

Bridging urban analysis and architectural design through digital modelling and fabrication

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Abstract. *This paper examines how bachelor-level architecture students translate urban analysis into design-relevant contextual information while engaging with analogue, digital and hybrid mapping, plus modelling and making practices. Thirty-two context study portfolios are analysed using a mixed methods approach that combines workflow mapping through Business Process Model and Notation (BPMN 2.0) with directed qualitative content analysis across four process oriented domains: data acquisition and grounding, analytical mapping, digital and physical modelling and exploration/interrogation. The BPMN model makes explicit students' decision pathways, read alongside their reflections. Results show that output quality hinges on the strength of cross-domain transitions, rather than on individual tools. Effective workflows exhibit strong coupling between domains: multi-modal data and contextual insights inform mapping and modelling, mappings are progressively refined and linked to explicit design criteria aligned with the brief, and digital outputs directly structure spatial representations used in physical models. Instead, ineffective workflows accumulate accurate artefacts without cross-domain synthesis (e.g., digital models lacking atmospheric or material integration). Thus, the paper argues for process-explicit pedagogies that better scaffold hybrid workflows, supporting the translation from analysis to design while preserving exploratory and creative agency.*

Keywords. *Design education, Urban analysis, Design process, Context modelling workflow, Computational pedagogy, Digital fabrication.*

INTRODUCTION

Architectural education has widely integrated digital methods and fabrication laboratories (Celani, 2012). However, support for their use remains limited (Al-Rqaibat et al., 2025), particularly in early years and in context investigation, where traditional design pedagogy emphasises mapping, analysis, and conceptual strategies (Derya Yorgancioğlu et al., 2023) over digital modelling (Mohammed & Elbelkasy, 2016). In parallel, the increasing availability

of open geo-datasets, user-friendly modelling, simulation and visualisation tools has reshaped early design processes. For instance, context/site mapping and analysis now routinely incorporate digital layers that extend beyond observation, enabling students to interrogate demographic patterns, land use, mobility networks, spatial relationships, environmental conditions, and planning constraints (Urban Design Lab, 2025). As a result, early design processes are becoming data-rich and multi-modal,

characterised by iterative, non-linear workflows that combine different modes of analysis and production. However, while existing research has examined specific aspects of the design development process – e.g. parametric modelling workflows (Woodbury, 2010), digital vs analogue design (Oxman, 2006), and reflective practices (Schön, 1983) – these studies tend to isolate tools or phases. Little attention has been paid to the workflow structures that students implicitly develop when moving between context/site analysis, modelling, and early design reasoning. Building on research calling for more explicit pedagogical frameworks to support workflow development in architectural education (Al-Rqaibat et al., 2025), this paper examines how students structure multi-modal workflows and use them to inform deliberate design decisions grounded in data, analysis, and material knowledge. Specifically, it analyses a "context study" exercise that combined GIS mapping, 3D digital modelling, and model-making, supported by lab sessions on digital fabrication (laser cutting, 3D printing) and analogue techniques, involving 32 student groups in a Bachelor-level accredited design studio at a university in the European continent. The study synthesises into a single workflow model the different workflows applied by students while moving from mapping and analysis to the creation of digital and physical models for their neighbourhoods and sites, prior to developing their design proposals. It, then, uses students' reflections to identify choices which support or hinder "informed creativity" at the interface of analysis, modelling, and fabrication, including how these techniques helped them to engage with urban morphology and site-specific constraints for developing designs in-context. Finally, it extracts what can be learned, such as how, and under which conditions, modelling and making act as cognitive bridges between urban analysis and architectural design. The findings contribute new empirical evidence on the relationship between workflow logic and creativity in

architectural education and add to existing literature on embedding digital methods in architectural pedagogy (Vrouwe & Osinga, 2022) by showing how multi-modal workflows enhance design translation.

MATERIALS AND METHODS

The dataset comprises 32 context study portfolios (10–12 A3 pages each), produced by 169 students organised into groups of five to six, across seven design studios, each focused on a different neighbourhood of a medium sized city in Europe. Students were tasked with developing their context studies through a blend of mapping, GIS-based analysis, digital modelling, physical fabrication, and reflective evaluation, under the guidance of 7 design studio leads plus 8 design tutors. While contexts varied, all studios were: given the same brief, supported by common workshops, and offered year-level feedback, including a mid-term formative review. The goal was to generate context-relevant insights to support the development of appropriate design responses throughout their atelier projects. Context studies relied on a combination of GIS-data and other digital datasets together with first-hand information collected through in-situ analysis. They showed a progression from broad neighbourhood-scale investigation to detailed site-specific studies by operating across multiple scales: typically, 1:2500 or 1:1000 for the neighbourhood analysis, and 1:250 or 1:100 for the site(s).

The exercise brief contained minimum required deliverables and a suggested structure for the portfolio presentation, but it allowed freedom regarding the tools to be used throughout the context study (Stokes, 2006). It invited students to independently select and mix digital and analogue tools and methods (according to their needs and modelling objectives), requesting them to describe the workflow used by documenting and justifying their choices, as well as the rationale behind them, following a constructive alignment pedagogy (Biggs, 2014). To avoid students shying away from using

digital fabrication tools, it was a requirement that no less than 50% of students in each group completed the training to use laser cutting and 3D printing machines so they could operate these in the school's Digital Lab to produce a physical model of site plus immediate context, if they chose to.

The portfolios' outputs constitute rich, multi-modal primary data, combining sketches, collages, annotated diagrams, including experiential viewpoints in the style of Cullen (Cullen, 2012) and Lynch (Lynch, 1960), (GIS) maps produced at different scales, renders of digital models and photographs of physical models, and written reflections. These reflections are data rich in terms of skills students applied (or chose not to apply), activities and decisions they undertook, information they used, etc. during the production of their context study.

Research design

This research extracts lessons on how and under which conditions modelling and making act as cognitive bridges between urban analysis and architectural design through two complementary steps: (i) Synthesising recurrent processes across all portfolios into a single BPNM workflow model (capturing activities, decision gateways, loops, inputs and outputs); (ii) Analysing students' reflections, through directed qualitative content analysis, into four predefined domains to identify recurring issues and perceptions. Before any analysis, portfolios were anonymised and assigned unique codes (S[studio]–G[group]). While this study does not isolate tutor or site effects, these codes ethically preserve traceability to studio contexts in cross-case comparisons.

BPMN Workflow Analysis

To capture recurrent decision pathways across the 32 context studies this paper leverages an established process modelling methodology (compliant with ISO 19510) known as Business Process Model and Notation (BPMN 2.0). Although rarely applied as

analytic tool in design research, BPMN provides a robust vocabulary of tasks, gateways, events (e.g., start, end, catching and throwing), and connectors that help systematically map task sequencing and concurrency, decision gateways, data-linked tasks, as well as loops and process iterations. When applied to student work, BPMN diagrams can reveal how creative decisions are embedded within constrained sequences of data acquisition, analysis, modelling, making and fabrication. Workflows described by students in each of the portfolios fed the BPMN model, that was built using the cloud-based service *Signavio (SAP, 2025) to allow automated syntax checks and ensure BPMN modelling conventions are respected. Whenever workflow descriptions were incomplete, they were reconstructed by making interpretative inferences based on the images provided together with reflective statements.

Qualitative content analysis

Alongside the BPMN analysis, this study uses students' self-reported reflections as a second major source of insights. These reflections reveal decisions undertaken, information filtering (e.g., data and fabrication constraints), students' perceptions of methods' value, and design-relevant insights. They were treated as qualitative evidence and synthesised it into structured summaries under four pre specified domains: (i) Data acquisition and contextual grounding; (ii) Analytical mapping; (iii) Digital modelling and digital exploration/interrogation; (iv) Physical modelling and digital exploration/interrogation. These domains were defined based on the clusters of activities identified from the BPMN model. This directed qualitative content analysis (Hsieh & Shannon, 2005) was conducted manually and refined using a private NotebookLM workspace containing the 32 anonymised student portfolios. The notebook's retrieval/summary features were used only to surface candidate passages aligned with the four selected domains and to flag possible outliers. These excerpts were treated

strictly as prompts (not findings), and systematically verified against the original portfolio materials (text, diagrams, models, photographs), rejecting, correcting, or expanding inconsistent suggestions. Visual artefacts (maps, diagrams, model photos, screenshots) were also coded in a digital whiteboard (Miro) using colour matched tags for the four domains, enabling triangulation between textual claims and visual evidence. Researcher-verified extracts were then used to write the domain summaries and support simple descriptive counts of recurring practices or challenges; these quasi-statistics indicate pattern prevalence only and are not used for statistical inference or generalisation. In this study, cross-domain coupling was used as an indicator of quality, considering the extent to which information produced in one domain informed subsequent activities or decisions in another, based on portfolio evidence and students' reflections.

RESULTS

Workflow Analysis

The BPMN workflow (Figure 1) captures hidden decision gateways (scale selection, Level of Detail (LoD) adjustments, material choices, digital-analogue transitions) that strongly shaped lessons learned as well as loops and transitions that the brief does not explicitly anticipate. Despite variations in sequencing and emphasis, students' workflow indeed presents a recognisable overall structure which can be conceptualised as four interlinked clusters of activity (which were used as domains for the subsequent content analysis):

- Data acquisition and contextual grounding (**Cluster A**). Students sourced spatial datasets online (e.g., footprints, land use, terrain, demographic indicators) and enriched them with on site observations, photography, sketches, and experiential notes. This hybrid

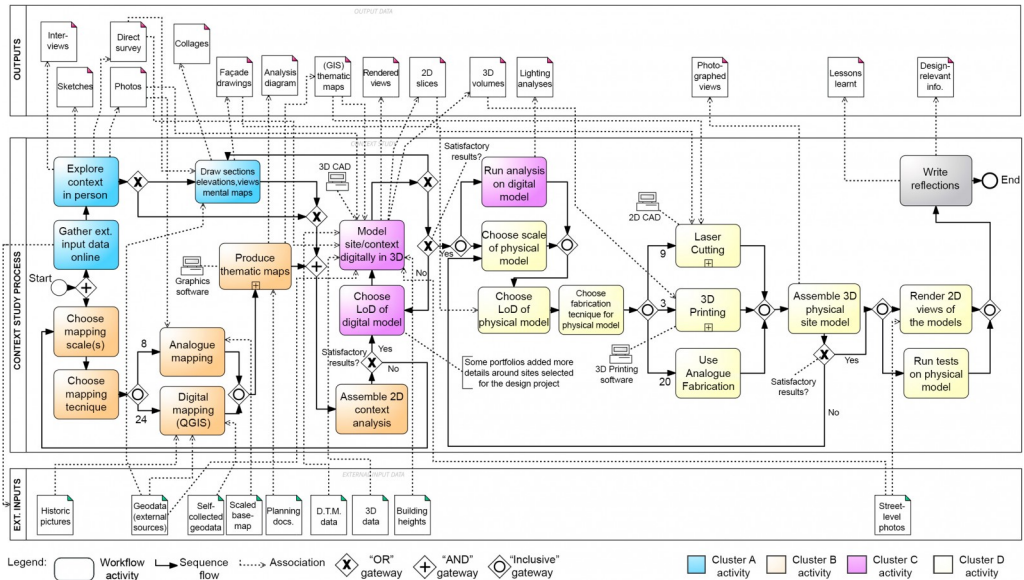


Figure 1
BPMN 2.0 workflow
diagram with
color-coded activity
clusters

approach provided both quantitative-spatial resolution and qualitative-situated nuance.

- Analytical mapping (**Cluster B**). Students produced layered mappings of infrastructure, morphology, amenities, transport and environmental conditions, mainly using GIS (24/32 portfolios).
- Digital modelling and digital exploration/interrogation (**Cluster C**). Students produced 3D digital models, deciding upon the geographic extent of these models, level of detail, texturing, etc. These models were then interrogated to produce different types of relevant digital explorations (e.g. sun path diagrams, overshadowing analysis, etc.)
- Physical modelling and physical exploration/interrogation (**Cluster D**). Physical modelling included both hand cut assemblies and digital fabrication workflows, with digitally fabricated models and components obtained through laser cutting and 3D printing. These models were then interrogated to produce different types of relevant physical explorations (e.g. material textures, overshadowing analysis in the lighting studio, etc.).

Examining decision pathways across these four activity clusters helps reveal the cognitive transitions students make as they move from data-driven problem framing to 2D spatial interpretation, volumetric reasoning through digital modelling, and finally to material-spatial reasoning in physical model construction. When paired with content analysis, the workflow helps identify where sequence breakdowns occur (e.g., "rich mapping but low translation"), plus support discovery of workflow topologies that correlate with deeper spatial reasoning.

Data acquisition and contextual grounding (A).

All groups grounded their analyses in a combination of digital datasets and field-based observations,

with most relying on QGIS and geospatial data (licensed or open-source) to compile layered spatial information (e.g., building age, use, and morphology). Many also drew on census data (e.g., age, ethnicity, housing tenure) to develop demographic user profiles (e.g., young professionals aged 25–29 etc.). Lynch's elements and Cullen's serial vision sketches provided detailing elements such as physical landmarks (railway bridge in S7-G4), architectural rhythms (sequence of vertical bay windows and terraced houses in S3-G6), contrasting scales (S7-G3), atmospheres (night-time impressions in S1-G5), public space vitality (S5-G4), visual attractors (street art in S2-G4) and individual memory and experience (S2-G1). Historical maps (1880–1970) were overlaid with contemporary data to trace morphological change, identifying shifts in land use and architectural typologies, including the loss of small green areas due to industrialisation pressures (S1-G5) and industry-driven housing developments (S2-G4). Some students experimented with gathering additional information from local households through interviews to develop a more holistic understanding of the neighbourhood. However, this effort was acknowledged as only partially successful due to its limited sample size (e.g., S6-G2). Throughout data acquisition, students frequently noted the limits of digital datasets - especially the absence of newly built structures in existing repositories - which required them to manually draw missing buildings (S4-G2) and correct roof heights (S4-G4) to verify massing. Students also used field measurements and photographic surveys to validate or enrich digital information, capturing the real-world dimensions and character of their sites, including the structure and materiality of surrounding buildings. A few groups encountered gaps in available data (such as incomplete social statistics in S2-G4 and missing information on historical uses or informal developments in S1-G5) and difficulties in locating relevant datasets (e.g., planning information in S5-G3), limiting their

ability to model or analyse their sites accurately. Others found that hand-drawing supported a deeper level of observation, which helped them consider the scale of site (S4-G4) and record the state of conservation of the urban fabric (S6-G1). Overall, students collected a wealth of quantitative and qualitative data. However, inconsistencies, gaps in data quality, and variations in interpretative depth meant that some contextual insights—such as Lynch- and Cullen-based observations—remained disconnected from later analytical mapping and modelling activities.

Analytical mapping (B).

The portfolios present inter-scalar mapping strategies, transitioning from urban-level overviews (showing city boundaries and neighbourhood location at 1:10000 scale) and neighbourhood-scale analysis (1:5000), to detailed site-level zoom-ins (1:500) providing site-specific accuracy. GIS platforms (QGIS) were widely used (24/32 portfolios) for city-scale overviews and to map the functional and morphological organisation of neighbourhoods by layering quantitative data extracted from geodatasets. Specifically, S3–G6 inferred movement patterns and pedestrian connectivity by mapping roads and paths, and identified uneven green-space distribution through land-use mapping. S1–G5 analysed spaces' temporal change by comparing maps produced at different moments in time, while S5–G3 assessed amenities' accessibility by mapping isochronic distances from points of interest to establish site constraints. Qualitative data from fieldwork, like on-site sketches, photography, and serial vision, was used to ground-truth these outputs or nuance site-level maps, providing them with atmospheric context and sensory detail (sound pollution in S5-G1, material information and sounds at closing times in S5-G2). S4-G1 specifically note that their site-analysis could have benefitted from a more in-depth exploration of buildings' character and social significance. Some groups perceived digital mapping as a time-efficient approach to urban

analysis (S1-G5) and generative of multiple design ideas, due to its ability to identify functional gaps, spatial relationships, and opportunities for design interventions (S2-G4, S3-G6). Other groups, however, argue that GIS-based mapping, though accurate and useful, had limited influence on design due to a lack of up-to-date and site-specific information. As some students noted, when mapping remained at a macro-scale, it became siloed and too detached from the site to offer contextual design intelligence. Although technically correct, these outputs were mainly descriptive rather than operational, providing little concrete guidance on access, site organisation, etc. Limited GIS proficiency further constrained outcomes: producing meaningful maps required substantial technical skill (S1-G4), and unclear visual communication hindered the interpretation of results (S1-G5).

Digital modelling and digital exploration/interrogation (C).

Digital modelling acted as a key intermediary between mapping and design, fostering the translation of 2D analytical outputs into 3D spatial understanding. In 11/32 portfolios, models were calibrated using GIS-derived footprints and topographic layers to establish accurate extents and building dimensions. Yet this passage was not always seamless as groups reported the need to manually correct GIS-derived geometry to retain "design-relevant truths" (e.g., by amending roof height data or adding missing new builds). Others encountered technical limitations: S6-G3 struggled with editing automatically generated terrain, while S6-G4 described extensive "cleanup" work after importing third-party meshes. Model extent and level of detail (LoD) emerged as key parameters for controlling model accuracy, scope, and workflow efficiency. Many groups prioritised high-resolution modelling of buildings immediately surrounding the site (capturing elements such as pitched roofs, chimneys, and façade details) and represented the broader urban context as

simplified massing blocks. This allowed scrutiny of adjacencies and supported more reliable solar and overshadowing simulations, informing early massing and fenestration decisions (e.g., S1-G3/4, S3-G3, S6-G4). Software choices further shaped outcomes. Some groups switched from Rhino or Blender to SketchUp to reduce time spent on modelling, despite control limitations, while others adopted hybrid workflows (e.g., S4-G4 combined Procreate and Photoshop) to overcome slow or unreliable rendering pipelines and communicate atmosphere, producing visualisations (e.g., night scenes, activity patterns) that raw 3D models cannot communicate. Overall, students appreciated digital models for being easily editable and easy to iterate with, making them effective for rapidly generating design variations, testing massing moves, and exploring environmental conditions. They also used eye-level views to approximate on-site perception remotely and superimpose design proposals into context, evaluating enclosure, visibility, and material palettes. However, where model construction absorbed excessive time (e.g., repairing datasets, rebuilding geometry, or learning software), models tended to remain basic and mostly (re)presentational, as effort was diverted away from design reasoning.

Physical modelling and physical exploration/interrogation (D).

'Making' played a central role in helping students transition from digital investigations to embodied spatial reasoning. Most groups adopted a scale of 1:200 or 1:250 for their physical models, noting that these scales enabled close engagement with building massing, street relationships, and spatial organisation. An exception was S7, which produced a 1:500 tiled model assembled across four groups - useful for coverage, but prone to alignment challenges. Some groups incorporated modular components (e.g., removable buildings or interchangeable plates) to test different design proposals within a shared context and used hierarchical material coding to differentiate

proposals or key elements from the broader urban fabric through colour and texture contrasts. Besides acting as working tools for iterative design negotiation, facilitating rapid testing of insertions and adjacencies, physical models were used in a lighting studio to explore lighting behaviour and assess shading conditions to calibrate massing envelopes and façade porosity. As such, physical models acted as active analytical instruments; intuitive, highly collaborative (S6-G3), and effective in real-time interactions with peers and tutors (S7-G4). Fabrication choices were shaped by material constraints, tool access and skill levels. While 3D printing was seen as offering higher precision when based on good source data, it was used only by 3 groups while 20 groups opted for manual methods or mixed media assemblies. 3D printing was, in fact, perceived as time consuming, hard-to-learn, prone to failure, and dependent on limited facility access, plus constraining creativity unless combined with hand-making (S1, G5). In contrast, laser cutting was more widely adopted (9 groups) for its speed and reliability in producing accurate topographies (sliced terrain, engraved footprints and outlines), despite issues such as burn marks, staining, and visible layering; material choices (e.g., mountboard thickness; wood vs acrylic) also affected models' legibility and overall appearance (S3-G6). Portfolios further documented material experimentation such as plaster-casting failures in S6-G; the use of organic materials (nails, coconut fibre for trees) in S4-G1; and sustainable material strategies (use of reclaimed plywood, MDF, and timber offcuts) in S2-G4. However, planning for making – albeit critical to model quality and fabrication processes – was generally weak, leading to reactive decision-making when technical failures or resource limitations occurred (e.g., S6-G1 abandoned a planned model and improvised mould supports, while S2-G1 realised mid-process the complexity of 3D printing). While making broadly acted as a cognitive bridge, fabrication inherently invited cross-domain links enabling more direct translations

between mapping, modelling, and physical representations. However, production errors, poor time management, and the absence of a clearly planned, integrated fabrication plan reduced the quality and utility of these models. When fabrication time was absorbed by logistics and troubleshooting (e.g., repairing prints, cleaning laser artefacts, re-making components) the analytical value of physical models was reduced, limiting design integration and the feedback loop to digital work.

Cross domain workflow dynamics

The BPMN workflow (Figure 1) frames the four activity clusters (A-D) as interdependent stages of an integrated process that students navigate through recursive reasoning (via decision gateways, loops, and iterations). In principle, each cluster establishes conditions for the next: data acquisition informs mapping; mapping defines modelling requirements; digital modelling prepares the ground for physical model testing; with insights collected at each stage feeding back and forward analytical stages. While these dependencies are represented in the workflow, cross-domain couplings were rare in practice. Across the 32 analysed cases, most groups treated intra-cluster activities as discrete and self contained, resulting in weak or inconsistent transitions across domains. Gaps at the data acquisition stage (A) - such as incomplete datasets, limited ground-truthing – reduced the operational value of digital mapping (B). When mapping remained at neighbourhood-scale, outputs were under-interpreted, while, when visual communication skills were limited, outputs stayed descriptive and offered little guidance for modelling. When data repair, software learning, or geometry cleanup absorbed substantial time in digital modelling (C), this diverted attention away from incorporating atmospheric qualities and supporting design exploration beyond morphology, weakening the link with domain B. In turn, physical modelling (D) was frequently constrained by limited model-production planning, reducing the model's role as an analytical instrument. In contrast, the

most effective workflows exhibited strong coupling between domains: data from A was translated into actionable mappings in B and these, in turn, informed model extents, LoD decisions, and spatial interrogations in C; while digital outputs directly shaped physical model construction and testing in D. These workflows tended to generate not only accurate outputs but also design-relevant criteria (such as solar access requirements, movement patterns, or adjacency constraints) that travelled across domains to form a layered spatial understanding. Thus, the analysis confirms that synthesis, as opposed to data accumulation, is the primary driver of informed creativity in early-stage design. Where such connections were absent, students likely required stronger scaffolding (Wood et al., 1976) to translate context study outputs into operational design drivers. Design tutor mediation was also frequently cited as important in guiding the context study development process, by aligning analytical efforts with emerging design intentions, fostering technology adoption and disciplinary crossovers. Cross-domain transitions were also mediated by data/tools interoperability and material considerations. Data incompatibilities, software constraints, or time-intensive processes sometimes prevented students from completing planned workflow transitions (e.g., some groups with strong GIS and digital modelling skills decided not to go ahead with digitally fabricating their models). At the same time, material practices—particularly those in domains A and D—introduced distinct ways of knowing, confirming that design reasoning develops through the interaction between computational procedures and embodied, hands on experimentation that occurs in drawing, making, and physical model testing (Ingold, 2013). In S7-G3, physical models revealed overshadowing effects that contradicted digital simulations, prompting students to revisit and reinterpret earlier analytical outputs, while revealing massing relationships not evident in virtual environments. Some groups also reported that manual sketching, on-site

observation, hand-making, and embodied model testing enhanced learning of context, refocusing attention on detail (Sennett, 2009), as opposed to digital methods. These observations raise an important pedagogical question: to what extent do data-intensive workflows or highly detailed models risk overshadowing other forms of contextual inquiry by absorbing disproportionate time and attention? And how can design education scaffold workflow transitions so that digital and physical tools act as catalysts (not obstacles) for the creative, critical, and contextual thinking required for design-in-context?

CONCLUSIONS

As architectural education integrates an expanding ecosystem of analytical, modelling, making and fabrication tools, students increasingly face the challenge of synthesising multi modal insights into coherent design intelligence. This study shows that workflow effectiveness depends less on individual tools than on the quality of transitions between clusters of activity. Effective workflows were characterised by tighter feedback loops—mapping verifying modelling, modelling informing fabrication, fabrication prompting reinterpretation of data—yet such integration was rare, suggesting gaps in scaffolding. In the analysed context studies, workflows were strongly shaped by how students collected, assembled, verified, and interpreted digital and field based data. Deficiencies at this stage often propagated across domains, limiting contextual understanding and weakening design translation. Conversely, when data was critically interpreted, mapped across scales, and validated through on site engagement, students were better able to define design relevant criteria (e.g., user needs, accessibility, environmental constraints) and use them to ground modelling and making into experience, expressing the atmospheric qualities of place. Design translation was also achieved when mapping scales were progressively reduced from neighbourhood to site and digital mapping layers were linked to design criteria (e.g.,

provide accessible green space). Digital modelling functioned both as a design development tool (making morphology more understandable and clarifying the requirements for solar access, acoustic buffering and privacy provision) and as a form of data curation, where LoD choices, data repair, and software constraints shaped what could be seen, explored or argued. Physical modelling, in turn, acted as a cognitive bridge between digital readings and embodied spatial reasoning, supporting iterative testing, environmental evaluation, and design negotiation. Its scale, modularity, material strategies, and fabrication processes directly influenced what could be learned, confirming the role of model-making as a practice where technical experimentation, craft knowledge, and design reasoning intersect (Kolarevic, 2004). While the transferability of these findings depends on contextual factors such as cultural setting, curriculum structure, and students' prior skill levels, the results highlight the value of hybrid, multi-modal workflows for producing situated architectural knowledge. The BPMN workflow developed in this study serves both as a descriptive map of student practice—surfacing cognitive operations often left implicit—and as a diagnostic tool to support workflow literacy. Addressing the identified gaps calls for process explicit design pedagogies, aligned with ongoing experiments in the field (Choto & Ramadan, 2026; Passe, 2020) that better integrate analytical and design stages. This may involve workflow frameworks that balance traditional and digital practices, ensuring slower, observational and interpretative modes of inquiry are not obscured by data heavy pipelines but instead find their place to inform design (e.g., by enriching and specifying digital and physical models), while enabling the selective integration of advanced analytical tools (e.g., network analysis, environmental simulations) where appropriate. This raises an open pedagogical question: How much should we constrain students, and what kinds of boundaries are necessary for certain analytical–design translations

to occur? Too little structure risks fragmentary, descriptive outputs siloed by medium, whereas too much structure risks limiting the exploratory, interpretative, and creative dimensions of design in context. The challenge lies in defining boundaries (e.g., scaffolds that sequence tasks and clear expectations, highlighting interdependencies across media) while preserving space for experimentation, failure, and workflow appropriation.

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