007) holds that aesthetic judgment about built form is inseparable from cultural use and lived experience. Architectural-aesthetic competence, on this view, is constituted by three distinguishable but interdependent registers: a visual-perceptual register (the trained recognition of proportion, ornament, composition, and stylistic syntax), an embodied-spatial register (the kinaesthetic, haptic, and atmospheric internalisation of scale, sequence, and material), and a socio-cultural register (the contextual, ritual, and ethical situatedness that distinguishes architectural judgment from generic preference).

Against this tradition, conventional studio pedagogy under-serves all three registers unevenly. Visual training is front-loaded and then assumed; embodied learning is structurally displaced by the representational economy of plan, section, and screen; and socio-cultural reasoning is left to the implicit culture of the jury. The result is a documented set of deficits — ocularcentrism, fragmented affective development, the

displacement of embodied learning, and the neglect of socio-cultural reasoning — that motivate the search for an alternative pedagogical instrument.

2.2. Game-based learning and serious games

Game-based learning and serious games have been applied across STEM and design education with documented effects on engagement, retention, and procedural reasoning, though meta-analyses report that effects are heterogeneous and that design features rather than the game format account for much of the variance (Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013; Clark, Tanner-Smith, & Killingsworth, 2016). Within architecture, a decade of work has produced gamification platforms, digital and physical serious games, and immersive VR/AR reconstructions addressing history, urban design, heritage, building technology, and disaster management. What this body of work has largely not done is target architectural aesthetics directly, or theorise the embodied and culturally situated registers that the architectural tradition holds to be constitutive of aesthetic competence. The mechanics that game-based learning has shown to be effective — identification, comparison, manipulation, navigation, role-play, negotiation — are available; what has been missing is a principled account of which of them cultivate which register of architectural-aesthetic learning, and how to combine them.

2.3. Existing game-design frameworks

That account is the proper work of a design framework, and the field offers several widely cited candidates. The Input–Process–Outcome model (Garris, Ahlers, & Driskell, 2002) describes the game cycle through which instructional content is converted into learning outcomes; the Mechanics–Dynamics–Aesthetics framework (Hunicke, LeBlanc, & Zubek, 2004) separates the designer’s and player’s views of a game, but its “aesthetics” denotes the player’s emotional responses rather than anything architectural; Schell’s (2008) *Lenses of Game Design* supplies a large repertoire of designer heuristics without a learning-outcome methodology; Kapp’s (2012) framework codifies the gamification of learning at both a structural and a content level; the Learning Mechanics–Game Mechanics model (Arnab et al., 2015) supplies the logic for mapping game mechanics onto intended learning mechanics; and the Integrated Design Framework (Plass, Homer, & Kinzer, 2015) integrates cognitive, affective, motivational, and socio-cultural foundations of game-based learning. Table 1 summarises these frameworks and the limitation each presents for architectural-aesthetic learning specifically.

Framework	Core contribution	Limitation for architectural-aesthetic learning
IPO (Garris et al., 2002)	Input–process–outcome game cycle linking content to outcomes	Generic; no aesthetic, embodied, or domain-specific dimension
MDA (Hunicke et al., 2004)	Separates designer (mechanics) and player (aesthetics) views	“Aesthetics” = emotional response, not architectural; no learning methodology
Schell’s Lenses (2008)	Large repertoire of designer heuristics (“lenses”)	Design heuristics, not a learning methodology; no domain specificity
Kapp (2012)	Structural and content gamification of learning	Generic instructional gamification; weak for studio-level aesthetic learning
LM-GM (Arnab et al., 2015)	Maps game mechanics to intended learning mechanics	Process-level logic only; no architectural specificity or embodiment
IDF (Plass et al., 2015)	Integrates cognitive, affective, motivational, socio-cultural design	Strong socio-cultural warrant; embodiment only conceptual; not architecturally native

Table 1. Six widely cited game-design frameworks and the limitation each presents for architectural-aesthetic learning.

These six are the field’s most cited general frameworks, but they are not its only ones: a larger corpus has accumulated for narrower domains — cultural heritage, multisensory learning, design-thinking pedagogy — rarely surveyed in comparative terms. Before developing a new framework, intellectual honesty requires asking whether this broader corpus already contains one adequate to the task. The next section reports the audit conducted to answer that question.

3. Establishing the gap: a two-step audit of the framework corpus

To determine whether the available framework apparatus is adequate to architectural-aesthetic learning, we conducted a structured audit of twenty serious-games design frameworks, and then tested the audit's structural findings against the empirical record of a decade of game-based learning in architecture. If a single adequate framework exists, the present contribution would be obliged to adopt it; if none does, the case for a new framework must be made by demonstrating both the inadequacy and the precise scope of the absence.

3.1. Audit rationale and the non-circularity protocol

The methodological commitment that organises the audit is non-circularity. A researcher who proposes a new framework and then evaluates prior work using that framework's own commitments as the criterion concludes tautologically. The two-step structure used here is designed to avoid this. Step 1 evaluates each framework against an external pedagogical standard — Anderson and Krathwohl's (2001) revision of Bloom's taxonomy — established independently of this work and either adopted or explicitly critiqued by the audited frameworks themselves. Step 2 applies a domain-specific criterion only to those frameworks that have already passed the Step 1 threshold, asking which registers of architectural-aesthetic learning each supports. The two steps were scored independently and in sequence: Bloom scores were assigned before aesthetic-coverage scoring began, the aesthetic criterion did not inform Bloom scores, and no framework was penalised on one axis for performance on the other. Per-framework evidence notes citing the specific feature justifying each score were retained as the audit trail.

3.2. Step 1 — pedagogical adequacy (Bloom's revised taxonomy)

Bloom's revised taxonomy specifies six cognitive levels of increasing complexity: Remember, Understand, Apply, Analyse, Evaluate, Create. For each framework we asked whether it explicitly names, operationalises, or provides design guidance for cultivating each level, scoring on a three-point scale (Y = explicit; P = partial; N = not addressed) and computing a weighted score of $2 \times Y + P$ out of 12. Frameworks scoring six or higher were judged generically adequate and retained for Step 2. Table 2 reports the result: twelve of the twenty frameworks proceed; eight are held. The held frameworks are not defective in any general sense — they occupy legitimate scopes (production methodology, affective rather than cognitive outcomes, post-hoc analysis, integration heuristics) that the audit does not contest — but they do not supply the cognitive-outcome scaffolding a designer of educational games requires. Two frameworks, ATMSG (12/12) and GAGE (11/12), achieve near-perfect Bloom coverage and constitute the pedagogical gold standard of the corpus.

ID	Framework	Bloom (/12)	Decision
F1	IPO (Garris, Ahlers, & Driskell, 2002)	4	Hold
F2	Serious 'Slow' Game Jam	5	Hold
F3	MDA (Hunicke, LeBlanc, & Zubek, 2004)	4	Hold
F4	FRACH (Mortara et al., 2014)	7	Proceed
F5	Emotion Design Framework	1	Hold
F6	GAGE (Lepe-Salazar, 2015)	11	Proceed
F7	Schell's Lenses (2008)	5	Hold
F8	Cognitive Assessment & Training Framework	9	Proceed
F9	ATMSG (Carvalho et al., 2015)	12	Proceed
F10	Kapp's Gamification of Learning (2012)	5	Hold
F11	EDA (Experience–Dynamics–Artifacts)	3	Hold
F12	LM-GM (Arnab et al., 2015)	8	Proceed
F13	Mid-Range Design Theory for SGs	9	Proceed
F14	WeDraw Multisensory Framework	7	Proceed
F15	Frictions Framework	4	Hold

ID	Framework	Bloom (/12)	Decision
F16	IDF (Plass, Homer, & Kinzer, 2015)	9	Proceed
F17	TENF / Narrative (Tracers of the Past)	7	Proceed
F18	IVR-SG Constructivist (Leonardo)	8	Proceed
F19	Participatory Methodology for SG Design	6	Proceed
F21	Press Play for Learning	6	Proceed

Table 2. Step 1 — generic pedagogical adequacy across twenty serious-games design frameworks. Weighted Bloom score = $2 \times Y + P$ (maximum 12); threshold to proceed = 6. Twelve proceed; eight held.

3.3. Step 2 — architectural-aesthetic coverage

Step 2 is the diagnostic step. Among the twelve pedagogically adequate frameworks, the question is whether each provides design support for the three registers of architectural-aesthetic learning identified in Section 2.1. The same three-point scale was applied (Y = usable design tools with architecture-specific operational guidance; P = conceptual acknowledgement without operational guidance; N = outside scope), with a weighted score of $2 \times Y + P$ out of 6. Table 3 reports the result, which is the audit’s central finding. Of the twelve, one achieves strong fit, six are moderate, and five are weak. The single strong-fit framework is a one-site case-study application of immersive VR to a single architectural corpus, whose authors make no claim that it constitutes a generalisable design methodology. The audited literature therefore contains no generalisable, pedagogically sound, architecturally targeted design framework that integrates all three registers.

ID	Framework	Visual-perceptual	Embodied-spatial	Socio-cultural	Score (/6)	Fit
F4	FRACH	P	P	Y	4	Moderate
F6	GAGE	P	P	P	3	Moderate
F8	Cognitive Assessment & Training	N	N	N	0	Weak
F9	ATMSG	P	P	P	3	Moderate
F12	LM-GM	P	N	P	2	Weak
F13	Mid-Range Design Theory	N	N	Y	2	Weak
F14	WeDraw	P	Y	N	3	Moderate
F16	IDF	P	P	Y	4	Moderate
F17	TENF / Narrative	P	N	Y	3	Moderate
F18	IVR-SG (Leonardo)	Y	Y	P	5	Strong
F19	Participatory Methodology	N	P	P	2	Weak
F21	Press Play for Learning	N	N	P	1	Weak

Table 3. Step 2 — architectural-aesthetic coverage among the twelve frameworks that passed Step 1. Weighted score = $2 \times Y + P$ (maximum 6); Strong ≥ 5 , Moderate 3–4, Weak ≤ 2 .

The pattern across the three registers is instructive. The four moderate-fit frameworks display complementary rather than overlapping strengths: WeDraw is the embodiment specialist (but its domain is primary-school mathematics); FRACH, TENF, and IDF are the socio-cultural specialists; ATMSG and GAGE supply cognitive scaffolding. No single framework integrates these strengths. Visual-perceptual coverage is the weakest register — only one framework provides explicit support, and that as a single case — so no pedagogically adequate framework provides a structured methodology for cultivating visual-architectural literacy. Embodied-spatial coverage is moderately served, but the two genuinely embodied frameworks are each constrained, one by domain and one by generalisability. Socio-cultural coverage is the best served, reflecting a mature tradition of cultural-heritage game design from which a new framework can borrow rather than invent.

3.4. Empirical corroboration: the architectural-affinity gradient

The audit’s findings are structural — they describe what is absent in the framework apparatus, not how that absence manifests in the games the field has actually built. To test the structural claim against an independent empirical record, we mapped the corpus of a PRISMA-compliant systematic review of 114 game-based-learning studies in architecture (2014–2024) onto the audited frameworks, coding each study for its architectural affinity — the degree to which the framework’s pedagogical claims connect to architecturally specific outcomes such as visual literacy, spatial cognition, embodied response, or contextual reasoning. The resulting gradient (Fig. 1) is strikingly uneven. The frameworks whose deployments produce a majority of high-affinity studies are precisely those whose objects are specifically architectural or cultural-heritage in nature; the frameworks borrowed wholesale from general instructional design or generic game-mechanic taxonomies systematically underperform. This is the empirical signature of a domain-specificity penalty: a generic pedagogical framework cannot, without architectural adaptation, deliver architecturally relevant outcomes, however internally well developed it may be (cf. Shulman, 1986; Kirschner, Sweller, & Clark, 2006).

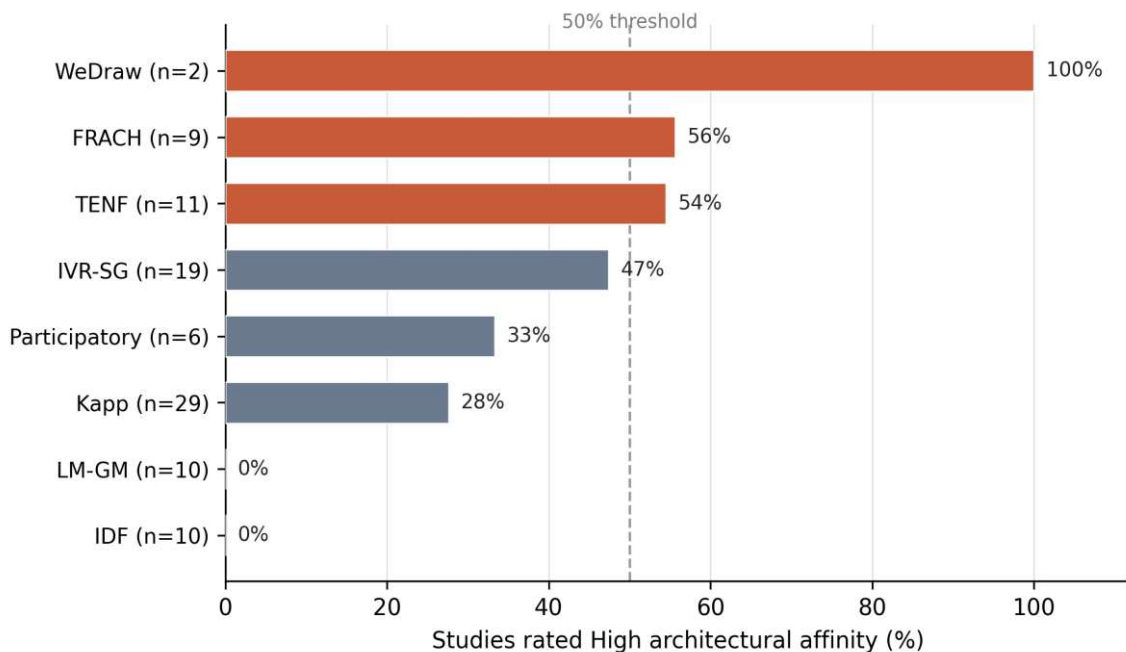


Fig. 1. *The architectural-affinity gradient: percentage of studies within each framework rated High architectural affinity (n = framework’s deployment count in the 114-study corpus). Bars above the 50% threshold (terracotta) mark frameworks whose architectural utility is borne out in deployment; those below (slate) are widely used but architecturally under-delivering. WeDraw’s 100% rests on only two studies and is diagnostic rather than determinative.*

Two further corpus patterns reinforce the diagnosis. First, the corpus exhibits near-deterministic mechanic–framework lock-in: each game-type category aligns almost exclusively with a single framework (gamification with Kapp, VR serious games with IVR-SG, participatory games with LM-GM), producing strong vertical specialisation but almost no horizontal integration across mechanic classes — no framework specifies how to combine, say, a gamification layer, an immersive core, and a participatory wrapper into a coherent sequence. Second, a sixth of the corpus (18 of 114 studies) deploys serious-game technologies — most often immersive VR, simulation, or commercial video games — without anchoring in any explicit pedagogical framework; across these simulation and commercial-game studies, not one was rated high architectural affinity, confirming that representational immersion is necessary but not sufficient for pedagogically consequential learning (Lee & Hammer, 2011; Plass et al., 2015).

3.5. Four structural absences

Read together, the audit and the corpus analysis converge on four structural absences whose convergent implication is the warrant for a new framework (Fig. 2; Table 4). They are structural rather than circumstantial: each is a property of the framework apparatus as a whole, not an accident of any one framework’s scope.

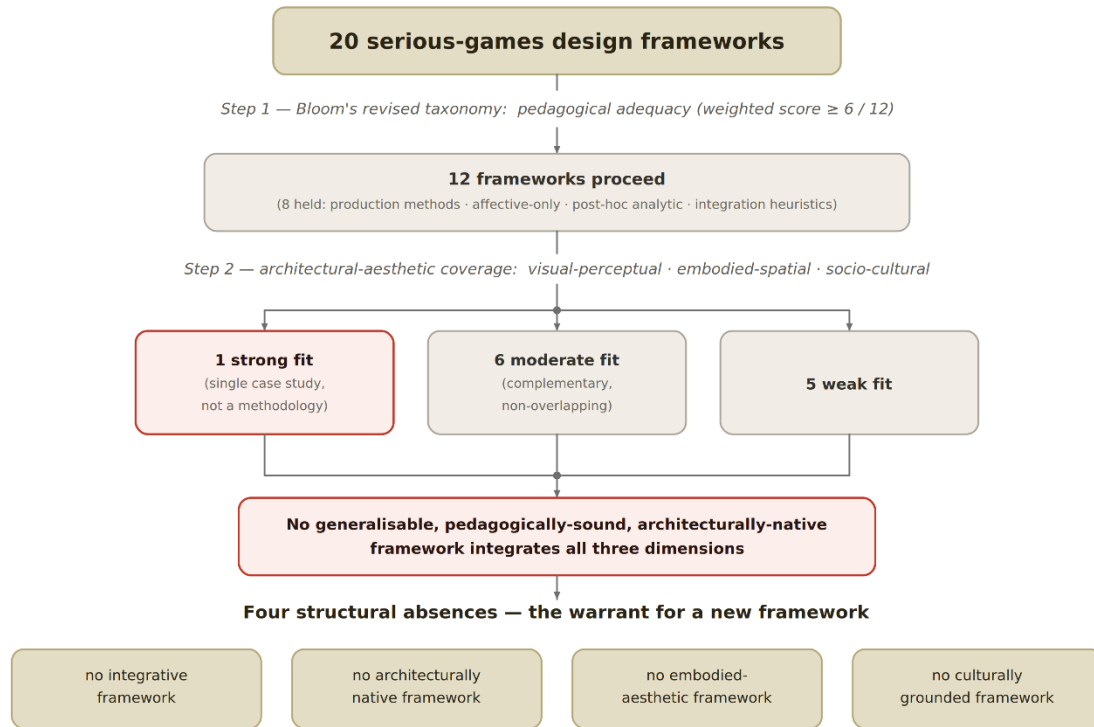


Fig. 2. The two-step audit, from twenty frameworks to four structural absences. Step 1 retains twelve pedagogically adequate frameworks; Step 2 finds one strong fit (a single case study, not a methodology), six moderate, and five weak, leaving no generalisable, architecturally native framework that integrates all three registers — and exposing the four absences that the APGF is designed to repair.

Structural absence	What is missing	Consequence for architectural-aesthetic learning
1. No integrative framework	A methodology operating across mechanic classes and the three registers	A studio sequence combining physical, immersive, and participatory modules is not theorisable in any single framework
2. No architecturally native framework	A framework developed from within architectural pedagogy, with the studio jury, the visual/spatial/embodied/contextual registers, and cultural anchors as design constraints	The best-performing frameworks succeed only because their objects are architectural; their pedagogy was developed elsewhere and adapted post hoc
3. No embodied-aesthetic framework	A framework that operationalises somatic, kinaesthetic, and atmospheric registers and treats embodiment as first-order	The claim that embodied cognition is constitutive of design competence is radically underserved by the existing instrument inventory
4. No culturally grounded framework	A framework engaging a non-Western aesthetic theory as a structural component of its design apparatus	For a corpus 0% of which engages Indian aesthetic theory, the absence is structural; aesthetic pedagogy remains tied to imported categories

Table 4. The four structural absences that jointly warrant a new framework, and their consequences for architectural-aesthetic learning.

4. Research approach: Design Science Research

4.1. Rationale

The framework was developed using Design Science Research (DSR), the paradigm appropriate to the creation and evaluation of artefacts intended to solve a class of problems (Gregor & Hevner, 2013; Peffers et al., 2007). DSR is well suited here for three reasons: the output is an artefact (a design methodology) rather than a theory or an empirical claim; the artefact must be justified against explicit design requirements

derived from a documented problem; and the artefact must be evaluated for utility, not merely truth. Following the design-theory conventions of the paradigm, the development proceeds from problem to artefact through the explicit derivation of design requirements stated in the form “the framework shall ...”, each traceable to specific empirical warrants (Gregor & Jones, 2007).

4.2. Three converging lines of empirical evidence

The APGF rests on three foundational studies whose independence is itself part of the design warrant (Fig. 3). The studies were conducted in different modes (literature analysis, methodological audit, classroom intervention), drew on different evidence types (published outcomes, framework features, observed effects), and addressed different parts of the design problem (population-level mechanic effects, methodological gap, mechanic feasibility). Convergence across independent investigations is methodologically stronger than agreement within a single one (Lincoln & Guba, 1985; Greene, 2007), so their agreement on a single mechanic inventory and a single set of design requirements is the framework’s principal claim to empirical grounding.

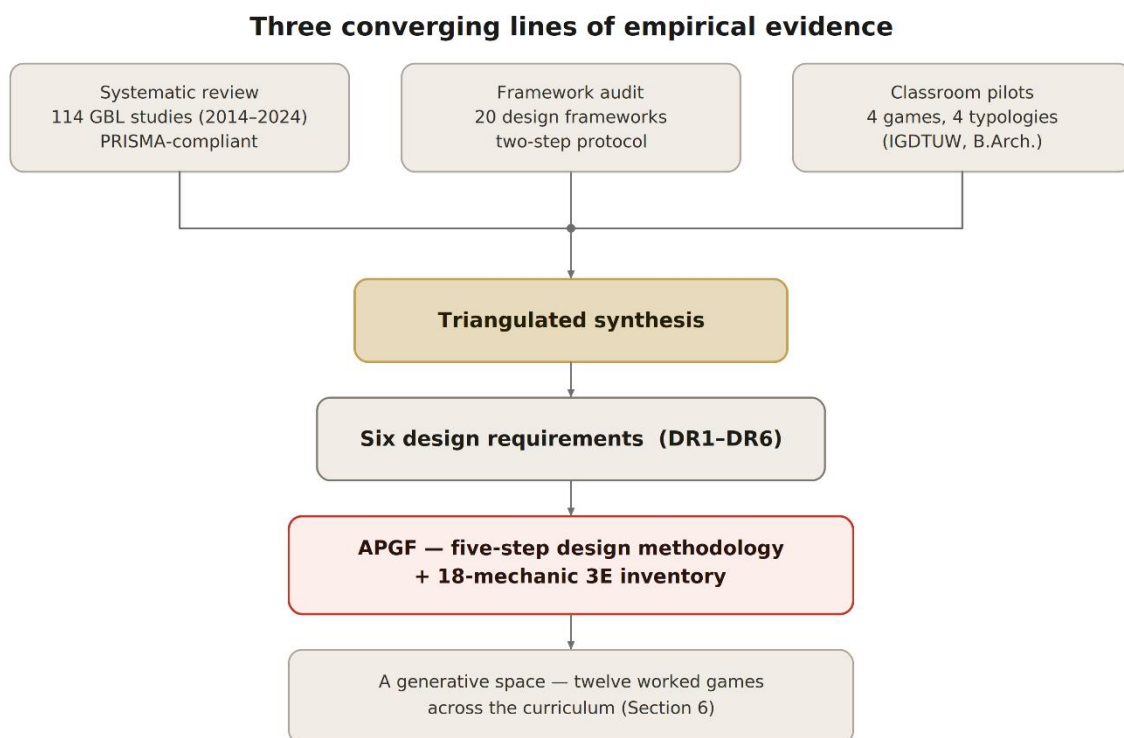


Fig. 3. The Design Science development of the APGF. Three independent empirical sources — a 114-study systematic review, a 20-framework audit, and four classroom pilots — converge on a triangulated synthesis, from which six design requirements are derived; these specify the APGF, which is then realised as a generative catalogue of games spanning the curriculum (Section 6).

The first source is the systematic review (Section 3.4): its 114-study corpus establishes that integrated 3E coverage is empirically attainable but unevenly distributed, that architectural-aesthetic learning is a minority concern (only ~5% of studies), that technology and dimensional profile cluster predictably, and that mechanic clusters map systematically to dimensional effects — supplying the evidence base for principled mechanic selection. The second source is the framework audit (Section 3): its four structural absences specify what the new framework must supply that no existing one does. The third source is a programme of four naturalistic classroom pilots at IGDTUW — a gamification platform (Gradecraft), a physical serious game (Climate Fresk), a stakeholder-negotiation game (Play the City), and a commercial video game used pedagogically (Assassin’s Creed: Odyssey, Discovery Tour) — deliberately spanning four game families. The pilots surfaced psychological-safety mechanics (Gradecraft’s safe-iteration affordances reduced studied cynicism), demonstrated embodied collaborative reasoning (Climate Fresk and Play the City), and showed that commercial immersive environments can supply most of the Eye and navigational-Embodiment

mechanics the framework needs. They also revealed their own limits: material-empathy, temporal-vision, and somatic-response mechanics were not surfaced by any pilot and had to be developed from theoretical first principles (Pallasmaa, 2005; Merleau-Ponty, 1962; Sheets-Johnstone, 2011), marking the boundary where the framework's inventory genuinely extends the empirical base rather than merely consolidating it.



Fig. 4. *Playtesting of game -Climate Fresk in natural classroom setting, source: author*

4.3. Six design requirements

The three sources converge on six requirements that jointly define the APGF's specification (Table 5). Each requirement is warranted by at least two of the three sources; the triangulation is therefore structural rather than rhetorical — the framework is what the three empirical sources jointly license. The requirements are collectively necessary (a framework lacking any one fails in a documented way), individually traceable (each warrant cites the particular finding on which it rests), and directly operationalised by the methodology of Section 5.2 and the evaluation criteria of Section 6.

#	The framework shall ...	Principal warrant
DR1	Integrate all three pillars — Eye, Embodiment, Everyday — within a single design methodology	Audit: no framework integrates all three (max 5/6, a single case). Review: 36% of corpus achieves full 3E (feasible)
DR2	Devote disproportionate design investment to the Eye pillar	Audit: only 1 of 12 adequate frameworks gives explicit Eye support. Review: ~5% of corpus addresses architectural aesthetics. (Hence seven Eye mechanics)
DR3	Be transferable across subjects, cases, platforms, and pedagogical traditions, with explicit adaptation guidance	Audit: the only architecture-specific framework is a one-site case. Pilots: four games spanned four platforms and four subjects
DR4	Incorporate Bloom-level cognitive scaffolding at the goal-definition step	Audit: ATMSG (12/12) and GAGE (11/12) set the field's adequacy marker; the APGF inherits it via Step 2
DR5	Treat Embodiment as a first-order dimension with its own mechanic category and instruments	Card-sort validation $\kappa = 0.92$ confirms Embodiment as coherent; only WeDraw and F18 give explicit support, neither generalising. (Hence six Embodiment mechanics + EARS)
DR6	Select mechanics on documented evidence of dimensional alignment, each traceable to specific evidence	Review: mechanic clusters produce documented dimensional effects. Pilots: 14 mechanics individually

#	The framework shall ...	Principal warrant
		traced to outcomes. Audit: LM-GM supplies the selection logic

Table 5. *The six design requirements for the APGF, each warranted by at least two of the three empirical sources.*

Because each requirement does specific work, and because they are referenced throughout the sections that follow, the six are set out in full below.

DR1 — Integration. DR1 requires the framework to integrate all three pillars — Eye, Embodiment, Everyday — within a single design methodology. Its warrant is twofold: the audit found that no existing framework integrates all three (the highest integrated score was 5/6, and that a single case study rather than a methodology), while the review found that 36% of the corpus nonetheless achieves full 3E coverage, establishing that integration is empirically feasible even though no framework theorises it. DR1 is what makes the APGF integrative rather than vertically specialised: a single studio sequence can combine a card-based Eye module, an immersive Embodiment encounter, and a participatory Everyday deliberation and remain theorisable within one design logic. The framework satisfies DR1 through Step 2, which maps each aesthetic goal onto one or more pillars, and through the non-overlapping mechanic inventory, which lets a designer combine mechanics across pillars without ambiguity.

DR2 — Eye emphasis. DR2 requires disproportionate design investment in the Eye pillar, because visual-analytical mechanics for architectural learning are the least supported in prior work. The warrant is a convergence of two findings: only one of the twelve pedagogically adequate frameworks provides explicit support for the visual-perceptual register, and only about 5% of the 114-study corpus addresses architectural aesthetics at all. Visual literacy — the trained reading of proportion, ornament, and stylistic syntax — is thus the register most starved of design tools. DR2 is reflected directly in the shape of the inventory: the Eye pillar carries seven mechanics, the largest single block, where Embodiment carries six and the Everyday five. The requirement corrects the field’s tendency to treat visual analysis as a solved or trivial problem rather than as a competence that must be deliberately trained.

DR3 — Transferability. DR3 requires the framework to be transferable across architectural subjects, cases, technological platforms, and pedagogical traditions, with explicit guidance for application to new contexts. The warrant is the gap between a case and a methodology: the only architecture-specific framework the audit identified was a single-site case study, while the four classroom pilots spanned four different platforms and four different subjects, demonstrating that architectural game-based learning is not platform-bound. DR3 is the requirement that makes the framework a generative method rather than a fixed artefact — and it is the requirement the twelve worked games of Section 6 most directly exercise, spanning five typologies and five media. The framework satisfies DR3 through Step 1 (which binds a design to a developmental stage using case-independent scaffolding), through its platform-agnostic mechanic realisations, and through the adaptation guidance and designer templates that let an educator reconstruct the framework for a non-Indian curriculum or a non-temple typology.

DR4 — Bloom scaffolding. DR4 requires the framework to incorporate Bloom-level cognitive scaffolding at the goal-definition step, so that designers inherit the pedagogical adequacy demonstrated by the strongest audited frameworks. The warrant is the audit’s Step 1 finding that the field’s pedagogical gold standards — ATMSG (12/12) and GAGE (11/12) — establish explicit Bloom integration as the marker of generic pedagogical adequacy. DR4 ensures the APGF does not sacrifice that adequacy for the sake of aesthetic specificity: Step 2 classifies every aesthetic learning goal by Bloom level, from Remember through Create, before any mechanic is selected, so the cognitive scaffolding of the best general frameworks is inherited rather than reinvented. DR4 is the requirement that keeps the framework pedagogically rigorous as well as aesthetically targeted.

DR5 — Embodiment as first-order. DR5 requires the framework to treat Embodiment as a first-order dimension with its own mechanic category and its own assessment instruments, not as a subordinate concern. The warrant is threefold: a card-sorting validation confirmed Embodiment as a coherent, independent category ($\kappa = 0.92$); the audit found only two frameworks providing explicit embodiment support, neither generalising to architecture; and the pilots demonstrated embodiment-rich learning beyond screen-based

games. DR5 corrects the most consequential omission in the existing apparatus, given the architectural tradition's insistence that embodied cognition is constitutive of design competence. The framework satisfies DR5 through six dedicated Embodiment mechanics and a purpose-built instrument (the Embodied Aesthetic Response Scale), so that the somatic, kinaesthetic, and atmospheric registers are designed for and measured rather than assumed.

DR6 — Empirically grounded mechanic selection. DR6 requires that mechanics be selected on the basis of documented empirical evidence of dimensional alignment, with each recommended mechanic traceable to specific evidence in the review or the pilot programme. The warrant is that the review showed mechanic clusters producing documented dimensional effects, the pilots traced fourteen mechanics individually to observed outcomes, and the audit supplied the principled-selection logic (from LM-GM) that the cognitive-scaffolding frameworks lack. DR6 is what distinguishes the APGF's third step from conventional game design: where conventional design selects mechanics for engagement or enjoyment, the APGF selects them for evidenced dimensional fit, and the inventory records that evidence for each mechanic. DR6 is the requirement that makes the framework's central claim — that specific mechanics cultivate specific registers of aesthetic learning — empirically defensible rather than asserted.

5. The Architectural Pedagogy Game Framework (APGF)

5.1. Theoretical foundation: the 3E framework

The APGF is organised by the 3E framework, which partitions architectural-aesthetic competence into three dimensions corresponding to the three registers of Section 2.1: the *Eye* (visual-perceptual analysis — proportion, ornament, composition, stylistic syntax), *Embodiment* (kinaesthetic, haptic, and spatial-material engagement through which scale, sequence, and atmosphere are internalised), and the *Everyday* (the socio-cultural, contextual, and ethical situatedness of architectural judgment). The independence of the three dimensions is not merely asserted: a card-sorting validation returned a high inter-rater agreement for the Embodiment category ($\kappa = 0.92$), confirming it as a coherent dimension distinguishable from the other two — the empirical basis for DR5's treatment of Embodiment as first-order.

It is useful to locate the 3E framework relative to the Mechanics–Dynamics–Aesthetics model (Hunicke et al., 2004), the most influential general account of how game mechanics produce player experience. In MDA, 'aesthetics' names the desirable emotional responses a game evokes in the player — the felt quality of play in general. The 3E framework supplies what that generic axis leaves unspecified for the discipline at hand: it states what aesthetics *means* for architecture — not undifferentiated player emotion but the three trained registers of architectural judgment (perceptual, embodied, socio-cultural). And where MDA runs only one way, from designer-authored mechanics to player-experienced aesthetics, the APGF inserts the pedagogical layer MDA omits, specifying which mechanics cultivate which register of aesthetic *learning* and making that link empirically defensible (DR6). The APGF is, in this sense, less an alternative to MDA than its architectural-aesthetic and pedagogical completion.

The framework's embodiment and aesthetic logic is grounded jointly in contemporary embodied cognition (Lakoff & Johnson, 1999; Varela, Thompson, & Rosch, 1991; Wilson, 2002; Barsalou, 2008) and the classical Indian aesthetics of *rasa*. In the *Nāṭyaśāstra* of Bharata-Muni and its elaboration by Abhinavagupta (Gnoli, 1968), aesthetic experience is theorised as a savoured, bodily-grounded process rather than a detached judgment. The APGF reconstructs this as a five-stage phenomenological progression of embodied aesthetic encounter with built space — *Kāma* (aesthetic attraction; the desire to approach), *Līlā* (playful, exploratory movement), *Anubhava* (integrated bodily understanding), *Māyā* (involuntary somatic wonder), and *Yoga* (spatial union; the sense of being one with place). This progression supplies both the conceptual spine of the framework's embodiment dimension and the subscale structure of its embodiment instrument (the Embodied Aesthetic Response Scale, Section 5.2). Grounding the framework in *rasa* is the substantive content of DR4's cultural requirement: Indian aesthetic theory functions here as a structural design resource, not as cultural decoration.

The grounding runs deeper than the embodiment dimension alone: the tripartite structure of the 3E framework is itself a reading of the *Rasa-Dhvani* tradition of classical Indian aesthetics, in which an aesthetic event is analysed into distinguishable but inseparable registers. In Bharata’s *Nāṭyaśāstra* and Ānandavardhana’s *Dhvanyāloka* (Bharata-Muni, 1967; Ānandavardhana, 1990), as elaborated through Abhinavagupta’s Kashmiri Śaiva commentaries (Gnoli, 1968), aesthetic experience is articulated through *vibhāva* (the aesthetic stimulus or determinant), *anubhāva* (the embodied, felt response), and *vyabhicāri-bhāva* (the transient, reflective accompaniments). The three pillars map directly onto these categories: the *Eye* corresponds to *vibhāva* and the *kāma* register of sensory recognition; *Embodiment* to *anubhāva* and the *līlā*–*anubhava* register of felt absorption; and the *Everyday* to *vyabhicāri-bhāva* and the *māyā*–*yoga* register of reflective, situated integration. The framework is therefore not a Western pedagogical schema applied to Indian content but a categorical specification drawn from Indian aesthetic theory itself — and it inherits from that theory a consequential proposition: the three registers are *concurrent* registers of a single aesthetic event rather than sequential phases, which is why a fully integrated game engages all three at once even as a given mechanic foregrounds one.

Read developmentally rather than categorically, the same five terms describe how aesthetic competence matures. Abhinavagupta’s account of the cultivated perceiver (*rasika*) moving from sensory delight (*kāma*) through playful immersion (*līlā*) and willing absorption (*māyā*) to a unified, self-possessed awareness (*yoga*, associated with *ānanda*) maps with notable precision onto modern taxonomies of affective learning, from initial receptivity to internalised commitment (Krathwohl, Bloom, & Masia, 1964; Gnoli, 1968). This is what licenses the framework to treat the progression as *learnable*: its embodiment instrument renders the arc as five body-anchored stages — *Kāma-Sparśa* (desire to touch), *Līlā-Gati* (playful movement), *Anubhava-Śārīra* (body knowledge), *Māyā-Vismaya* (embodied wonder), and *Yoga-Sthāna* (union with place) — each tied to a specific bodily locus so that what is measured is somatic response rather than reported preference. Grounding the framework this way is a deliberately decolonial move (Escobar, 2018; Tunstall, 2023): rather than importing Indian motifs as ornament, it puts three indigenous epistemic resources to structural work — *anubhava* as an embodied epistemology, *rasa* as an affective taxonomy, and *māna*, the proportional logic of the *Mānasāra* and *Mayamata* treatises, as a compositional grammar — so that Indian aesthetic theory operates as a generative foundation rather than a peripheral supplement, in the register the National Education Policy 2020’s mandate for Indian Knowledge Systems calls for (Ministry of Education, 2020).

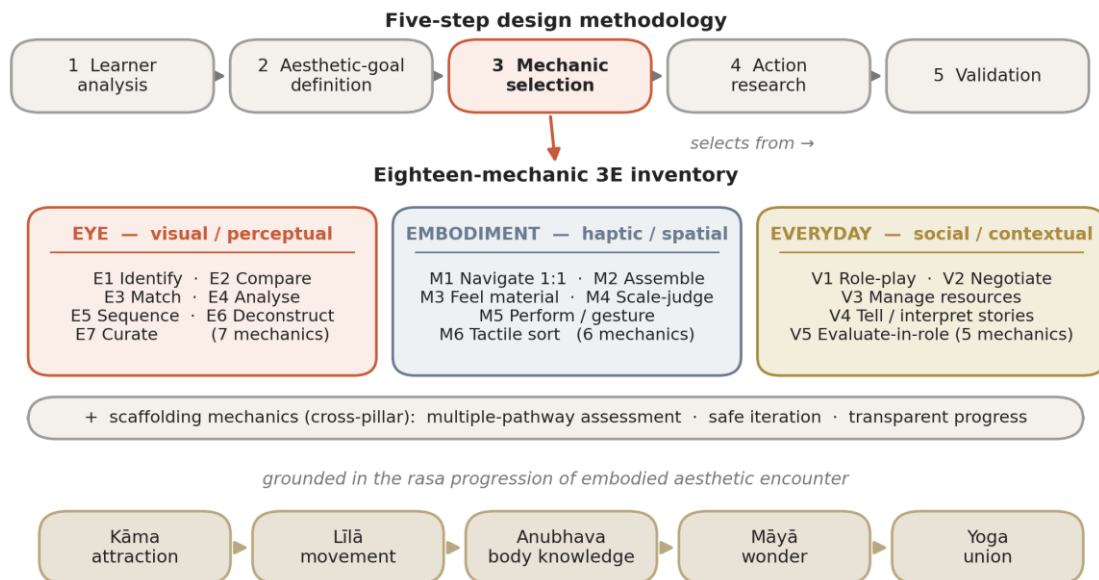


Fig. 5. The APGF artefact. A five-step design methodology (top) whose third step selects from an eighteen-mechanic 3E inventory (Eye 7, Embodiment 6, Everyday 5), supported by three cross-pillar scaffolding mechanics, and grounded in the *rasa* progression of embodied aesthetic encounter (bottom).

5.2. The five-step design methodology

The APGF specifies five sequential design steps — Learner Analysis, Aesthetic-Goal Definition, Mechanic Selection, Action Research, and Validation — whose ordering follows a logical dependency chain (the appropriate dimensional emphasis depends on the learner’s stage; the appropriate mechanics depend on the goal; the appropriate validation depends on the mechanics) and is recursive rather than strictly linear: any step can return the designer to an earlier one if evaluation reveals a mismatch. Table 6 maps the steps to the design requirements they satisfy.

Step	Primary DRs	What the step does
1 — Learner Analysis	DR3	Binds the design to a year level and cognitive developmental stage; supplies case-independent scaffolding for cross-context generalisability
2 — Aesthetic-Goal Definition	DR1, DR4	Locates aesthetic content in the syllabus; classifies the target outcome by Bloom level (DR4) and maps it onto one or more 3E pillars (DR1)
3 — Mechanic Selection	DR1, DR2, DR5, DR6	Selects mechanics from the eighteen-mechanic inventory by dimensional alignment, with disproportionate investment in Eye (DR2) and Embodiment treated as first-order (DR5)
4 — Action Research	DR3, DR6	Runs Plan–Act–Observe–Reflect–Revise cycles on prototype games; refines mechanic selection against observed dimensional effects
5 — Validation	DR1, DR5, DR6	Applies dimension-aligned instruments to measure outcomes against the targeted pillar(s); makes the integration claim testable

Table 6. *The five methodology steps mapped to the design requirements they operationalise.*

The methodology’s most distinctive step is the third. Where conventional game design selects mechanics for engagement or enjoyment, the APGF selects them for dimensional alignment: from the goal specification produced by Step 2, the designer identifies the target pillar(s) and queries the inventory, reading the empirical warrant for each candidate mechanic and selecting those whose dimensional fit is documented in the review or the pilots. Learner analysis (Step 1) calibrates the dimensional emphasis to developmental stage — foundational years weighting the Eye, intermediate years Eye-plus-Embodiment, senior years moving toward the full 3E — and goal definition (Step 2) classifies each aesthetic learning objective by Bloom level and 3E focus, so that the pedagogical adequacy of ATMSG and GAGE is inherited rather than reinvented. Validation (Step 5) closes the loop with dimension-aligned instruments, triangulated with think-aloud protocols and reflective journals to guard against reducing aesthetic learning to numerical scores.

5.3. The eighteen-mechanic 3E inventory

The core of the framework is an inventory of eighteen game mechanics organised by primary 3E alignment, each specified with an implementation, a pedagogical rationale, and a documented evidence source (Table 7). The non-overlap of the three pillar inventories is a deliberate design feature: it lets a designer specify ex ante that a game targets, say, Embodiment exclusively, and makes that specification operationally definite rather than rhetorical. The Eye pillar carries seven mechanics — the largest single block, reflecting DR2’s disproportionate investment in the field’s least-supported register; Embodiment carries six, each treated as a first-order activator with its own assessment instrument (DR5); and the Everyday carries five, drawing on the mature cultural-heritage and participatory-design traditions the audit identified as borrowable. Of the eighteen, fourteen are inherited directly from the pilot programme; three are anchored in theoretical literature where pilot evidence was absent (material empathy, temporal vision, somatic response); and one is recovered from the review’s analysis of cooperative-multiplayer studies.

Pillar	Code	Mechanic	What it teaches
Eye	E1	Identify	Active visual discrimination; building professional vocabulary
	E2	Compare	Critical visual literacy through representational comparison
	E3	Match	Relationships between elements, styles, parts and wholes

Pillar	Code	Mechanic	What it teaches
Embodiment	E4	Analyse / Annotate	Makes invisible patterns visible — forces, proportional systems
	E5	Sequence	Temporal vision — how buildings and styles evolve
	E6	Deconstruct	Reveals hidden structures and palimpsests (layer removal, X-ray)
	E7	Curate	Curatorial judgment through completion-driven engagement
	M1	Navigate at 1:1 scale	1:1 locomotion builds cognitive maps that 2D cannot create
	M2	Assemble	Tectonic logic through sequenced placement
	M3	Feel material	Material properties — weight, texture, resistance (haptics)
	M4	Scale-judge	Felt proportion; true-size relationships invisible in drawings
	M5	Perform / gesture	Whole-body action; embodied cultural knowledge
	M6	Tactile sort	Kinaesthetic sense-making through physical manipulation
Everyday	V1	Role-play	Perspective-taking through embodied other-experience
	V2	Negotiate	Architecture as negotiated settlement among competing interests
	V3	Manage resources	Design operates within real constraints; trade-offs are constitutive
	V4	Tell / interpret stories	Architecture as cultural text; design as meaning-making
	V5	Evaluate-in-role	Design judgment varies by stakeholder; mirrors practice

Table 7. *The eighteen-mechanic 3E inventory (Eye 7, Embodiment 6, Everyday 5). Each mechanic in the full framework additionally carries an implementation and a documented evidence source establishing its dimensional alignment (DR6).*

Three further mechanics — multiple-pathway assessment, safe iteration through penalty-free resubmission, and transparent progress visualisation — operate as scaffolding across all three pillars rather than as activators of any one. Inherited from the Gradecraft pilot, they address the psychological-safety conditions (fear of subjective criticism, vocabulary gap, time pressure) that the pilots documented as the principal barriers to aesthetic engagement. They are not counted within the dimensional inventory because they target no specific pillar, but the designer should consider them present in any APGF game for the senior years, where the barrier syndrome is strongest.

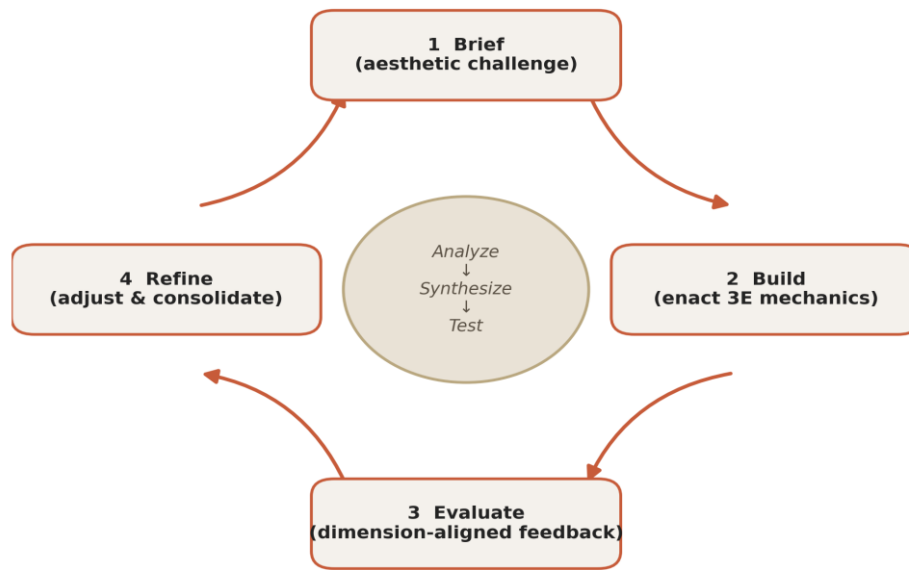
5.4. Complexity scaling and platform guidance

Two final design parameters make the inventory deployable. First, mechanic count scales with learner readiness: simple games (1–3 mechanics) suit first-year students in short interventions; moderate games (3–5) suit second- and third-year students in one- to two-hour sessions; complex games (5–7) suit senior students across multi-session experiences; comprehensive games (8+) are reserved for thesis-level work. Complexity should track learner readiness rather than designer ambition, since an over-mechanised game frequently performs worse on the same content — a caution the pilots corroborated, where a one-mechanic tactile game was a strength rather than a weakness in a second-year cohort. Second, the framework is platform-agnostic: the same mechanic can be realised in high-tech or low-tech form (scale-judgement in VR or in tactile blocks; role-play in multi-user VR or around a table), so the designer matches medium to the target dimension and to the resources available, rather than letting the available technology dictate the pedagogy. This platform-agnosticism is what makes the framework usable in Indian B.Arch. programmes that cannot afford immersive infrastructure, and it is the property the twelve worked games of Section 6 most vividly exercise.

5.5. The learner-facing game loop

Sections 5.2–5.4 specify the framework from the designer’s side; the learner’s experience inside an APGF-designed game is a tight iterative loop that renders the studio’s own design cycle — analyse, synthesise, test — playable (Fig. 6). The loop has four phases. The **Brief** poses a dimension-targeted aesthetic challenge calibrated to the goal defined in Step 2: for the Eye, to read a proportional system or stylistic syntax; for

Embodiment, to register true scale or material character through the body; for the Everyday, to reconcile competing stakeholder needs in a contested space. In the **Build** phase the learner enacts the mechanics selected in Step 3 — manipulating, navigating, assembling, role-playing — so that the response is produced through perception and action rather than recited. The **Evaluate** phase returns dimension-aligned feedback, and it is here that the APGF departs most sharply from a performance-simulation loop: because aesthetic competence admits no single correct answer, the feedback is relational and qualitative rather than a pass/fail computation — a comparative reveal that makes a proportional judgment visible (Eye), a somatic or scale prompt that registers in the body (Embodiment), or a stakeholder reaction that exposes the consequence of a spatial decision (Everyday). Finally, in **Refine**, the learner adjusts and re-engages, consolidating the perceptual or embodied understanding through repetition that conventional studio schedules cannot afford.



Feedback is perceptual, embodied, or contextual — dimension-specific, with no single correct answer.

Fig. 6 *The learner-facing game loop. A dimension-targeted brief is met through enacted mechanics and answered with dimension-aligned, relational feedback, then refined — rendering the studio’s analyse–synthesise–test cycle playable. Unlike a performance-simulation loop, the evaluation phase is qualitative and admits no single correct answer.*

Two clarifications keep the loop faithful to the framework’s aesthetic remit. First, quantitative performance information — daylighting, thermal behaviour, structural action — is not excluded, but it enters an APGF game as *content* for the Analyse/Annotate mechanic (E4), which makes invisible forces and proportional systems visible to the eye, rather than as the loop’s scoring logic; the framework evaluates aesthetic learning, not building performance. Second, the loop is deliberately medium-independent: the same Brief–Build–Evaluate–Refine cycle structures a virtual-reality session, a tabletop assembly, and a multi-stakeholder board game, which is why the twelve games of Section 6, realised across five media, each exhibit it.

5.6. The 3E-to-APGF crosswalk

The framework’s two specification layers — the 3E account of what architectural-aesthetic competence is (Section 5.1) and the five-step methodology for designing games that cultivate it (Section 5.2) — are joined by a crosswalk that makes the framework operational: a single mapping that tells a designer, for any learner and any goal, which pillar or pillars to foreground, at what cognitive level to pitch the tasks, and how heavily to load the game with mechanics (Fig. 7). Two axes generate it. The developmental axis — the learner’s year and cognitive stage — sets the dimensional emphasis, with foundational years weighting the Eye, intermediate years Eye-plus-Embodiment, and senior years moving toward the full 3E. The cognitive-demand axis — Bloom’s revised taxonomy (Anderson & Krathwohl, 2001), grouped into lower-, middle-, and higher-order bands (LOTS, MOTS, HOTS) — sets the complexity of the tasks and, with it, the mechanic

load the game can carry. The crosswalk is the operational content of Steps 1 and 2: Step 1 fixes the learner's row, Step 2 reads off the dimensional emphasis and cognitive band, and the eligible mechanics are thereby constrained before Step 3 begins.

Read top to bottom, the crosswalk traces the canonical B.Arch. progression and shows why the dimensional emphasis is neither fixed nor arbitrary but migrates across the pillars as the learner matures: a first-year game pitched at the LOTS band is properly Eye-dominant and simple (one to three mechanics), whereas a thesis-year game pitched at HOTS requires the full 3E and licenses comprehensive designs of eight or more mechanics. The twelve games catalogued in Section 6 each occupy a definite position in this crosswalk, and the generative space of Section 6.1 is, in effect, the crosswalk read as a grid of designable cells.



Fig. 7. *The 3E-to-APGF crosswalk. Learner stage (rows) and cognitive demand jointly set the dimensional emphasis across the three pillars (filled dots denote rising emphasis), the Bloom band, and the game-complexity tier — the operational content of methodology Steps 1–2. The twelve games of Section 6 are instances drawn from this space.*

5.7. The multi-dimensional assessment protocol

A framework that claims to cultivate competence across three registers is testable only if its assessment is correspondingly multi-dimensional. The APGF therefore integrates a multi-dimensional assessment protocol grounded in three principles. The first is alignment: every measure maps onto one of the Eye, Embodiment, or Everyday pillars, so that a game's gain is attributable to the register it targets rather than to learning in general. The second is triangulation: because no single measure captures the richness of aesthetic learning, the protocol combines objective performance tasks, subjective phenomenological scales, behavioural analytics drawn from gameplay, and qualitative inquiry (Lincoln & Guba, 1985; Greene, 2007). The third is embedding: assessment is conducted within gameplay wherever possible — the embedded-quiz format of the commercial-game pilot is the paradigm case — using the game itself as a measurement instrument, complemented by external validated instruments for comparable evaluation.

The protocol is organised as a pyramid (Fig. 8) whose lower tiers apply to every APGF game and whose apex is deployed selectively by target dimension. Tier 1 (foundational) captures the baseline against which any gain is read — demographics, prior architectural knowledge, and baseline affect — and is administered for every game. Tier 2 (game experience) measures whether the game functioned as a game, using established serious-games instruments (EGameFlow for flow, GUESS-18 for game-user satisfaction) and behavioural analytics; a learning result is uninterpretable until the experience itself is shown to be sound. Tier 3 (dimension-specific validation) is where the framework's distinctive claims are tested, and it splits

into three dimension-pure batteries: an Eye battery of visual-analysis, element-identification, and comparative-judgement tasks; an Embodiment battery of scale-judgement and construction-logic tasks together with the Embodied Aesthetic Response Scale (EARS) anchored in the *rasa* progression of Section 5.1; and an Everyday battery of design-justification essays, stakeholder-empathy scales, and stakeholder-transfer maps. A game targeting one pillar deploys only that battery; a full-3E game deploys all three.

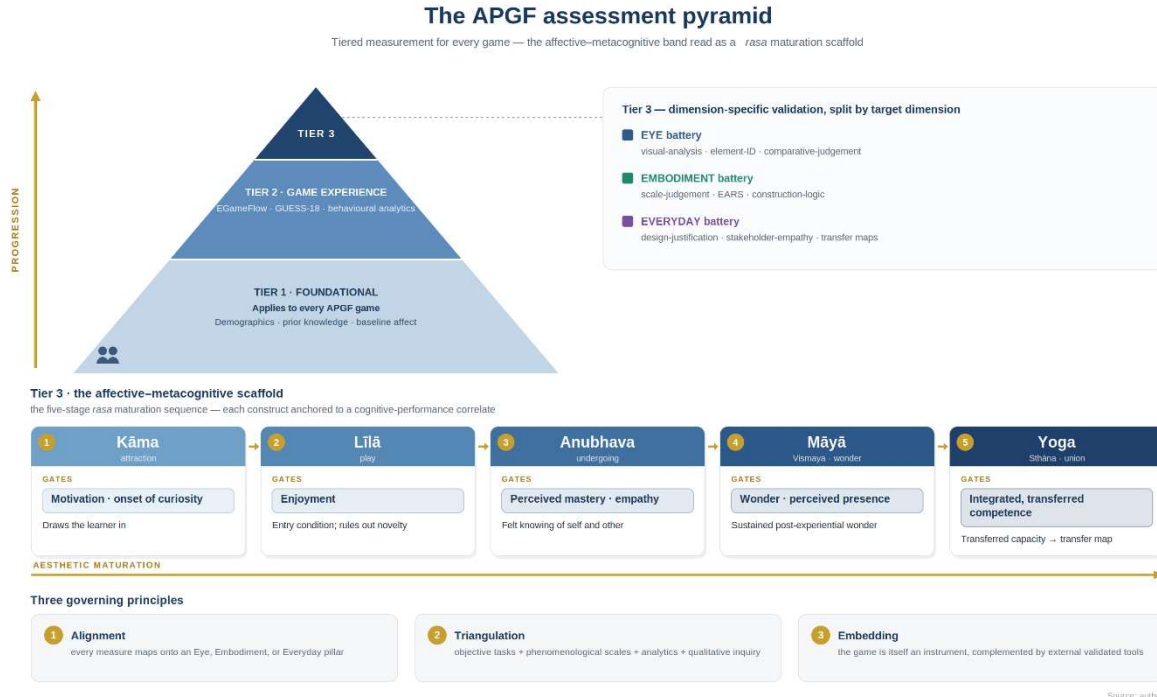


Fig. 8. The APGF multi-dimensional assessment pyramid. Foundational and game-experience measures (Tiers 1–2) apply to every game; dimension-specific batteries (Tier 3) are deployed by target pillar. The protocol is governed by the principles of alignment, triangulation, and embedding.

The affective-metacognitive measures within Tier 3 are a governed selection rather than an open inventory. A systematic reading of evaluation practice across the review’s 114-study corpus (Section 3.4; Appendix A) yields two parameter bands — a cognitive-performance backbone (competency scores, time-on-task, feedback effects, in-game behaviour, and overall game experience), consolidated in the serious-games meta-analyses (Clark et al., 2016; Wouters et al., 2013), and an affective-metacognitive band (self-efficacy and perceived mastery, curiosity, empathy, enjoyment, motivation, and collaboration). The protocol is selective rather than exhaustive: it foregrounds the affective-metacognitive band — the dimensions a studio jury cannot see at all — while anchoring every affective claim to a cognitive correlate, so that felt engagement is never reported as learning without a performance measure to certify it. The *rasa* progression already embedded in the framework — *Kāma* → *Līlā* → *Anubhava* → *Māyā* → *Yoga* — converts this list into a scaffold by reading the five stages not as parallel outcomes but as sequential gateways, each gating one construct with a distinct assessment intent: *Kāma* indexes the initial sensory pull (motivation and onset of curiosity) that confirms the artefact draws the learner in at all; *Līlā* the spontaneous play (enjoyment) that establishes the entry condition and rules out novelty as the cause of any gain; *Anubhava* the consolidated undergoing in which perceived mastery and empathy — felt knowing of self and of the other, treated in Indian aesthetics as a single cognitive event — are measured; *Māyā-Vismaya* the post-experiential wonder and perceived presence of a learner who now reads the medium’s constructedness; and *Yoga-Sthāna* the integrated, transferred competence that is the framework’s terminal goal, indexed by instruments such as the stakeholder-transfer map etc. The pyramid encodes *tiers* (what applies to whom) on a vertical axis; the *rasa* progression encodes aesthetic *maturation* (*Kāma* → *Yoga*) on a horizontal one.

Because the Tier-3 batteries are dimension-pure, a measured gain can be attributed to the specific register a game claims to cultivate — the property that makes the framework’s integration claim (DR1), its

first-order treatment of embodiment (DR5), and its evidenced mechanic selection (DR6) empirically testable rather than asserted. The protocol thus completes the framework: Section 5.2 specifies how an APGF game is designed and the pyramid specifies how its dimensional claims are measured, before Section 6 demonstrates the family of designs the framework generates.

6. The generative capacity of the APGF: games a pedagogue can create

A framework earns its keep when it generates coherent designs beyond the cases that motivated it. Because the APGF's mechanic inventory is non-overlapping and dimension-aligned, and because Step 3 selects mechanics by evidenced dimensional fit, the framework does not prescribe a single game; it defines a generative space. Any combination of a target dimension (or combination of dimensions), a complexity tier, and a delivery platform locates a principled design within that space. This section makes the space concrete in four ways: it sets out the three choices that generate a design, it works one game through the five-step methodology end to end, it illustrates the breadth of the space with a catalogue of twelve games spanning the B.Arch. curriculum from first year to thesis, and it gives the procedure and templates by which an educator generates their own.

6.1. The generative space: three design choices

From the aesthetic goal produced by Step 2, an educator makes three decisions that jointly determine a game (Fig. 9). The first is dimensional: which of the 3E pillars the game targets, read directly off the Bloom-and-3E classification of the goal. The second is platform: whether the game is realised in a high-technology medium (virtual or augmented reality) or a low-technology one (cards, tactile kits, board games), chosen by the target dimension and — decisively, in many Indian programmes — by the infrastructure actually available. The third is complexity: which of four tiers, scaled to the learners' developmental stage, from a single-session first-year game to a semester-integrated thesis-level simulation. The non-overlap of the inventory is what makes these choices definite rather than rhetorical: once the dimension and tier are fixed, the eligible mechanics are determinate, and the platform decision changes how a mechanic is realised but not which dimension it serves.



Fig. 9. The three design choices that generate an APGF game. The aesthetic goal fixes the target dimension(s); infrastructure and dimension fix the platform; learner stage fixes the complexity tier; together they yield a principled mechanic shortlist from the eighteen-mechanic inventory.

6.2. The framework in use: a worked example

To show the methodology producing a design rather than describing one, this section walks the five steps end to end for a single game — Scale Walk, a moderate-tier game targeting the Embodiment dimension — making explicit the decision taken at each step and its warrant. Every game in the catalogue that follows is the product of the same procedure.

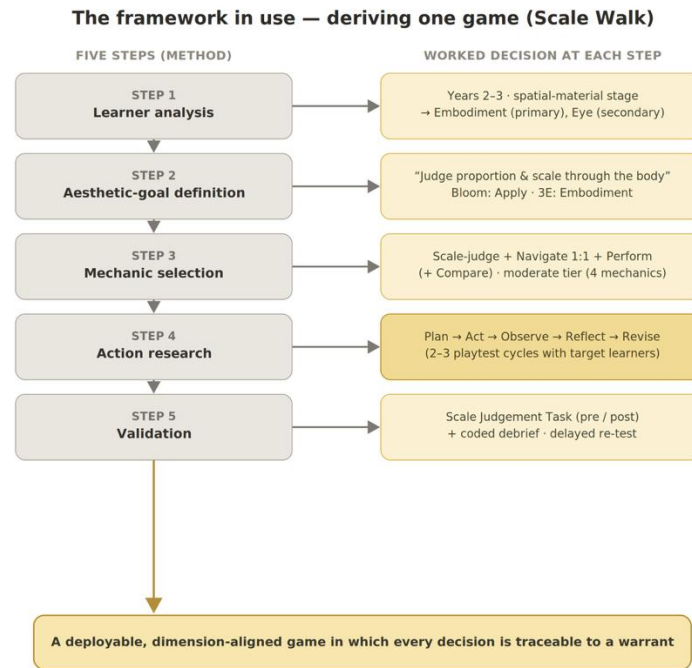


Fig. 10. *The framework in use: the five steps deriving a single game (Scale Walk). The left lane is the generic method; the right lane records the decision taken at each step, each traceable to a warrant (learner stage, Bloom level, evidenced mechanic fit, action-research calibration, dimension-aligned instrument).*

Step 1 — Learner analysis. The game is written for second- and third-year students, who in the developmental mapping of Step 1 sit at the spatial-material exploration stage: they have acquired disciplined visual analysis but are still translating two-dimensional representation into three-dimensional reality, and scale and proportion are their characteristic difficulty. The learner specification therefore fixes the cohort (Years 2–3), the stage (spatial-material), and the primary dimension the stage indicates — Embodiment, with a secondary Eye emphasis.

Step 2 — Aesthetic-goal definition. Locating aesthetic content in the syllabus surfaces ‘proportion’ and ‘scale perception’ under the experiential/sensory keyword category, typically in an early design or environmental-psychology course. Classified by Bloom, the target sits at the Apply level — students must apply proportional judgment to real built dimensions, not merely recognise proportion — and the 3E classification places it on Embodiment. The resulting aesthetic-goal statement is: after playing, students will judge architectural proportion and scale through the body, at the Apply level, primarily engaging the Embodiment dimension.

Step 3 — Mechanic selection. With the goal fixing Embodiment at the Apply level, the designer queries the Embodiment inventory and selects the mechanics whose documented dimensional fit matches. Scale-judge (felt proportion; true-size relationships invisible in drawings) is the core mechanic; Navigate at 1:1 (locomotion that builds cognitive maps) supplies the bodily traversal that makes the judgment embodied rather than visual; and Perform (whole-body action) anchors the estimate in posture and pace. A single Eye mechanic, Compare, is added so students can juxtapose their bodily estimate against the measured value. The selection is principled rather than aesthetic: each mechanic is chosen because the evidence base associates it with the targeted dimension (DR6), and the resulting four-mechanic count sits in the moderate tier that Step 1 indicated.

Step 4 — Action research. The design is prototyped and run through the framework’s Plan–Act–Observe–Reflect–Revise cycle. A first cycle tests whether the Scale-judge mechanic produces genuine estimation behaviour rather than guessing: observing estimation errors and student talk against design intent reveals, for instance, whether the stations are legible, and a revision might add a calibration station or sharpen the debrief prompt. Two to three cycles with target learners calibrate the mechanic-to-dimension match before the design is fixed.

Step 5 — Validation. Finally, the instrument is chosen to match the targeted dimension: a Scale Judgement Task administered pre and post measures the Embodiment gain directly, triangulated with a thematically coded debrief that captures the scale vocabulary the cohort develops, and a delayed re-test some weeks later checks durability. The validation closes the loop back to the goal — the instrument measures precisely the competence the mechanics were selected to cultivate.

Worked this way, the five steps convert a developmental observation into a defensible design in which every decision — dimension, mechanic, complexity, instrument — is traceable to a warrant. The catalogue that follows is the same procedure applied across the curriculum.

6.3. Twelve worked games across the curriculum

Table 9 catalogues twelve games that populate the generative space across all four complexity tiers and the full B.Arch. curriculum. Three descend directly from the framework’s validated work; the remaining nine extend it to typologies the research identified as targets for transfer — Indo-Islamic, colonial and Art-Deco, vernacular, Modernist Chandigarh, and contemporary urban fabric — and the deck populates only part of a larger generative space — a grid of dimension × complexity in which the twelve are worked instances and many cells remain open for an educator to fill (Fig. 11). The games are described tier by tier below; each is a fully specified design that an educator can deploy or adapt, not a finished product, and each carries its own pre/post measurement logic.

#	Game	Sem · Bloom	3E focus	Platform	Core idea
1	Style Snap	1–2 · Remember	Eye	Cards	Snap-match architectural elements across styles to build discriminative vocabulary
2	Material Memory	1–2 · Understand	Embodiment	Samples + blindfold	Identify materials by touch alone, then match them to the buildings made from them
3	Façade Decoder	1–2 · Apply	Eye + Emb.	Smartphone AR	Tag elements on a city walk; learn to read the everyday street as architectural text
4	The Pattern Codex	2–4 · Analyse	Eye + Emb.	Board + tiles	Decode and then extend the generative geometry of Indian ornament
5	Scale Walk	2–4 · Apply	Embodiment	Site + tape	Estimate dimensions by body, then measure; build proportional intuition
6	The Vernacular Detective	3–4 · Evaluate	Full 3E	AR field	Read a vernacular building as an integrated climatic–social–material response
7	Mohalla	5–6 · Evaluate	Everyday + Emb.	Board + roles	Negotiate a contested neighbourhood street among six stakeholders
8	The Climate Council	4–5 · Create	Full 3E	Model + climate data	Design and defend a climate-tuned courtyard house across seasonal scenarios
9	Heritage on Trial	5–7 · Evaluate	Everyday + Eye	Board + dossier	Arbitrate an adaptive-reuse case among competing claimants
10	The Commission	7–8 · Create	Full 3E	Studio-embedded	Run a whole studio brief as a live multi-stakeholder commission
11	Decolonising the Canon	6–10 · Analyse	Eye + Everyday	Board + archive	Reassemble the history syllabus into a defensible alternative curriculum
12	City Pasts / Futures	7–9 · Create	Full 3E	VR + model	Inhabit a city’s past in VR, then negotiate its future on a physical model

Table 9. Twelve worked games populating the APGF’s generative space, across four complexity tiers and the B.Arch. curriculum. “Emb.” = Embodiment.

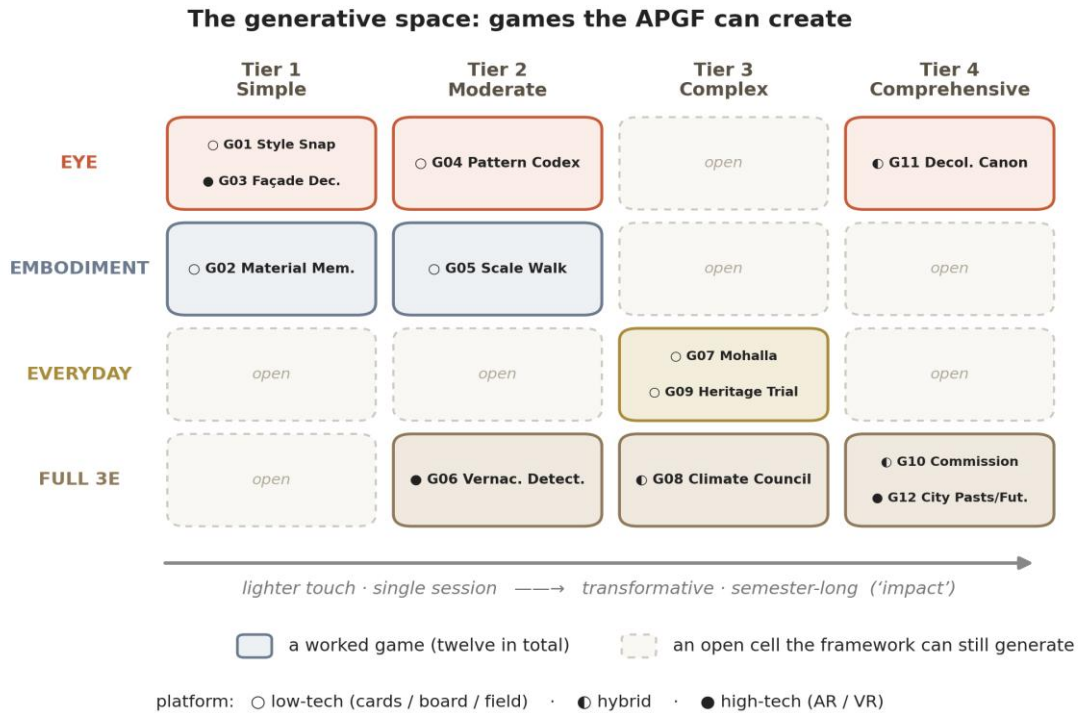


Fig. 11. The generative space, as a grid of 3E dimension (rows) against complexity tier (columns), ordered left-to-right from lighter-touch, single-session games to transformative, semester-long ones. The twelve worked games are placed in their cells; the dashed cells mark designs the framework can still generate — for example an Everyday game at the simple tier, or an Embodiment game at the comprehensive tier — which an educator can build through the templates of Section 6.4. Each game is additionally tagged by platform — an open marker for low-tech (cards, board, field), a half marker for hybrid, and a filled marker for high-tech (AR/VR).

Tier 1 — simple (Year 1, single session)

Game 01 · Style Snap (Eye; cards). A sixty-card deck juxtaposes visually similar but stylistically distinct elements — a Mughal jharokha against an Indo-Saracenic window, a vimana against a Corinthian capital — and rewards the first player to call “Snap!” on a same-family match. The mechanics are Identify and Match under light time pressure, and in twenty to thirty minutes a first-year cohort builds the discriminative vocabulary that lecture coverage rarely consolidates. Assessment is a pre/post style-identification quiz on photographs not used in the deck, with a four-week retention check, and the deck regionalises easily (a Bengal deck, a Dravidian deck) without changing the mechanics.

Game 02 · Material Memory (Embodiment; samples and blindfolds). Blindfolded students identify Kota stone, Makrana marble, terracotta, teak, and lime plaster by touch alone, then match each sample to images of buildings made from it, moving from blind memory to integrated visual–tactile association. The mechanic is Feel-material, supported by Identify and Match, and the tactile memory it builds is the substrate of the material empathy that later design judgment depends on. Assessment combines tactile-identification accuracy with a short reflective journal scored for sensory-vocabulary specificity.

Game 03 · Façade Decoder (Eye + Embodiment; smartphone AR). Students walk a curated one-kilometre route with an augmented-reality overlay that prompts them to find and tag a chajja, a jaali, or a corbelled balcony, then reveals the correct identification — producing a personal catalogue of forty to sixty elements read in their own city. The mechanics are Identify, Curate, and Navigate, and the game instills the habit of reading the everyday built environment as a layered architectural text. A no-AR version (camera plus printed worksheet and a faculty debrief) preserves the exercise where infrastructure is limited.

Tier 2 — moderate (Years 2–3, one to two hours)

Game 04 · The Pattern Codex (Eye + Embodiment; board and tiles). Teams reverse-engineer the generative geometry behind Indian ornamental systems — a Sidi Sayyed jaali, a Kerala kolam, a vimana

grid — reconstruct each from a tile set, and then, given only a corner, generate the rest. The mechanics span Match, Analyse, Sequence, Deconstruct, and Assemble, carrying students from recognising ornament to decoding and extending its rule. Assessment rates both reconstruction accuracy and the coherence of the generated variation, distinguishing a principled rule-extension from an arbitrary one.

Game 05 · Scale Walk (Embodiment; outdoor site and tape). Across eight to twelve stations on a heritage site, pairs first estimate courtyard width, cornice height, and arcade depth by body alone — paces, arm-spans, breath — then measure with tape and confront the signed error. The mechanics are Navigate, Scale-judge, and Perform, and the game cultivates the proprioceptive sensitivity that distinguishes an architect's reading of scale from a layperson's. A debrief codes the discursive vocabulary the cohort develops — “intimate”, “monumental”, “oppressive” — and the game can be repeated across a semester to quantify cumulative gain.

Game 06 · The Vernacular Detective (Full 3E, Embodiment primary; AR field). Teams arrive at a haveli, a nalukettu, or an Ahmedabad pol with AR overlays that reveal, on demand, the building's climatic, social, material, and economic logics, and produce a field report reading the vernacular building as an integrated response rather than a picturesque object. The mechanics draw on all three pillars — Explore and Feel-material, Analyse and Deconstruct, Tell-stories and Evaluate-in-role — and the report is scored for layered observation and integrative reasoning across the four logics. Typology substitutes by region, and a forensic-structural variant (“why is this wall cracking?”) repoints the same mechanics.

Tier 3 — complex (Years 4–5, multi-session)

Game 07 · Mohalla — Whose Street Is It Anyway? (Everyday + Embodiment; board and role cards). Six or seven students take the roles of a kirana-shop owner, an elderly resident, an auto-rickshaw driver, a civic-design officer, a temple trustee, and a flower-vendor on a contested 150-metre street, resolving four escalating scenarios — a working day, monsoon flooding, a religious procession, a redevelopment proposal — through tile placement and resource allocation. The mechanics are the full Everyday set plus Role-play, and the game asks students to reconcile every legitimate claim without surrendering aesthetic intention. It descends from the framework's validated stakeholder-negotiation core and ports readily to a Mumbai chawl, an Old Delhi gali, or a small-town bazaar.

Game 08 · The Climate Council (Full 3E; physical model and climate-data overlays). Teams design a courtyard house for a specific climate zone — hot-dry Rajasthan, hot-humid Kerala, cold Ladakh — then run it through peak-summer, monsoon, and winter scenarios with energy-cost and comfort-hour playouts before defending it to a council of faculty and student juries. The mechanics integrate analysis and assembly with the full negotiation set, binding embodied climate experience to stakeholder-cost reasoning. Performance information such as comfort hours and energy cost enters here as in-game content for the analytic mechanics, not as the aesthetic scoring logic — the council judges climate fitness, cultural fit, material logic, and aesthetic integration together.

Game 09 · Heritage on Trial (Everyday + Eye; board, role cards, and dossier). Students arbitrate the fate of an at-risk heritage building — a Bombay Art-Deco cinema, a Delhi haveli, a Pondicherry bungalow — taking the roles of owner, conservation officer, developer, community group, architect, and financier across a guided site visit and three negotiation rounds. The mechanics combine the Eye's identification and analysis with the Everyday's negotiation and storytelling, making adaptive reuse a problem of reconciling aesthetic fidelity with financial and social pressure. The reuse proposal is rated on a four-criterion rubric, with an external faculty jury added as a concurrent-validity check.

Tier 4 — comprehensive (Years 5+, semester-integrated)

Game 10 · The Commission (Full 3E; studio-embedded). A whole studio brief is reframed as a live commission, with four role-play events across the semester — a client briefing, a community consultation, a regulatory review, and a financier review — staffed by faculty and senior students, and a final jury that evaluates both the design and the trajectory of stakeholder accommodation through which it was reached. It exercises the entire mechanic catalogue, and the individual studio project is itself the simulation's outcome.

As the studio-scale extension of the validated negotiation game, it integrates into any sixth- or seventh-year design studio and can be embedded in the final-year thesis.

Game 11 · Decolonising the Canon (Eye + Everyday; board and digital archive). In a recurring weekly session inside a history-of-architecture course, the cohort reassembles the syllabus period by period — negotiating which buildings, theorists, and themes to include and how to weight them — and produces a documented alternative curriculum that can be put to the curriculum committee. The mechanics span identification and sequencing with the full negotiation set, and the game converts a passive diagnosis of canonical imbalance into an active, defensible cohort response. The cohort’s syllabus proposal is the principal outcome, and a cross-institutional variant pools proposals from several schools.

Game 12 · City Pasts / Futures (Full 3E; VR and physical hybrid). Across three sessions students inhabit a historical layer of an Indian city in virtual reality — Shahjahanabad, the 1899 Bombay Improvement Trust, Chandigarh in 1953 — diagnose the gap to its present condition, and then negotiate a fifteen-year future for the same fabric on a physical model with the city’s contemporary stakeholders. It is a comprehensive integration of all three pillars with immersion, simulation, and narrative; a pure-board version substitutes archival photographs and oral-history recordings for the headset. The design is most powerful when set in the institution’s own city, where the historical and present-day fabric are immediately accessible.

Beyond the twelve: two open cells, worked

The twelve are instances of the space, not its limits, and the open cells of Fig. 12 are designable rather than rhetorical. Two short stubs, each occupying a currently empty cell, make the point.

The Threshold (Everyday; cards; simple, Year 1) fills the open Everyday-simple cell — the Everyday pillar presently has no first-year game. It is a thirty-minute card game in which first-years sort everyday spatial situations (a courtyard at noon, a doorway during a festival, a shared stair, a street-facing verandah) by the social rule each encodes: who may use it, when, and with whom. Players justify each placement aloud, and the reveal pairs every card with a short ethnographic note. The mechanics are Evaluate-in-role and Tell-stories at the Understand level; the game gives first-years an early habit of reading space as socially governed rather than merely formal, long before the senior-year negotiation games. Assessment is a pre/post situational-judgment task with a brief reflective note.

The Sensory Logbook (Embodiment; site and journal; comprehensive, semester) fills the open Embodiment-comprehensive cell — the Embodiment pillar presently stops at the moderate tier. Run across a semester alongside a design studio, it asks students to bodily document one building or urban room each week — pacing it, registering its material temperature and acoustic character, recording the postures it invites — in a structured kinaesthetic journal, and to feed the accumulating somatic vocabulary directly into their studio scheme. The mechanics are Feel-material, Scale-judge, and Perform sustained over time, scaffolded by Reflect; the game treats embodied attention as a semester-long discipline rather than a single encounter. Assessment combines the journal, rubric-scored for sensory specificity and design transfer, with a pre/post Embodied Aesthetic Response Scale.

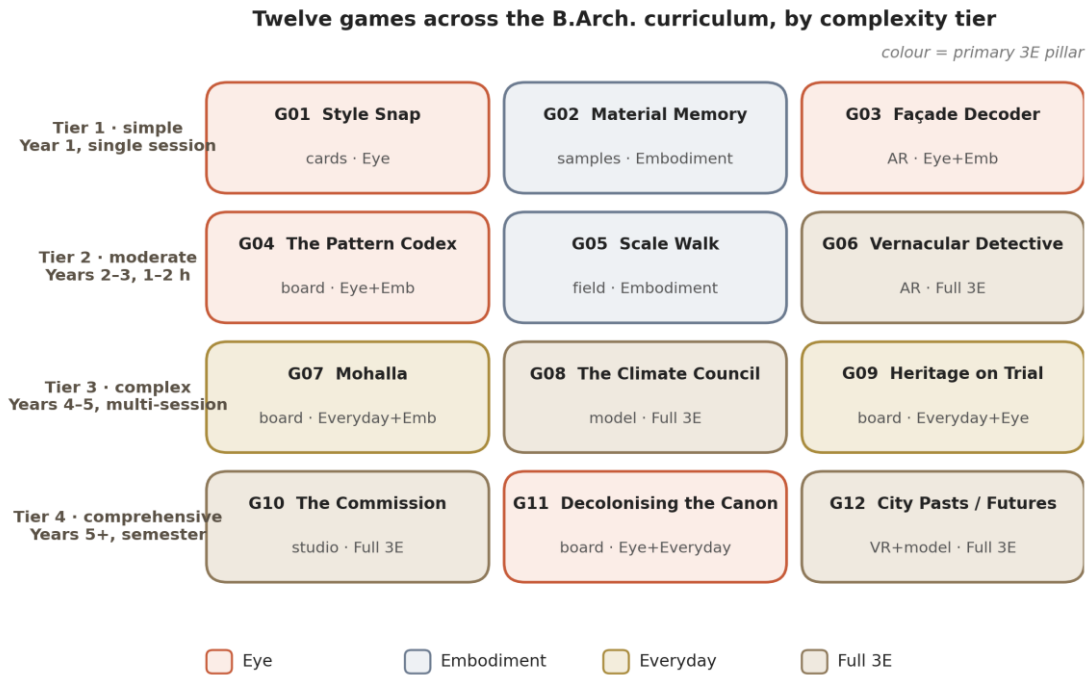


Fig. 12. A complementary at-a-glance view of the twelve games organised by complexity tier (four rows, three games each), each labelled with its medium and primary 3E pillar. Where Fig. 10 plots the games against the 3E dimension to expose the open cells, this view foregrounds the curricular sequence from a first-year single session to a thesis-level semester.

6.4. Generating a new game: the five-template pathway

The twelve games are illustrations of the space, not its boundary. An educator generates their own game by working through the five steps of the methodology as a sequence of fill-in worksheets, one per step (Table 10; the blank templates are reproduced in Appendix B). Completed in order, the five produce a complete design specification for a game targeted at one of the educator's own courses — a learner specification, a one-sentence aesthetic-goal statement, a justified mechanic shortlist, an action-research log, and an assessment plan. The pathway is deliberately low-tech: it can be photocopied and completed by hand, and it makes the framework usable in a faculty workshop without any software.

Template	Step	What the educator produces
T1	1 — Learner analysis	A learner specification: year, cohort size, institutional context, Bloom level targeted, primary and secondary 3E emphasis, the pedagogical gap observed, and the time available
T2	2 — Aesthetic-goal definition	A one-sentence aesthetic-goal statement (Bloom verb + aesthetic content + Bloom level + 3E dimension) and the measurement instrument(s) that will evidence it
T3	3 — Mechanic selection	A mechanic shortlist: the complexity tier, the core mechanics drawn from the dominant pillar(s), any cross-cutting mechanics, and a one-line justification per mechanic
T4	4 — Action research	An action-research cycle log: for each playtest cycle, what it tests, the intervention specifics, what was observed, whether the targeted dimensional effect appeared, and the revision for the next cycle
T5	5 — Validation	An assessment plan: pillar-aligned quantitative and qualitative instruments, pre-, post-, and delayed-retention timing, and the analytic strategy

Table 10. The five-template workshop pathway. Working through the templates in sequence produces a complete design specification for one APGF-aligned game; the blank forms are reproduced in Appendix B.

6.5. Adoption notes and common pitfalls

The most common failure in a first deployment is over-design: an educator new to the framework attempts a complex game with eight mechanics across all three pillars at once. The recommended first attempt is the

opposite — a Tier-1 game with one or two mechanics, a single pillar, and a clear pre/post measurement plan. Build one, run it, measure it, and only then progress. Three further pitfalls deserve explicit naming, each a corollary of a design requirement.

The first is **choosing mechanics for fun rather than for dimension**. Points, badges, and leaderboards are familiar from commercial games, but adding them because they are familiar can dilute or even invert the targeted dimensional effect; across the evidence base, fewer and more dimensionally aligned mechanics consistently outperform more and less aligned ones. This is the practical face of DR6. The second is **skipping the playtest cycles**: a paper design is not a working game, and Step 4's action-research cycles are where the mechanic-to-dimension match is actually calibrated — two to three cycles with target learners is the minimum for any new design. The third is **skipping retention testing**: an immediate post-test gain is encouraging but does not by itself demonstrate durable learning, so a follow-up assessment some weeks after the intervention should be built into the measurement plan from the start. Each pitfall is avoidable, and each is avoided by treating the framework's steps as obligations rather than options.

7. Discussion

The twelve games are not merely a list of suggestions; collectively they demonstrate four properties that the audit predicted a fit-for-purpose framework would need. They demonstrate platform-agnosticism: the same mechanic appears in high- and low-technology realisations — scale judgment in a virtual-reality headset (City Pasts / Futures) and with a tape measure (Scale Walk); role-play in multi-user simulation and around a board (Mohalla) — so the framework's dimensional logic is independent of any one medium. They demonstrate curricular span, reaching from a twenty-minute first-year card game to a fourteen-week thesis-level commission, calibrated at each stage to developmental readiness. They demonstrate typological reach: where the framework's origin cases were Hindu temples, the catalogue extends without modification to Indo-Islamic, colonial and Art-Deco, vernacular, Modernist, and contemporary urban fabric, operationalising the typological transfer the research identified as its principal frontier. And they demonstrate dimensional balance: every mechanic in the inventory is exercised by at least one game, and the deck distributes across the three pillars rather than defaulting to the visual. Together these are the practical content of DR1 and DR3 — a single framework generating an integrated, transferable family of designs.

Locating the framework against the field's dominant general model sharpens what it contributes. The Mechanics–Dynamics–Aesthetics model (Hunnicke et al., 2004) names the player's emotional responses as 'aesthetics' but leaves unspecified what aesthetics means for any particular discipline; the 3E framework supplies that specification for architecture, and the learner-facing game loop of Section 5.5 supplies the pedagogical layer MDA omits — a Brief–Build–Evaluate–Refine cycle in which the evaluation is dimension-aligned and relational rather than a single-correct-answer computation. Each of the twelve games is an instance of that loop: a dimension-targeted brief, mechanics enacted, dimension-specific feedback, refinement. Crucially, the framework's mechanic-to-dimension associations are evidenced rather than stipulated (DR6); the catalogue inherits that grounding, so that a game's claim to cultivate a particular register rests on the documented evidence consolidated in the inventory rather than on the designer's intuition.

The framework also models a way of building pedagogical design knowledge from a non-Western aesthetic theory. The *rasa* progression is structural to the framework rather than ornamental — it organises the embodiment dimension and its instrument — and one of the twelve games, Decolonising the Canon, turns the critique of an imbalanced architectural canon into a playable, defensible act of curriculum-making. For educators the consequence is practical and equitable: because the framework is platform-agnostic, deep aesthetic learning does not require immersive infrastructure, and a programme with nothing more than cards, tape, and a board can deploy games targeting all three dimensions. The five-template pathway lowers the barrier further, turning the framework from a thing to be read into a thing to be used.

8. Limitations and future research

The catalogue is a demonstration of generative capacity, not a body of validated interventions. Most of the twelve games are worked designs whose efficacy in deployment remains to be established, and the framework's typological transferability beyond its origin cases is a hypothesis the catalogue operationalises rather than a settled result — the proper way to settle it is precisely the action-research the framework prescribes (Steps 4–5), conducted by educators in their own contexts. The framework and its illustrative games originate in a single institution and an Indian B.Arch. curriculum, and the representative developmental-stage mapping will need local reconstruction in other settings. The audit underlying the gap argument is interpretive, mapping the corpus to best-fit frameworks by design signature rather than by citation, and should be read as a structural diagnosis rather than a bibliometric measurement. These limits define the agenda: independent-educator deployments documented through the templates, cross-typology and cross-cultural replication, longitudinal retention designs, and an open repository of action-research logs through which the framework's evidence base can grow by use.

9. Conclusion

From a two-step audit that exposed four structural absences in the serious-games framework apparatus, this paper developed a framework that repairs them — integrative, architecturally native, embodiment-first, and culturally grounded — and then showed that the framework is generative rather than singular. Its five-step methodology and eighteen-mechanic 3E inventory define a space of principled designs that a catalogue of twelve worked games realises across the B.Arch. curriculum, five media, and five typologies, and a five-template workshop pathway lets educators generate and test their own. The contribution is therefore not a fixed intervention but a method to be taken up, adapted, contested, and extended — and a demonstration that rigorous pedagogical design can be built from Indian aesthetic theory treated as a structural resource rather than as ornament.

Abbreviations

APGF: Architectural Pedagogy Game Framework; 3E: Eye, Embodiment, Everyday; DSR: Design Science Research; DR1–DR6: Design Requirements 1–6; LOTS/MOTS/HOTS: Lower-/Middle-/Higher-Order Thinking Skills; EARS: Embodied Aesthetic Response Scale; MDA: Mechanics–Dynamics–Aesthetics; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; VR: Virtual Reality; AR: Augmented Reality; B.Arch.: Bachelor of Architecture.

Declarations

Ethics approval and consent to participate

The 114-study systematic review and the 20-framework audit use only published secondary sources, so they need no ethical approval. The two human-subjects components are the four naturalistic classroom pilots at IGDTUW (Gradecraft, Climate Fresk, Play the City, Assassin's Creed) — students were the participants, and the paper reports outcomes derived from them ("reduced studied cynicism," fourteen mechanics traced to observed outcomes) — and the card-sorting validation behind DR5 ($\kappa = 0.92$), where raters generated inter-rater data. This study uses minimal-risk educational research using anonymised classroom data and is routinely granted exemption from full institutional review by the Indira Gandhi Delhi Technical University for Women (IGDTUW) Institutional Ethics Committee (IEC) because it utilized anonymous, non-invasive participant surveys. The study adhered to the Declaration of Helsinki through the following measures:

1. **Ethical review:** All human-subjects components underwent institutional ethical review by the Institutional Ethics Committee (IEC) of Indira Gandhi Delhi Technical University for Women, registered with the Department of Health Research (DHR), Government of India, and operating under the Indian Council of Medical Research (ICMR) National Ethical Guidelines.
2. **Informed consent:** All participants provided written informed consent prior to participation, with full disclosure of study objectives, classroom-based data collection, and use of anonymised outcomes.

3. **Risk minimisation:** The research involved minimal risk, limited to standard educational classroom activities; no invasive procedures, biomedical interventions, or sensitive personal data collection were undertaken.
4. **Participant protection:** All participant identities were anonymised in data collection, analysis, and reporting. No personally identifiable information was retained beyond the consent process.
5. **Vulnerability and autonomy:** All participants were 18 years of age or older; no vulnerable populations (minors, cognitively impaired individuals, or institutionalised persons) were enrolled. Participation was voluntary with no coercion or undue inducement.
6. **Benefit-risk balance:** The anticipated benefits of understanding pedagogical outcomes in game-based architectural education outweighed foreseeable risks, and findings were disseminated to advance the field.

Clinical trial number

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The framework documentation, the full game designs, the designer templates, and the assessment instruments are available from the corresponding author on request.

Competing interests

The author declare that they have no competing interests.

Funding

The author received no specific funding for this work.

Author's contributions

The author conceptualised the study, designed the framework and its games, conducted the framework audit, the systematic review, and the classroom pilots, performed the analysis, prepared the figures, and drafted the manuscript and contributed to the conceptualisation and methodology, supervised the work, and reviewed and edited the manuscript. The author read and approved the final manuscript.

Acknowledgements

During the preparation of this work the author used Claude (Anthropic) to assist with language editing, drafting, and formatting of the manuscript. All research design — the framework audit, the systematic review, the design of the framework and its games, and their analysis and interpretation — was carried out by the author without the use of such tools. The author reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Appendix A. The 114-study corpus mapped to best-fit audited framework

Table A.1 lists the full corpus of the systematic review (114 game-based-learning studies in architecture and related domains, 2014–2024) underlying the architectural-affinity analysis of Section 3.4. Each study is mapped to the audited framework whose design signature best fits the game’s described mechanics, modality, domain, and pedagogy. The mapping is interpretive rather than citational: source papers were not surveyed for explicit framework citations, but matched to the framework their design most closely resembles. Architectural-affinity ratings: High = framework signature directly matches architecturally specific learning; Medium = partial alignment; Low = weak or conceptual alignment; None = no clear single-framework fit (framework-free).

#	Year	Authors	Title	Game type	Best-fit framework	Affinity
1	2024	Shi et al.	Cities in electronic games	VIDEO GAMES	Framework-free	None
2	2024	Zhang et al.	KiteMR: Chinese kite craftsmanship	MR-SG	F4 FRACH	High
3	2024	Wee & Chua	Personalized Learning Environment	D-SG	F16 IDF	Low
4	2024	Cellura	Greek Doric Architecture	VR-SG	F18 IVR-SG	High
5	2024	Lee et al.	AR Book: Hong Kong heritage	AR-SG	F4 FRACH	High
6	2024	Pickersgill et al.	Virtual Site Visits Gamification	G	F10 Kapp	Medium
7	2024	Yang et al.	Role-play micro-game computational thinking	G	F10 Kapp	Medium
8	2024	Minas et al.	Environmental education 3D Virtual Worlds	D-SG	F16 IDF	Low
9	2024	Dib et al.	Sustainable Design and LEED	D-SG	F16 IDF	Medium
10	2024	Linjing Sun et al.	Fire Safety VR with Haptic Feedback	VR-SG	F14 WeDraw	High
11	2024	Bienvenido-Huertas et al.	Quiz Games building engineering	G	F10 Kapp	High
12	2024	Kara	Cultural Heritage SG mixed-methods	D-SG	F17 TENF	High
13	2024	Çalışkan	Construction VR interior architecture	VR-SG	F18 IVR-SG	High
14	2024	Li Ye et al.	AR traditional pattern learning	AR-SG	F4 FRACH	High
15	2024	Peng et al.	Rural architectural transformation SG	P-SG	F12 LM-GM	Medium
16	2024	Tan & Ng	Mobile sensing storytelling cultural	D-SG	F17 TENF	High
17	2024	El Hassan et al.	Gamified AR education	AR-SG	F10 Kapp	Medium
18	2024	Hanni et al.	HistoLab VR hazard awareness	VR-SG	F18 IVR-SG	Medium
19	2024	Chen et al.	Virtual Site Tours construction tech	D-Simulation	Framework-free	None
20	2024	Figueroa-Garrido et al.	VR architectural structures	VR-Simulation	Framework-free	None
21	2024	Liu	Dunhuang frescoes VR	VR-SG	F18 IVR-SG	High
22	2024	Ahmadi Yousefi	Earthquake emergency VR	VR-SG	F18 IVR-SG	Medium
23	2024	Kim et al.	Urban Gentry gentrification	P-SG	F12 LM-GM	Medium
24	2024	Mahamarowi & Redzuan	Islamic architecture VR	VR-Simulation	F18 IVR-SG	Medium
25	2024	Miller & Vaca Núñez	Project Win Game project management	D-SG	F16 IDF	Low
26	2024	Wang et al.	Immersive virtual exhibitions heritage	VR-Simulation	F4 FRACH	Medium
27	2023	Mark	Ecotopia sustainability board game	P-SG	F12 LM-GM	Medium
28	2023	Kumar et al.	Hawamahal UNESCO 3D heritage	VR-Simulation	F4 FRACH	Medium
29	2023	Louro	Playing with architecture space-time	G	F10 Kapp	Medium

#	Year	Authors	Title	Game type	Best-fit framework	Affinity
30	2023	Ilbeigi	Construction engineering gamified	G	F10 Kapp	High
31	2023	González-Cacho et al.	GAMEX meaningful learning	G	F10 Kapp	High
32	2023	Li Ye et al.	Puzzle-Based cultural heritage eye-mov	D-SG	F17 TENF	High
33	2023	Huertas et al.	Kahoot building engineering	G	F10 Kapp	High
34	2023	Kleftodimos et al.	Dispilio AR prehistoric heritage	AR-SG	F4 FRACH	High
35	2023	Masson et al.	Scrum in Practice city reconstruction	P-SG	F12 LM-GM	Medium
36	2023	Xu et al.	HeritageSite AR exploration	AR-SG	F4 FRACH	High
37	2023	López-Pernas et al.	Educational escape rooms analytics	G	F10 Kapp	High
38	2023	Forina et al.	Experimental design pedagogy	G	F10 Kapp	Medium
39	2023	Boušková & Švárová	Experiential urban design landscape	P-SG	F12 LM-GM	Low
40	2023	Alp et al.	AR architectural design studio	AR-Simulation	Framework-free	None
41	2022	Bjørner et al.	Making homework fun reading engagement	G	F10 Kapp	Medium
42	2022	Ashtari et al.	PONI personalised AR/VR onboarding	G	F10 Kapp	Low
43	2022	Bonacini & Giaccone	Gamification cultural institutions Italy	G	F10 Kapp	Medium
44	2022	Alcindor et al.	Heritage places videogame realism	VIDEO GAMES	F17 TENF	Medium
45	2022	Ruggiu et al.	Responsible innovation gamification	G	F10 Kapp	Medium
46	2022	Poplin et al.	Geogames youth co-creation	G	F10 Kapp	Medium
47	2022	Mohd Puzi et al.	Scenario based learning city built	VIDEO GAMES	Framework-free	None
48	2022	Shareef & Rauf	Technical courses gamification	G	F10 Kapp	High
49	2022	Sanchez et al.	BIM and game engines	VR-Simulation	Framework-free	None
50	2022	Thompson et al.	Climate BufferNet biodiversity	VR-Simulation	Framework-free	None
51	2022	Öksüz & Cordan	Earthquake home environments scenarios	VIDEO GAMES	Framework-free	None
52	2022	Cole	Assassin's Creed Odyssey heritage	VIDEO GAMES	F17 TENF	Medium
53	2022	Fioravanti & Carrara	X-House collaboration architectural design	G	F10 Kapp	Medium
54	2022	Castronovo et al.	Problem-solving construction simulation	D-Simulation	F12 LM-GM	Medium
55	2022	Goli et al.	Architectural design game multimodal	D-SG	F12 LM-GM	Medium
56	2021	Anifowose et al.	BIM LOD VR visualization	VR-Simulation	Framework-free	None
57	2021	Hart et al.	Resilience Playtest participatory design	G	F19 Participatory	Medium
58	2021	Mylonas et al.	Sustainability awareness schools	D-SG	F16 IDF	Low
59	2021	Puggioni et al.	SchoolAR VR education	VR-G/SG	F18 IVR-SG	Low
60	2021	Mavros et al.	Architectural Cognition Cards	P-SG	F14 WeDraw	High
61	2021	Vennarucci et al.	Villa Romana WebGL exploration	D-Simulation	F4 FRACH	Low
62	2021	Fonseca et al.	Mixed virtual SG architectural urban	VR-SG	F18 IVR-SG	High
63	2021	Walls	Urban landscape microclimate digital	D-Simulation	Framework-free	None
64	2020	Taylor	AR campus guide learning game	AR-SG	F10 Kapp	Low
65	2020	Melian Diaz et al.	Minecraft 3D construction creativity	VIDEO GAMES	Framework-free	None
66	2020	Sepasgozar	Digital Twin construction management	D-SG	F16 IDF	Low
67	2020	Lee et al.	Construction safety simulation auth learning	VR-SG	F18 IVR-SG	Medium
68	2020	Chen et al.	Code+ digital heritage narratives Asia	G	F17 TENF	Medium
69	2020	Vinella et al.	Intangible cultural heritage mobile	G	F17 TENF	Medium
70	2020	Hahn & Chamberlain	Konza prairie interdisciplinary studio	G	F10 Kapp	Low
71	2020	Lawson et al.	Multimodal virtual fire safety	VR-Simulation	Framework-free	None
72	2020	Peters et al.	Toolkits cards analogue ideation	P-SG	F19 Participatory	Medium
73	2020	Redondo et al.	EDUGAME4CITY VR urban gamification	VR-SG	F18 IVR-SG	High
74	2020	Egea-Vivancos & A-Ferrer	VR history heritage video games	VR-SG	F18 IVR-SG	High
75	2020	Kandi	VR educational game design review	VR-SG	F18 IVR-SG	High

#	Year	Authors	Title	Game type	Best-fit framework	Affinity
76	2020	Sánchez García et al.	Games studies architectural Granada	D-SG	F12 LM-GM	Low
77	2020	Pojani & Rocco	Edutainment role-play planning	G	F10 Kapp	Medium
78	2020	Poplin et al.	Geogames for change	D-SG	F16 IDF	Low
79	2020	Andrade et al.	Minecraft Tirol Brazil children urban	VIDEO GAMES	Framework-free	None
80	2020	Rizvić et al.	Interactive digital storytelling heritage	G	F17 TENF	High
81	2019	Kharvari & Höhl	VR 3D architectural visualization	VR-SG	F18 IVR-SG	High
82	2019	Yıldız	Game-based sketching architectural	G	F10 Kapp	Medium
83	2019	Madden	Video games teach history	VIDEO GAMES	F17 TENF	Medium
84	2019	Krishnan et al.	VR disaster management	VR-SG	F18 IVR-SG	Medium
85	2019	Firdausi et al.	Gamification explicit instruction	G	F10 Kapp	High
86	2019	Din & Gibson	Prevention through design SG	P-SG	F12 LM-GM	Low
87	2019	Poplin	Energy Geogame E-Footprints	D-SG	F16 IDF	Low
88	2018	Pánek et al.	Encountering place location-based	G	F10 Kapp	Low
89	2018	Martyniuk	Teaching video game studies	VIDEO GAMES	Framework-free	None
90	2018	Vidal et al.	MAGIS mobile AR instructional	D-SG	F10 Kapp	Low
91	2018	Ampatzidou & Gugerell	Energy Safari energy transition	P-SG	F12 LM-GM	Medium
92	2018	Rocha & Miron	House Factory mass customization	D-Simulation	Framework-free	None
93	2018	Chapman & Rich	Educational gamification motivation	G	F10 Kapp	High
94	2017	Hidalgo Montenegro et al.	ATAM-RPG architecture trade-off	G	F10 Kapp	Medium
95	2017	Dinis et al.	VR civil engineering interfaces	VR-SG	F18 IVR-SG	Medium
96	2017	Erdogmus et al.	Gamer personality engineering	G	F10 Kapp	Low
97	2017	Şahbaz & Özköse	Historical buildings digital games	D-SG	F17 TENF	High
98	2017	Fonseca et al.	Urban Gamification architecture	VR-SG	F18 IVR-SG	High
99	2017	Castronovo et al.	Virtual construction simulator	VR-SG	F18 IVR-SG	Medium
100	2017	Jones et al.	Board Game Prototyping co-design	P-SG	F19 Participatory	High
101	2016	León	Prisoners of Ritoque open city	D-Simulation	Framework-free	None
102	2016	Zhou et al.	Ancient Japanese architecture VR	VR-Simulation	F4 FRACH	Medium
103	2016	George et al.	Crane operator serious game	VR-SG	F18 IVR-SG	Low
104	2016	Merschbrock et al.	Healthcare facility relocation	VR-SG	F18 IVR-SG	Low
105	2016	Ayer et al.	AR Gaming Sustainable Design	AR-SG	F10 Kapp	Low
106	2015	Hoang Giang et al.	Medieval castle Waldenfels	D-SG	F17 TENF	High
107	2015	Economou et al.	Edu-simulation serious games	D-SG	F16 IDF	Low
108	2015	Wu & Yang	Social media gaming construction	G	F10 Kapp	Medium
109	2015	Overby & Jones	Minecraft art education curriculum	VIDEO GAMES	Framework-free	None
110	2014	Vaajakallio & Mattelmäki	Design games codesign tool	G	F19 Participatory	Medium
111	2014	Laureyssens et al.	ZWERM urban participation	P-SG	F19 Participatory	High
112	2014	Poppins	B3 Design Your Marketplace	D-SG	F16 IDF	Low
113	2014	Melonio	Game-based co-design children	G	F19 Participatory	Medium
114	2014	Owen et al.	Informal urbanism design studio	D-Simulation	Framework-free	None

Table A.1. The 114-study systematic-review corpus (2014–2024) mapped to best-fit audited framework, with architectural-affinity rating. Game-type codes: G = gamification; D-SG = digital serious game; VR-SG / AR-SG / MR-SG = immersive serious games; P-SG = physical serious game; “Simulation” and “VIDEO GAMES” denote technology appropriated without an explicit pedagogical framework.

Appendix B : Materials: The 60 challenge cards

A set of 60 cards was developed, each describing a specific pedagogical challenge in architectural aesthetic education. The cards were derived directly from the literature study, ensuring they represent authentic issues faced in architectural education. The complete card set, organized by their intended categories based on the 3E framework, is presented below.

Table: Complete Set of 60 Challenge Cards with Intended 3E Categories

Card ID	Card Text (Physical card (Postcard size))	Intended Category
EYE DIMENSION CARDS (Visual Perception)		
E01	Students may lack the ability to "read" architectural elements (e.g., proportions, light-shadow interplay, material textures) critically, leading to superficial design responses.	EYE
E02	In urban or complex environments, students may struggle to filter relevant details, leading to incoherent design interpretations.	EYE
E03	Students often focus on isolated elements (e.g., façade design) while missing the interplay of light, shadow, texture, and spatial hierarchy.	EYE
E04	Architectural aesthetics requires distilling complex environments into diagrams or conceptual sketches, but students struggle to move beyond literal representation.	EYE
E05	Without exposure to diverse architectural traditions, students impose Eurocentric or trendy aesthetics without understanding regional nuances.	EYE
E06	Students misjudge materiality (e.g., specifying polished concrete for a quiet library, ignoring its acoustic harshness).	EYE
E07	Students prioritize visual aesthetics while neglecting sound, touch, smell, and thermal comfort.	EYE
E08	Borrowing aesthetic elements (e.g., Japanese joinery, Moroccan tiles) without understanding their cultural logic leads to shallow pastiche.	EYE
E09	Student replicates a glass-and-steel façade for a hot climate because it "looks global," ignoring traditional jaali screens that naturally cool buildings.	EYE
E10	Students mechanically copy "safe" exam-friendly elevations (e.g., symmetrical facades with arches) instead of innovating based on site context.	EYE
E11	Students use a digital "ethnic pattern" on a façade without understanding its cultural symbolism or material constraints.	EYE
E12	Students from urban backgrounds struggle to read rural landscapes (e.g., agrarian terraces, tribal settlements), resulting in designs that alienate local communities.	EYE
E13	A student designs for visual appeal rather than thermal comfort, ignoring India's diverse climates (e.g., hot-dry, humid, cold).	EYE
E14	A student specifies imported marble when locally sourced Kota stone would be cheaper, sustainable, and equally elegant.	EYE
E15	Students design for "ideal" open spaces, ignoring India's dense urban fabric (e.g., Mumbai's slums, Old Delhi's alleys).	EYE
E16	Student proposes a wide plaza for a congested market area, failing to see how narrow, shaded lanes naturally regulate foot traffic.	EYE

Card ID	Card Text (Physical card (Postcard size))	Intended Category
E17	A student chases "international styles" (e.g., minimalist lofts) that clash with Indian domestic habits (e.g., joint families, street vendors, multi-use spaces).	EYE
E18	A student designs a static bus stand, ignoring how Indian bus stops organically expand with tea stalls, street vendors, and waiting crowds.	EYE
E19	Students rarely consider social hierarchies in space-making (e.g., segregated village wells, gendered temple entry).	EYE
E20	A student designs a "universal" community center but doesn't account for caste-based seating or women's safety in lighting and pathways.	EYE
E21	Studio projects often tokenize artisans (e.g., adding "handicraft elements") without collaborating meaningfully.	EYE
E22	Students trained on B&W technical drawings struggle with real-world colour harmony, resulting in garish or incoherent material palettes.	EYE
E23	Students imagine sites as empty utopias, ignoring existing trees, street noise, or neighbour's peeping windows.	EYE
E24	Urban students romanticize rural aesthetics (e.g., thatched roofs) without understanding maintenance or monsoon leaks.	EYE
E25	Students use software defaults (e.g., generic textures) without critical thought.	EYE
E26	Students sketch buildings as isolated objects, ignoring shadow interplay.	EYE
E27	Students confuse Art Deco motifs with Brutalist geometry.	EYE
E28	Students struggle with nuanced observation, cultural visual literacy, and contextual analysis.	EYE
EMBODIMENT DIMENSION CARDS (Spatial & Haptic Experience)		
M01	Difficulty translating 2D plans to 3D mental models.	EMB
M02	Lack of hands-on engagement with materials (e.g., concrete, wood, light) can lead to designs that look good on paper but lack sensory richness.	EMB
M03	Movement through space (e.g., circulation, thresholds) is hard to internalize without physical modelling or full-body simulations.	EMB
M04	Students often design from a detached, plan-view perspective rather than embodying the user's experience (e.g., failing to anticipate how a space feels at human scale).	EMB
M05	Heavy use of software (e.g., AutoCAD, Rhino) can lead to flattened perception, where students think in 2D plans rather than immersive 3D experiences.	EMB
M06	Students design on paper/screen without feeling the space kinaesthetically, leading to impractical proportions (e.g., corridors too narrow, ceilings too low).	EMB

Card ID	Card Text (Physical card (Postcard size))	Intended Category
M07	Students often design static "postcard views" rather than sequences of spatial events.	EMB
M08	Over-reliance on digital zoom tools leads to scale blindness—students design details that look good on-screen but fail in real life (e.g., oversized handles, microscopic textures).	EMB
M09	Students design spaces for standing or sitting postures only, forgetting Indian habits like squatting (baithak), lounging (charpai), or eating on the floor.	EMB
M10	Students underestimate muscle memory, designing spaces that fight natural movement (e.g., right-handed doors in left-dominant cultures, clockwise temple circuits disrupted).	EMB
M11	Students design homes assuming domestic help, leading to kitchens with no servant quarters or back entrances, ignoring class realities.	EMB
M12	Students avoid designing for taboo spaces (e.g., menstruation huts, cremation grounds), leaving gaps in social equity training.	EMB
M13	Students design a staircase too steep for elderly users.	EMB
M14	Students specify slippery marble for a rainy courtyard.	EMB
M15	Students forget to model wheelchair turns in corridors.	EMB
M16	Students can't visualize how sunlight moves through a space.	EMB
M17	Poor materiality understanding—can't imagine weight, texture, tactility.	EMB
M18	Students cannot sense proportion through their bodies.	EMB
M19	No tactile memory of different materials.	EMB
M20	Cannot judge scale without measuring tools.	EMB
M21	Designs look good in renderings but feel wrong in person.	EMB
M22	Students have no embodied understanding of structural forces.	EMB
M23	Cannot visualize spatial sequences from section drawings.	EMB
M24	Cannot feel the difference between compression and tension.	EMB
M25	Students have no bodily memory of proportion.	EMB
EVERYDAY DIMENSION CARDS (Contextual Application)		
D01	Students may impose abstract aesthetic ideals without considering local culture, climate, or everyday user behaviours.	EVE

Card ID	Card Text (Physical card (Postcard size)	Intended Category
D02	Students prioritize visual novelty over long-term functionality leading to "Instagrammable" but impractical spaces.	EVE
D03	Overlooking mundane yet critical details (e.g., how natural light changes at different times of day) due to lack of habitual observation.	EVE
D04	Students design based on idealized user scenarios rather than real-world habits (e.g., people shortcutting across lawns despite paved paths).	EVE
D05	A student designs a hospital corridor as a straight line, missing the psychological calm of curved, processional paths found in Indian palaces.	EVE
D06	Students design "perfect" systems that ignore informal adaptations (e.g., a "smart" park with no space for the chaiwala who inevitably sets up shop).	EVE
D07	Students propose glass walls in a hot climate, ignoring AC costs.	EVE
D08	Students design a 'quiet' library next to a noisy market.	EVE
D09	Students ignore street vendors' space needs in plaza designs.	EVE

Appendix C. The five workshop templates

The templates below complete the workshop pathway of Section 6.4. Worked through in sequence, they yield a complete design specification for one APGF-aligned game targeted at one of the educator's own courses. They may be photocopied and completed by hand or replicated in any writing tool.

Template T1 — Step 1 · Learner specification

Course: _____
 B.Arch. year / semester / cohort size: _____
 Institutional context: _____
 Bloom level targeted: ☐ Remember ☐ Understand ☐ Apply ☐ Analyse ☐ Evaluate ☐ Create
 Primary 3E emphasis: ☐ Eye ☐ Embodiment ☐ Everyday
 Secondary 3E emphasis (if any): ☐ Eye ☐ Embodiment ☐ Everyday
 Principal pedagogical gap I observe: _____
 Time I can give to this intervention: _____

Template T2 — Step 2 · Aesthetic-goal statement

After playing the game, students will _____ (Bloom verb)
 _____ (aesthetic content)
 at the _____ Bloom level, primarily engaging the _____ 3E
 dimension (and secondarily the _____ dimension, if applicable).
 Measurement instrument(s): _____.

Template T3 — Step 3 · Mechanic shortlist

Game complexity tier: ☐ T1 simple ☐ T2 moderate ☐ T3 complex ☐ T4 comprehensive

Core mechanics from the dominant 3E pillar(s):

- | | |
|----------|----------|
| 1. _____ | 4. _____ |
| 2. _____ | 5. _____ |
| 3. _____ | 6. _____ |

Cross-cutting mechanic(s) used: _____

Satellite mechanic(s), if any: _____

Justification: each selected mechanic is empirically associated with the targeted 3E pillar through the implementations recorded in the eighteen-mechanic inventory.

Template T4 — Step 4 · Action-research cycle log

Cycle number: _____ of _____

PLAN — what does this cycle test, and why? _____

ACT — intervention specifics (who, when, how long, where, what materials): _____

OBSERVE — what was recorded (times, errors, quotes, engagement signals): _____

REFLECT — did the mechanic produce the targeted dimensional effect? _____

REVISE — changes for the next cycle: _____

Template T5 — Step 5 · Assessment plan

Quantitative instrument(s) — pillar-aligned:

- | | |
|----------|----------|
| 1. _____ | 2. _____ |
|----------|----------|

Qualitative instrument(s) — for triangulation:

- | | |
|----------|----------|
| 1. _____ | 2. _____ |
|----------|----------|

Pre-test timing: _____ Immediate post-test timing: _____

Delayed retention test (recommended): timing _____ weeks after intervention

Analytic strategy: ☐ paired t-test ☐ within-subjects ANOVA ☐ rubric-scored ☐ thematic analysis