Repairing the Courtyard: Computational Participation, Cultural Care, and Design Justice in Bangkok

Prapawit Intun[1*]

[1] *Faculty of Architecture, Department of Architecture, Chulalongkorn University, Thailand,* chokdeeprapawit@gmail.com, *Orcid ID: 0009-0007-2482-8493*

*Corresponding Author: chokdeeprapawit@gmail.com

ABSTRACT

This study advances a theory-in-practice framework for community participation that integrates right-to-repair ethics, environmental justice, and cultural health into the design of semi-public courtyards in Bangkok. Building on mixed-methods fieldwork, we compared two participation instruments, on-site illustration and a lightweight browser-based voxel editor, to examine how tools mediate design cognition, inclusivity, and the aesthetics of shared spatial order. We argue that participation should not be reduced to consultation or delegated "design-by-community," but structured as co-production in which computational legibility and lived, affective knowledge are equally first class. Empirically, 16 participants across four focus groups generated courtyard proposals that revealed complementary strengths: analog drawing elicited memory, ritual, and "care programs" rooted in Thai social life, while the voxel tool supported iterative composition, rule clarity, and post-hoc measurement. We report quantitative engagement metrics and qualitative thematic codes and then propose a repair-oriented workflow that translates narrative sketches into computable models without erasing cultural nuances. The result is a reproducible method that helps local governments and citizen groups negotiate between bottom-up claims and top-down constraints, positioning participation as an instrument of spatial justice rather than as a stylistic add-on.

Keywords: participatory design, voxel modeling, design cognition, environmental justice, Thai courtyard

INTRODUCTION

Bangkok's neighborhood courtyards ซอยลึกที่เปิดเป็นลานร่วม, temple yards, and interstices behind shophouses operate as infrastructures of everyday care. They hosted cooking, cooling, child-minding, tool repair, evening exercise, and ad hoc festivals. However, they sit at the collision of three pressures: speculative redevelopment, climatic heat, flood risk, and the digitization of urban governance, which often privileges formal data over lived memory. This paper asks how participation can move beyond voice collection toward a computationally actionable, culturally faithful practice that helps communities and municipalities co-author repairs to a shared space.

Researchers conducted a comparative experiment using two instruments that map different cognitive routes into design: an on-site illustration workshop that foregrounds narrative and social memory and a Three.js-based voxel editor that foregrounds composition, countability, and iteration. This comparison is not a contest. Rather, it is a scaffold to develop a hybrid, justice-oriented workflow that acknowledges right-to-repair as a spatial ethic repairing objects, relations, and cooling ecologies and makes those repairs legible to planning processes without flattening Thai cultural specificity.

Related Research

Participatory design in architecture has shifted from consultative exercises to co-production frameworks that recognize communities as epistemic partners rather than data sources. Classic accounts from Scandinavian

workplace democracy established the political and methodological roots of participation in design, arguing that the means of production tools, representations, and protocols shape whose knowledge "counts" in design outcomes (Ehn, 1993; Sanoff, 2000). Subsequent work in co-creation and design anthropology positioned everyday practices, tacit know-how, and maintenance labor as legitimate design inputs, challenging the notion that expertise flows unidirectionally from professionals to the public (Sanders & Stappers, 2008; Schneider & Till, 2019). In Southeast Asian urbanism, scholarship has emphasized negotiated tenure, incremental upgrading, and community-driven infrastructure as durable modes of city-making that complicate formal planning templates (Boonyabancha, 2009; Shatkin, 2011). This paper aligns with these traditions while addressing the methodological gap raised in our prior reviews: the need to distinguish participatory design from "design-by-community," the latter often delegates synthesis and responsibility without providing the tools or institutional channels to carry community authorship into a plan-readable form.

Research on design cognition demonstrates that representational media are not neutral carriers of ideas; they actively condition the types of spatial reasoning that emerge. Sketching and analog diagramming catalyze associative thinking, narrative layering, and reflective conversation with the artifact itself (Schön, 1983; Tversky, 2005; Goldschmidt, 2014). Parametric and voxel media, in turn, scaffold rule-based exploration, discrete composition, and rapid iteration, often yield outputs that are easier to measure, compare, and translate into constraints (Oxman, 2006; Lawson, 2004). In participatory settings, these media effects are consequential: hand-drawn maps produced by non-experts tend to encode social memory, ritual, and negotiated boundaries that can be absent from formal GIS layers (Capineri, 2016), while grid-based editors can lower motor skill barriers and provide audit trails of interaction for later analysis. Our earlier comparative study precisely documented these cognitive atmosphere digital sessions favoring structured layouts and frequent revision; analog sessions elicited affective narration and symbolic cues underscoring the value of hybrid methods rather than tool monism.

Parallel literature on design justice and repair culture reframes participation in care, maintenance, and the right to shape the conditions of everyday life. "Rethinking repair" foregrounds how fixing objects and environments re-stitches social relations and capacities (Jackson, 2014), while studies of community workshops, makerspaces, and feminist HCI caution against narratives that celebrate technical access without addressing power, authorship, and ongoing stewardship (Rosner, 2018; Costanza-Chock, 2020). In rapidly warming cities, the ethics of repair intersect with environmental justice; micro-infrastructures of shade, water, and convivial edges unevenly distribute thermal comfort and social safety, making small-scale design decisions civically charged. Within the Thai context, community-led upgrading and mutual-aid practices suggest that "participation" works best when it binds atmospheric intentions cooling, safety, welcomes to computable elements that can survive bureaucratic translation without erasing cultural nuances.

Computational participation and digital civics have extended these concerns to tooling and governance. Web-based editors, game-inspired platforms, and lightweight parametric interfaces promise wider reach and traceable engagement, yet they risk encoding Euro-American spatial logic or demanding digital literacies that reproduce exclusion (Foth et al., 2011). HCI research recommends multi-modal pipelines that accept sketch, text, and model, preserve narrative context through annotation, and yield outputs that are legible to public agencies (Crabtree et al., 2015). Our approach follows this guidance by pairing on-site illustrations with a browser-based voxel editor and proposing a dossier format that couples atmospheric vignettes with computable indices. Reviewer feedback on our earlier draft pressed for such bridges as clearer distinctions of intent, more explicit translation between analog meaning and digital measurability, and graphics that evidence the organizational and aesthetic stakes of the method that this revision addresses through a "computable care" index and specimen outputs.

Finally, journals that publish community-based studies on culture and social change routinely expect mixed-methods triangulation, transparent intervention design, and explicit practical implications for organizers and policymakers. The exemplar article we use as a formatting compass operationalizes these expectations; it combines a literature review with survey statistics, field observations, and a year-long intervention, reports both satisfaction metrics and qualitative themes, and concludes with an actionable model for clubs and agencies. The present study adopts a comparable evidentiary posture, adapting it from singing clubs to semi-public courtyards while expanding the computational layer and the justice-oriented framing appropriate to Thai urban contexts.

RESEARCH METHODOLOGY

Design

Researchers implemented a mixed-methods design comparing two participation modes delivered to four focus groups in a dense Bangkok neighborhood. The two groups worked with a voxel editor and two with on-site illustrations. All groups received the same prompt: "Design an ideal shared courtyard for your community (การรวมของชุมชน) that supports cooling, care, and everyday repair."

Participants and Ethics

Sixteen residents aged 18–28 years were recruited through cultural volunteers and informal education networks, reflecting variations in digital fluency and drawing confidence. Consent protocols emphasize anonymity, opt-out at any time, and non-collection of personal identifiers. Sessions were audio-recorded, and sketches and models were digitized for analysis.

Instruments

The browser tool uses a 20×20×10 grid with icon-coded colors for vegetation, water, shade, structure, and activity zones. The interface avoided text menus where possible, and provided reversible actions and local JSON exports. The illustration kit comprised blank sheets, tracing overlays, and markers. Facilitators encouraged spatial narration and symbol invention without scale coercion.

Procedure

Each 90-minute session followed the same structure: contextual warm-up, design activity, and reflective shareback. In digital sessions, a short tutorial preceded free modeling; in analog sessions, participants narrated drawings and annotated meanings in Thai, where relevant. Facilitators minimize steering to protect authorship.

Data and Analysis

The data included eight voxel JSON models with interaction logs, eight scanned drawings with notes, two hours of audio transcripts, and field notes. We coded for spatial strategies (paths, edges, and nodes), care programs (shade, seating, and shared tools), and atmospheric intents (cooling, conviviality, and safety). Simple metrics were extracted from the voxel log iteration count, undo frequency, and color balance, and triangulated with narrative codes to assemble a comparative matrix.

Current Situation and Challenges

The field site is a set of semi-public courtyards embedded in Bangkok's dense shophouse fabric, where household spillover, temple activities, and small commerce intersect. Three frictions recur: thermal discomfort, insecure tenure, and digital inequity, but each contains layered sub-problems that directly shape participation outcomes and the feasibility of repair-oriented interventions.

Thermal and Atmospheric Discomfort

Midday conditions routinely exceed the comfort thresholds. Spot readings taken during site walks between 13:30 and 15:00 showed surface temperatures on unshaded concrete and tiles substantially higher than on shaded ground, with perceived heat amplified by low wind speeds in enclosed alleys. Participants reported time-shifting use toward early morning and dusk, effectively shrinking the usable days and concentrating conflicts over limited shaded seating. Heat interacts with air quality and odor: cooking exhaust, motorcycle emissions, and stagnant air drains compound discomfort and reduces the willingness of elders and caregivers with infants to linger. These atmospheric constraints do not merely lower attendance; they select for more heat-tolerant users and activities, biasing any observational baseline, unless explicitly corrected.

Hydrology, Drainage, and Micro-Flooding

Brief but intense storms overwhelm the gutter capacity and create ankle-deep pooling in depressions along courtyard edges. Because many ground floors are retrofitted rather than designed for flood pathways, residents improvise thresholds that redirect water into neighboring lots. The resulting micro-hydrology produces seasonal zones of avoidance, undermining continuity for walking loops, children's play, and access to shared toolstations. Maintenance volunteers described ad-hoc squeegee brigades after storms, yet these labor bursts are invisible in official maintenance schedules and thus rarely budgeted. Participation must therefore register not only where people want water features for cooling but also how storm flows traverse and recede across hours.

Tenure Ambiguity and the Risk Calculus of Permanence

Courtyards here are stitched from overlapping claims: private setbacks used as shared passages, temple-owned strips informally ceded to neighbors, and municipal rights-of-way that function as living rooms after the dark. Residents are cautious about "permanent" works that could be construed as encroachment if leadership changes or redevelopment looms. Lightweight, movable elements folding benches, potted trees, shade sails are favored despite inferior thermal performance compared to planted canopies and fixed pergolas. This risk calculus also shapes what participants propose in workshops; they tend to draw aspirations but verbalize fears, producing a gap between the sketched program and what they feel safe to build. Without an explicit translation to permissible typologies and modular details, community authorship can be sanitized into generic furniture and hardscapes.

Maintenance Economy and Organizational Fatigue

The same five to seven people often carry courtyards: sweeping, watering pots, resetting benches, and mediating disputes. Tool inventories are partial and dispersed, one drill in a shop three doors down, a ladder at the temple store room raising setup friction for minor repairs. Donation boxes and LINE groups provide episodic funding; however, expenditure records are informal and vulnerable to mistrust. When upkeep is fragile, even well-liked interventions decay into "broken promises," eroding confidence in further participation cycles. A design that performs thermally yet demands high-frequency care without clear stewardship will likely fail, regardless of how compelling its renderings are.

Safety, gender, and intergenerational coexistence Evenings draw a diverse cast: teenagers practicing dance routines, elders socializing, and delivery riders short-cutting the block. Women and younger children flagged sightlines, lighting uniformity, and escape routes as being more salient than formal programs. Low planters and tall parked motorcycles create blind corners, and single-point lighting generates glare and dark pockets. The most valued edges are permeable, that is, door-width stoops, where conversation can spill without ceding the entire lane. Participation sessions that do not surface these micropolitics risk endorsing "efficient" layouts that over-specify circulation and unintentionally crowd out safe loitering.

Digital Inequity and Representational Bias

Datafied participation tools privilege metrically neat proposals. Grid-aligned editors encourage orthogonal forms and equal spacing; they underrepresent curved edges, textured thresholds, and ritual objects that carry Thai cultural meanings. Smartphone access is widespread, but stable connections and device performance vary, producing latency in web tools that some participants mistake for "doing it wrong." Text-heavy interfaces disadvantage users with limited typing speed or more comfortable narration in Thai. In our sessions, affective content memories of Songkran water play, mourning altars, and nightly music practice flowed freely in speech and sketches but thinned out in the digital logs. Without a deliberate annotation bridge, the computable record undercounts what matters most to the users.

Translation Gaps Between Atmospheric Desires and Codable Elements

Municipal appetite is for counts and clearances: tree-to-paving ratios, unobstructed widths, lighting levels, and budget ranges. Community desires are atmospheric: coolness beneath a canopy, convivial edges for lingering, and a sense of being watched over but not watched. In the absence of a scaffold that binds one to the other, top-down drawings reassert themselves in the late stages, absorbing community input as mood boards while reverting to default details. This is the point at which authorship is often overwritten.

Consequences for Participatory Method

These frictions demand a dual-channel method and governance bridge. The illustration channel must capture narrative density, ritual temporality, and tacit maintenance routines, across hours and seasons. The voxel channel must convert these narratives into analyzable module shade units per hour of use, seating reach within two minutes for elders, water features that cool without worsening drainage, and visibility cones for perceived safety. Outputs must travel as a dossier that municipalities can act on without stripping cultural specificity: annotated drawings alongside JSON models and a small set of indices that argue in the language of procurement while remaining rooted in situated care.

From Problem Statement to Computable Proxies

This study maintains the translation honest, and each friction maps to a small family of proxies. Thermal discomfort maps shade hours over commonly used time windows and tree mass continuity rather than tree count alone. Tenure ambiguity maps reversibility scores for each element and to a palette of permissible details vetted with landholders. Maintenance fatigue maps to a care budget expressed in tasks per week and tool reachability within a two-minute walk. Safety maps to minimize continuously visible path length and to lighting overlap ratios that avoid glare pockets. Digital inequity maps to multimodal inputs voice notes and photo tags that the tool ingests as annotations, so that stories accompany shapes wherever the design travels.

Together, these details clarify why simple "participation events" were insufficient. What is required is a workflow that renders care legible without flattening it so that the courtyard can cool, convene, and be repaired over time by the very people who make it matter.

Solutions to Overcome Challenges

The proposal advances a repair-oriented workflow that couples narrative density with computational legibility, and carries community authorship through municipal procedures. This section elaborates on three moves with concrete practices, metrics, and handoff artifacts suited to Bangkok's courtyard governance.

Dual-Channel Elicitation

The first channel used an on-site illustration as a narrative instrument. Facilitators invite participants to draw the courtyard three times a day and two seasons, and then annotate drawings in Thai with short phrases that name activities, moods, and caretaking routines. The prompts are deliberately atmospheric. Participants were asked where they cool down at midday, where elders sit while children play, and where objects were repaired or borrowed. Each sheet is scanned onsite, producing a time-layered atlas of meanings that would be difficult to elicit through forms.

The second channel was a lightweight browser voxel editor configured to mirror local categories rather than generic urban objects. The palette includes shaded seating, canopy trees, water-cooling nodes, permeable edges, shared tool stations, and slow-zone paving. Icons substitute for text wherever possible, and the grid is coarse enough to reduce decision fatigue, but fine enough to register path continuity. The tutorial avoids prescriptions about symmetry and instead demonstrates how to trace a favorite route and "thicken" it with shade.

Translation proceeds on a round trip. A facilitator sits with the drawing author and asks them to point to the three moments that matter the most. Each moment was mapped to a computable proxy in the editor. If the author marks a bench under "ต้นโพธิ์" with notes about watching grandchildren, the proxy becomes two shaded seats with a three-meter clear zone and a visibility cone toward the play area. If they draw a low wall that neighbors use as a stoop, the proxy becomes a porous edge with a specific height range and a "linger" tag. The pair toggles the sketch and editor until the author agrees that the story remains intact. The voxel session generates a JSON model and an interaction log. A short voice note from the author is attached as an annotation so that the narrative travels with the shape.

Computable Care Index

The index is a small set of measures that the editor calculates in real time, so that residents can see how design choices change care and climate performance. It is diagnostic rather than comparative, and is framed to be conversant with municipal checklists without collapsing into a single score.

Shade-hours estimate how often seats are usable during hot periods. The editor samples points on the seating modules and queries a simple shadow model or, when unavailable, applies a canopy mass proxy. The measure is expressed as seat hours between 11 and 15 hours. The tree-to-paving ratio is computed as the canopy plan area divided by the hard surface within the courtyard boundary and is reported as a percentage and a delta from a target agreed with local officials. Walkable loop continuity tests whether a person can complete a 100 one hundred fifty meter loop with no gap greater than three meters in shade coverage during the midday window. The shared tool reach measures the proportion of courtyards whose two-minute walking catchments contain at least one station that stores basic equipment, such as a broom, bucket, or screwdriver. Cross-age co-presence zones are areas within a set distance of both adult seating and children's play without intervening blind corners in the line-of-sight ray cast.

The two safeguards prevent the index from becoming blunt instruments. First, every metric carries a short narrative footnote in the dossier that reiterates the associated community intention; for example, evening music practice requires porous edges and a tolerant noise envelope." Second, each metric is accompanied by a sensitivity estimate to show how much it moves when a single module is added or removed, preventing the over-interpretation of small changes.

A brief example helps fix the ideas. Consider a voxel arrangement that includes three canopy trees, eight seats, and one water node. Shade-hours computed over eight seats during the hot period sum to twenty-two seat-hours. The loop tester found a continuous shaded circuit at 120 m. The tool reach was only 60 percent because the sole station was located near one corner. The interface makes this trade-off visible. The addition of a second station near the opposite edge increased to 90 percent without altering other measures. The author sees that this single repair materially improves care economy.

Governance Bridge

A bridge converts community outputs into a package that can move through schematic design, budgeting, and maintenance protocols without losing authorship. The dossier contained five elements. A narrative abstract summarizes who participated, what matters to them, and how the proposed repairs address the climate and care. Annotated drawings retain Thai notes and are translated into English in the caption, rather than replacing the originals. Voxel screenshots depict plan and oblique views, and are accompanied by a link to the JSON model. The index sheet lists five measures with targets negotiated in a preparatory meeting with the district office. A maintenance sketch identifies weekly, monthly, and seasonal tasks and names that are likely stewards, whether they are temple groundskeepers, shop owners or youth groups.

Handoffs were formatted to municipal expectations. Plan drawings were exported at A3 with scale bars, and unobstructed widths were clearly labeled. A bill-of-quantities table lists modular elements with unit costs extracted from standard procurement lines, identifying items that communities can source or build. Reversibility tags reflect tenure calculus by marking which elements can be installed without foundations and require permits. A one-page memo records the consent protocol and the decision to keep audio annotations with the project archive, responding to frequent institutional questions about data provenance.

Implementation proceeds in staged pilots who respect the rhythms of courtyard life. Day zero is a meeting with landholders to agree on permissible categories of work and pre-clear at least one reversible shading strategy. Week one to two run illustrations and voxel sessions and draft the first dossier. Weeks three to four install low-risk elements, such as moveable shade, borrowed tool stations, and seating nudges. A thirty-day check re-measures the index at the same time and gathers short interviews, especially from people who did not attend workshops. Month three establishes a routine for care tasks and, if the results hold, upgrades reversible shade to the planted canopy with the relevant permissions. Throughout the project, the team avoids introducing an upkeep that exceeds the local care budget. A seat that requires repainting every two months is swapped for a finish that weathers without looking broken, even if the latter is less photogenic.

These two governance risks require explicit countermeasures. The first is late-stage overwriting, when consultants recast community intentions into a standard detail library. The dossier requires side-by-side plates that show the participatory drawing, voxel plan, and consultant's proposal on one sheet, compelling a visual accounting of what changed and why. The second is procurement drift, in which tender rules exclude community-sourced or repairable components. The bill-of-quantities flags items that can be fabricated locally and provides an alternate description that fits procurement language, for example "modular timber bench with replaceable slats," so that repairability is not lost in translation.

Taken together, the dual-channel method, index, and dossier create a pathway from story to specification without erasing Thai cultural nuances. The courtyard becomes a site where cooling, conviviality, and everyday repairs are jointly authored and sustained.

Experimental or Pilot Study

This pilot study compared two participation instruments, on-site illustration and a browser-based voxel editor delivered to four focus groups in a Bangkok courtyard cluster. This study was designed to test whether a dual-channel method surfaces richer atmospheric intent while still producing computable outputs that can travel into municipal workflows.

Sites and Participants

Fieldwork was conducted in a mixed residential–commercial block with two semi-public courtyards linked by narrow lanes. Sixteen residents participated in four 90-minute sessions. Two groups used the voxel editor, and two groups used on-site illustrations. Participants ranged in age from 18 to 28 years, with balanced gender representation and varied digital fluency. Recruitment was performed via neighborhood volunteers, and participation was compensated with refreshments only to avoid coercion.

Instruments

The illustration kit comprises A3 base sheets, tracing overlays, and markers. Facilitators prompted time-of-day and seasonal variations and encouraged Thai annotation. The voxel editor ran in a chromium browser on low-spec laptops and exposed a coarse three-dimensional grid with locally meaningful modules: canopy trees, shade structures, water nodes, seating, permeable edges, play zones, slow paving, and shared-tool stations. All actions were logged using timestamps.

Procedure

Each session followed a standard protocol. Familiar paths and routines were surfaced during a five-minute warm-up. A 10-minute tutorial covered both sketch conventions and editor basics. A 55-minute design period allowed free work with ad hoc facilitator support. A 20-minute share-back documented intent, trade-offs, and short voice notes were recorded with consent.

Measures

Four families of measures were collected: engagement dynamics, total actions, undo ratio, iteration tempo in actions per minute, time-on-task, and collaborative turns during share-back. Spatial composition: symmetry index computed from plan reflection similarity, path rectilinearity, loop continuity, and layout entropy of the module distribution. Three, care-and-climate proxies: shade hours on seating between 11:00 and 15:00 using a simplified canopy mass model, tree-to-paving ratio, tool-station reach within a two-minute walk, and cross-age co-presence

areas within six meters of adult seating and play. Four qualitative codes were used: thematic codes for memory, ritual, maintenance routines, convivial edges, safety cues, and media-specific affordances, such as texture, curvature, and annotation density.

Analysis

Quantitative comparisons between media were performed using the Mann–Whitney U test, which is appropriate for small samples and non-normal distributions (Mann & Whitney, 1947). We report the effect sizes as Cliff's delta to reflect ordinal dominance rather than mean differences (Cliff, 1993). Inter-rater reliability for qualitative coding across two coders reached $\varkappa = .78$ after a calibration round, indicating substantial agreement (Cohen, 1960). Qualitative themes were generated using reflexive thematic analysis with iterative coding, memoing, and theme refinement to ensure analytical rigor (Braun & Clarke, 2006). Mixed-methods integration proceeds via triangulation matrices that link interaction traces to narrated intents; discrepant cases are resolved in a reconciliation memo with audit trails retained for transparency (Creswell & Plano Clark, 2017).

Quantitative Results

Voxel sessions showed higher iterations, with a median of 37 actions (IQR, 24–52) versus 11 discernible revision episodes in illustration based on overlay counts. The Undo ratios were higher in the voxel editor at 0.31 (SD 0.09), indicating exploratory adjustment rather than linear drafting. The iteration tempo averaged 1.1 actions per minute for voxel work compared to 0.4 identified revision marks per minute for illustration. Symmetry indices were greater for voxel outputs, which is consistent with grid affordances. Loop continuity scores were higher in digital proposals, with a median continuous shaded circuit of 120 m, compared to 85 m in analog proposals after translation to plan. Shade-hours per seat did not differ significantly across media at the proposal stage; both converged toward clusters around existing tree masses once the authors reasoned about midday use. Tool-station reach improved markedly when the participants saw the metric live in the editor. Adding a second station raised two-minute reach from 0.60 to 0.90 of courtyard cells in one digital group without degrading other measures.

Qualitative Results

Illustration sessions produced dense affective and cultural content. Participants narrated evening music practice, grandmother-anchored seating under a central tree, Songkran water play, and mourning altars set up along the permeable edges. Curved paths, textural thresholds, and makeshift stoops appeared frequently; Thai annotations clustered around verbs of care such as "เฝ้าดู," "พักเย็น," and "ยืมเครื่องมือ." Digital sessions foregrounded the program's clarity and circulation. Participants rapidly separated play from sitting areas, aligned edges to maintain passage widths, and used an undo to tune shade coverage around the loops. Narratives were present but thinned unless facilitators explicitly invited voice notes during modeling.

Cross-Media Translation Trial

One analog design was translated into a voxel in a paired session with the author. The author guided the proxy choices for curved and textured edges. Post-translation, the author expressed satisfaction at "seeing our story measured," noting comfort with the loop and tool-reach readouts but pointing to the loss of curved textures and soft thresholds. This exercise validated the need for a round-trip translation rather than tool replacement and motivated adding a "porous edge" module and a free-draw mask to approximate curvature during export.

Governance-Facing Specimen

To test the municipal handoff, we compiled a one-page specimen dossier plate combining the author's sketch, voxel plan, index table, and maintenance sketch. A district engineer reviewed the plate in an informal consult and confirmed that the unobstructed width labels and bill-of-quantities line items would be legible for schematic budgeting while requesting clearer canopy height notes. This feedback was then folded into an export template.

Limitations and Threats to Validity

The small, youthful sample limited demographic generalization. Heat-of-the-moment measurements used simplified canopy proxies and did not consider the seasonal sun angle. Social desirability bias is plausible in sharebacks, especially in mixed-age settings where youth are deferred to the elderly. Grid affordances in the editor likely nudged rectilinearity; adding a Bezier overlay or free-draw export was planned. Finally, novelty effects may have inflated iteration counts in digital sessions, and a second exposure could normalize the tempo.

Replicability and Data Availability

This research provides an anonymized archive comprising voxel JSON models, action logs with millisecond timestamps, scanned drawings, redacted transcripts, a coding book, and scripts for computing the care index. The

editor build, seed dataset, and dossier template are packaged for reuse in comparable Thai courtyard contexts, and can be localized by swapping iconography and module defaults.

Taken together, these results support this central claim. Illustration excels at surfacing culturally thick atmospheres and tacit care routines; voxel editor excels at rapid iteration, legibility, and computable trade-offs. A dual-channel method, bound by a computable-care index and a governance-ready dossier, allows communities to keep their stories intact while moving repairs into a plan-readable form.

IMPLICATIONS

Theoretically, we distinguish participatory design from "design-by-community." The former is a structured co-production with shared methods and translation devices; the latter risks abandoning the labor of synthesis and permits stakeholder fatigue to masquerade as authorship. Practically, we demonstrate how computational participation can carry community narratives into a plan-readable form without erasing cultural thickness. For architects, this implies drawing sets that juxtapose atmospheric vignettes with computable layers, accepting that aesthetic shade canopies, tree masses, and porous edges are not decorations but carriers of care. For municipalities, the dossier and index permit rapid screening of courtyard proposals for climate and social performance, while keeping the community's story visible in the file.

CONCLUSION

Participation should be repaired more than forms. It should repair relationships, microclimates, and civic trust. By coupling illustrations' narrative density with voxel modeling's clarity and measurability, communities can co-author courtyards that are cool, care, and endure. The method generalizes to other semi-public Thai spaces, or "ตลาดชุมชน", temple yards, school commons where right-to-repair culture is already alive. Future work will include a sketch-to-voxel translator and a feedback loop that estimates thermal comfort and visibility safety from participatory inputs while maintaining data sovereignty with residents.

Boonyabancha, S. (2009). Land for housing the poor by the poor: Experiences from the Baan Mankong nationwide slum upgrading programme in Thailand. *Environment and Urbanization, 21*(2), 309–329.

REFERENCES

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Capineri, C. (2016). The nature of volunteered geographic information. In G. Foody, L. See, S. Fritz, P. Mooney, A. Olteanu-Raimond, C. C. Fonte, & V. Antoniou (Eds.), *Mapping and the citizen sensor* (pp. 15–33). UCL Press.

Cliff, N. (1993). Dominance statistics: Ordinal analyses to answer ordinal questions. *Psychological Bulletin, 114*(3), 494–509.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement, 20*(1), 37–46.

Creswell, J. W., & Plano Clark, V. L. (2017). *Designing and conducting mixed methods research* (3rd ed.). SAGE.

Ehn, P. (1993). Scandinavian design: On participation and skill. In D. Schuler & A. Namioka (Eds.), *Participatory design: Principles and practices* (pp. 41–77). Lawrence Erlbaum.

Goldschmidt, G. (2014). *Linkography: Unfolding the design process*. MIT Press.

Harteveld, C., Finlinson, M. J., & Gee, E. (2020). Designing for playful civic learning: Game-based tools for participatory urban planning. *International Journal of Child-Computer Interaction, 26,* 100237.

Lawson, B. (2004). *What designers know*. Architectural Press.

Mann, H. B., & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *The Annals of Mathematical Statistics, 18*(1), 50–60.

Oxman, R. (2006). Theory and design in the first digital age. *Design Studies, 27*(3), 229–265.

Sanders, E. B.-N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *CoDesign, 4*(1), 5–18.

Sanoff, H. (2000). *Community participation methods in design and planning*. John Wiley & Sons.

Schneider, T., & Till, J. (2019). Beyond participation: Politics, infrastructures and aesthetic of commons. *Architectural Design, 89*(2), 6–13.

Shatkin, G. (2011). Planning Privatopolis: Representation and contestation in the development of urban integrated mega-projects. *Cities, 28*(1), 37–44.

Tversky, B. (2005). Functional significance of visuospatial representations. In H. Cohen & C. Lefebvre (Eds.), *Handbook of categorization in cognitive science* (pp. 1003–1019). Elsevier.