

FROM STATIC ARCHITECTURE TO PLAYABLE SYSTEMS: GAMIFICATION AS A TOOL FOR REIMAGINING ARCHITECTURAL DESIGN

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Abstract

Architecture is often taught and represented as a finished object, although design practice increasingly depends on dynamic systems, collective decisions, and digital interaction. This study examines gamification and immersive digital environments as methods for participatory and adaptive design thinking in architectural education. An exploratory multiple-case design was used to analyze three studio projects developed by three two-student teams. Each team converted a thematic system, swarm intelligence, circularity or Square Kufic calligraphy into a playable rule set, documented gameplay and translated the resulting decisions into architectural drawings and three-dimensional proposals. Cross-case analysis focused on how rules, feedback, interaction, and iteration shaped design reasoning and spatial outcomes. The results show that gamification supported systems thinking, made design trade-offs visible, and connected collective decisions with generative form-making. The Liberty Market project used decentralized behavior to reorganize circulation; the Lyari project converted player choices into a community-oriented design brief; and the Bannai Geode translated calligraphic constraints into voxel-based massing and jaali structures. The findings position gameplay as a research instrument rather than a representational add-on. Although the small academic setting limits generalization, the study provides a structured basis for comparing gamified and conventional studios, analyzing gameplay data and testing participatory applications in professional practice.

1. INTRODUCTION

The architectural design studio continues to be the core environment for the learning of drawing, model making, critique and iterative development. It is an asset to make use of the imagination in combination with discussion but the studio itself has a strong tradition of individual authorship and of the teacher's judgment. Digital tools have revolutionized representation and simulation but they are frequently used in addition to existing instructional practices without reflection on

students' participation, collaboration and reflection. This is an increasing separation between digitally mediated practice and the social organization of studio learning (Kuhn, 2001).

Students today are regularly using three-dimensional modeling, real-time rendering, virtual reality (VR) and interactive media. These tools can create a spatial experience prior to construction and show design decisions that are hard to assess using drawings. The literature reviewed shows that VR technology has the potential to enhance

spatial understanding, experimentation, and collaborative review in the field of architecture (Ashgan et al, 2023; Asghar et al., 2024; Wang et al, 2024). Technical immersion is not a guarantee of participatory learning. In the absence of a clear pedagogical structure, advanced media can still be used as a presentation tool.

Participative design is a more suitable alternative since it involves users and designers as collaborators in a process. Co-creation can be described as a change in which the boundaries between expert and participant become less rigid, as described by Sanders and Stappers (2008). This transformation can take place in architectural learning, from defending a proposed building to collectively testing options. Structured interaction is also found to benefit design reasoning and collaboration through collaborative studio research (Emam et al, 2019).

Gamification is a way to organize that interaction. It is the use of game design elements in situations that are not games, like game rules, game goals, game feedback, game progression, game choice and visible consequences (Deterding et al, 2011; Kapp, 2012). In a design studio, these components can be used to transform problems that are abstract into problems that students can enter, test and modify into systems. Gamification is not about making architecture fun but it's about making relationships, constraints and trade-offs playable.

This paper attempts to explore the possibility of playing the game as an architectural research tool. It examines three experimental studio projects which combined biomimetic behavior, circular resource systems and calligraphic logic with interactive design frameworks. It poses questions about the generation of architectural knowledge from the rules of the game, decisions made by players and feedback received and how the resulting knowledge can be translated into spatial organization and form. The paper compares the projects and offers a model connecting the game mechanics, immersion, participation, reflection and creativity.

2. Literature Review

2.1 Gamification, Motivation and Flow

Gamification is different from serious games and game theory. While serious games are a full game environment created for learning, training or simulation, gamification integrates game features into an activity. In contrast, Game theory models choices strategically, mathematically. Gamification focuses mainly on experience and behavior: it structures goals, feedback, challenge and progression to keep people engaged (Deterding et al, 2011; Kapp, 2012).

Relationship between mechanics and purpose is an educational value of gamification. Generally positive outcomes were found in a broad review by Hamari et al. (2014), which revealed that effects are context, participant and implementation dependent. In the realm of higher education, systematic reviews also show that points or rewards are not enough; challenges, feedback and agency are more likely to be correlated with sustained engagement (Subhash & Cudney, 2018). Mora et al. (2015) call for considering the choice of a framework and ensuring the alignment of the game elements, the learners and the intended outcomes.

The results can be concentrated in well-structured activities, as explained in Flow. It points to the kind of involvement that features a productive balance of challenge and skill. In the context of learning, this state is related to concentrated focus, intrinsic motivation and a sense of self-control (Heutte et al, 2021). Similar conditions can be supported through architectural design, as students continually go through the cycle of uncertainty, action, feedback and revision. Gamification can help to make this cycle more visible by making it easier to understand the goal and to see what each decision does.

2.2 Architectural Studio Learning and Collaboration

Studio learning is project-based, reflective and social. Pupils create representations, give feedback on and adapt their ideas in an ongoing conversation. The studio is described by Kuhn (2001) as a learning environment for complex and open-ended problems and by Schön (2017) as a

model of reflection-in-action: The designer does, sees and reframes. These features make the studio ideal for gamified inquiry as play is a process of action, feedback and adjustment.

The studio while collaborative, is sometimes used to assess individual products and is not very structured when it comes to group decision making. The contribution of collaborative pedagogy to the balance is to assign roles, set shared objectives and let negotiation be a part of the design task (Emam et al, 2019). Gamification takes this idea one step further and makes collaboration an explicit system. The rules dictate what the participants can do, feedback tells them what they have achieved from the choices made and the common goal means that they must coordinate and not work independently.

2.3 Immersion, Virtual Reality and Design Behavior

Gamified design takes a somersault when we add the experiential aspect of immersion. Slater (2003) identifies two different types of immersion: immersion as a technical characteristic of a system and presence as the psychological feeling of being in a mediated environment. This is significant in architecture because users may not be engaged by a model that is visually complex if they cannot perform actions in the model and understand the effects of their actions. VR can facilitate for this active relationship by enabling the navigation, manipulation and evaluation of space on full scale (Ashgan et al, 2023).

A study on the spatial design behavior of VR has been conducted on a large scale and patterns in students' spatial design behavior in virtual environments have been discovered (Wang et al, 2024). Similar experiments in Pakistan in the studios earlier also indicate that gamification of VR and AR can help in participation and iterative review (Asghar & Javeed, 2024). This result has changed focus from the "look" of the digital models to the design process captured during interactions with the model.

2.4 Game-Based Approaches in Architectural Education

Game-based approaches for architectural education have been employed for testing

knowledge, promoting rapid prototyping, adding constraints and facilitating collaborative decision making. Goli et al. (2022) designed an open-ended architectural game that allowed students to assess the knowledge of design in a multimodal way. The EDUGAME4CITY project used the idea of serious game in the field of urban design education by creating interactive scenarios and collaborative interventions (Redondo et al, 2020). As seen in these studies, the games are able to bridge the gap between abstract concepts and situated design action.

But most of the literature addresses the use of gamification as a means to enhance motivation, visualization or participation in the classroom. The number of studies that focus on gameplay as a generative research approach such as a code of architectural rules, briefs or forms, that is directly informed by player behavior is limited. This is the difference that is fundamental to the current research. The aim is not to embed game elements into a standard task but the game is to become the medium of the production of design knowledge.

3. Theoretical Framework

Four dimensions are involved in this framework: game mechanics, immersion, participation and cognition of design. Goal, rules, constraints and feedback structure action within the game mechanics (Deterding et al, 2011). Immersion can help in maintaining attention and the experience of the spatial consequences instead of seeing them from the outside (Slater, 2003). Agency is spread among participants and design is a negotiation process (Sanders & Stappers, 2008). Design cognition refers to the influence of representations, rules and feedback in the evolution of ideas (Gero & Maher, 1993).

These dimensions make an iteration sequence. A player applies a rule, performs an action, sees what happens, talks about it, thinks about it and alters the action. As in reflection-in-action, knowledge is built through interactions with the changing situation and not by using a predetermined solution (Schön, 2017). Creativity is born out of constraint and choice. Rules constrain what can be done, feed-back sets the stage for new recombination's and revisions.

In this study we use the combined framework to refer to the fact that students are not just involved in a design process but also in the design of the process in which they participate, for this reason, we call it meta-participatory. They recognize variables, establish relationships, develop game mechanics and based on the recorded results, direct architecture. This is a dual role, putting game design in the center of both learning and research.

3.1 Research Gap: From Game Mechanics to Architectural Generation

While the relationships between feedback, engagement, immersion, collaboration and reflective learning have been validated in previous studies, the interdependency of these relationships as a generative approach in architectural education has not yet been examined. The most common studies are related to either the effects of gamification on motivation and VR on spatial experience. There is less focus on the translation of design evidence from gameplay to circulation, program, material cycles or architectural form. This gap is addressed in the present study, with three cases where the playable system was intentionally designed for an architectural result.

4. Research Methodology

4.1 Research Design and Participants

An exploratory multiple-case design was used in the study with a mini-thesis architecture studio. Three teams of two each chose one of the thematic trajectories: biomimetic processes, circularity or calligraphic form-finding. Each team was given a common brief for the studios where they were asked to design a playable research instrument and to convert the results of this instrument into an architectural proposition. There were no plans to produce statistically generalizable results, as the small format of the studios allowed for close observation of the decisions that were made in the design.

4.2 Studio Procedure

There were five stages that each team went through. The first step was to look at the chosen thematic system and determine how it works.

Second, they converted those principles into game variables, rules, goals, choices and feedback. Third, they built a working prototype in an appropriate virtual space. Fourth, they recorded players' actions and spatial patterns created during the game. Lastly, they turned the recorded results into drawings, diagrams, massing studies and three-dimensional architectural representations.

The standard way of conducting the tests was to have different subjects compared without imposing the same game format. This biomimetic project employed decentralized movement and collective behavior; the circularity project employed sequential tasks, resource choices and voting; and the calligraphy project employed geometric constraints and Boolean intersection. In both instances, the game resulted in a linkable action to design outcome.

4.3 Data Sources and Analysis

Analyzed material consisted of research diagrams, game rules, interface screenshots, choice sequences were recorded where applicable, reflective studio observations, design-development drawings and final 3-D proposals. Using a qualitative cross-case analysis, common relationships were found between rules, feedback, player agency, iteration and architectural output. The analysis was on process evidence, rather than aesthetic judgment. Three cases were analyzed for (a) the system that was translated into game logic, (b) the kind of player decision recorded and (c) the architectural variable informed by the player's decision.

5. Research Objectives

- To position game design as an architectural research tool rather than only a representational technique.
- To examine how rules, feedback and player interaction can generate architectural form and organization.
- To develop coherent architectural proposals grounded in explicit research narratives and system logic.

6. Results

6.1 Gamification of Biomimetic Processes

The first case was Exploring Swarm Intelligence Through Gamification for Redesigning Liberty Market, explored the possibility of decentralized behaviour informing an urban intervention in Lahore. The studio analysis revealed congested pedestrian routes, disjointed circulation, uncoordinated and unplanned extension of informal vendors and limited coordination between the activities of the space. Rather than proposing a single master plan, the team developed a game in which the users navigate through the market, engage with the spatial assets

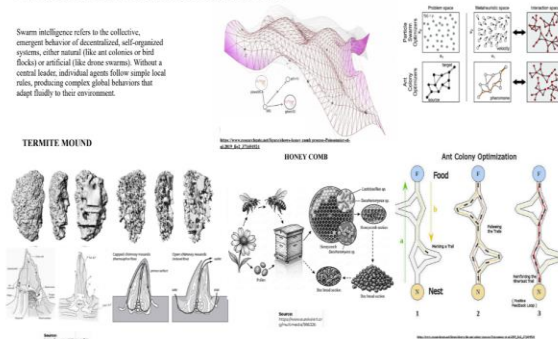
and generate collective patterns by making local decisions repeatedly.

The behavior of the agents was broken down into simple rules: agents reacted to moving objects, obstacles, attractants and varying densities, not to a central command. These interrelationships were brought to light through gameplay. Repeated routes showed zones of attraction or conflict and movement changes showed where additional connections (shaded nodes) or new vendor zones (reorganized zones) could facilitate movement. The game served as a medium between the observed behavior and the architectural intervention.

(a)

BEHAVIOUR OF SWARM INTELLIGENCE

Swarm intelligence refers to the collective, emergent behavior of decentralized, self-organized systems, either natural (like ant colonies or bird flocks) or artificial (like drone swarms). Without a central leader, individual agents follow simple local rules, producing complex global behaviors that adapt fluidly to their environment.



(b)

GAME VISUAL

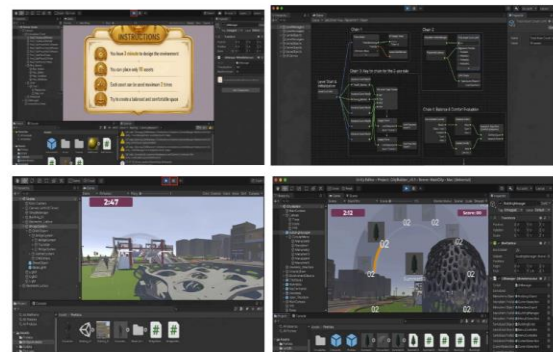


Figure 1. Swarm-intelligence research mapping and screenshots from the Liberty Market game. Note. Studio documentation and design outputs generated during the study.

The recorded patterns were subsequently used to plan the circulation and interventions throughout the market in the proposed plan. Branching and self-organization were also implemented in the architectural language, as well as different approaches, which enabled paths, structural

elements and places of congregation to grow as parts of a larger system. The central contribution of the case was methodological: collective behavior was no longer seen as information but rather as design intelligence, regarded as a product of a formal solution.

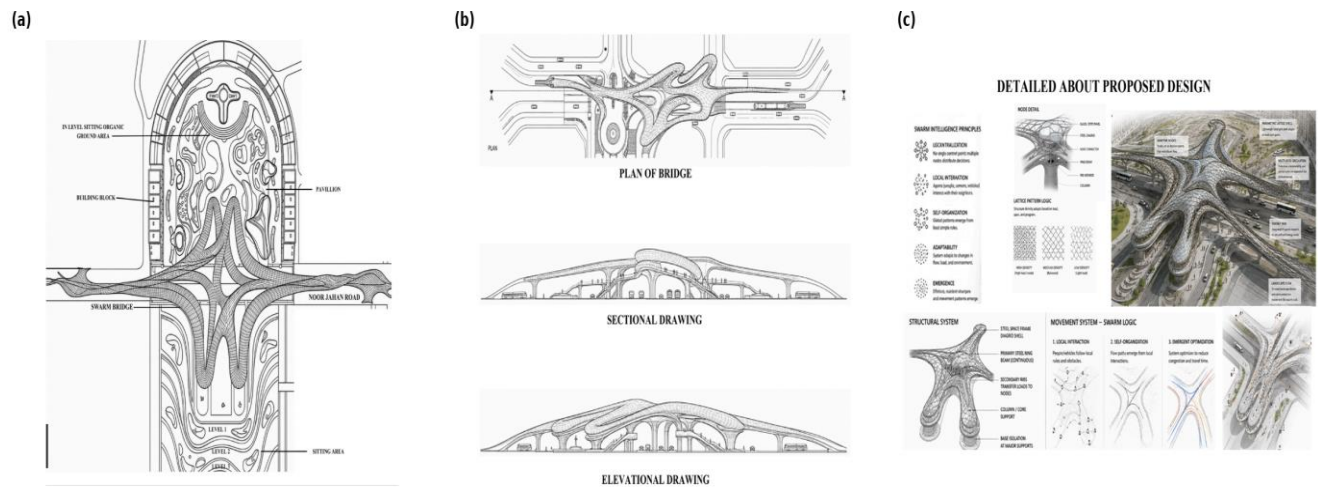


Figure 2. Architectural interventions for Liberty Market generated through the gamified process. Note. Studio documentation and design outputs generated during the study.

In the scope of the studio exercise, the case demonstrated a successful approach to linking agent-based thinking to a human choice. It was impossible to claim that it was a complete simulation of the complexity of the market. Rather it offered a space to experiment with the potential for the local decisions to coalesce into spatial patterns and how these patterns could be transformed into an adaptive urban proposal.

6.2 Gamification for Circularity in Architecture

The second one was located in the Jahanabad neighborhood in close proximity to Lyari, Karachi and was known as Circular Economy Through Gamification. The project brief was the connection of waste, food production, skill development and collective decision making. Players were asked to vote on the facilities to be

built, vote on a productive skill and help with the food growing, as well as identify waste, collect and recycle materials and learn a productive skill, in a three-tiered game designed by the team. Limited choices, player goals, scores and visible consequences assisted players to see links between resources and community infrastructure.

The game had two related functions. First, it related circularity as a series of steps that waste can turn into a resource and one intervention can aid another. Second, it captured the sequence and player selection of the players. These traces were looked at qualitatively to discover common themes and to develop a design brief prior to the finalization of the architectural form. Gamification was employed in the data collection, not as an afterthought after the research process but as an integral part.



Figure 3. Circularity game developed for the Jahanabad neighborhood near Lyari, Karachi. Note. Studio documentation and design outputs generated during the study.

The architectural proposal interpreted the sequence of the gameplay into a network of programs that are oriented to the community. The construction of a community kitchen, vocational hub, recycling activities and food-growing spaces were arranged as interrelated extensions and not detached buildings. The formal language is built

upon the concept of cycles and created through continuous envelopes and connected public spaces. The design was not a literal representation of the players' choices; it was instead a representation of the programmatic relationships and priorities of the players.

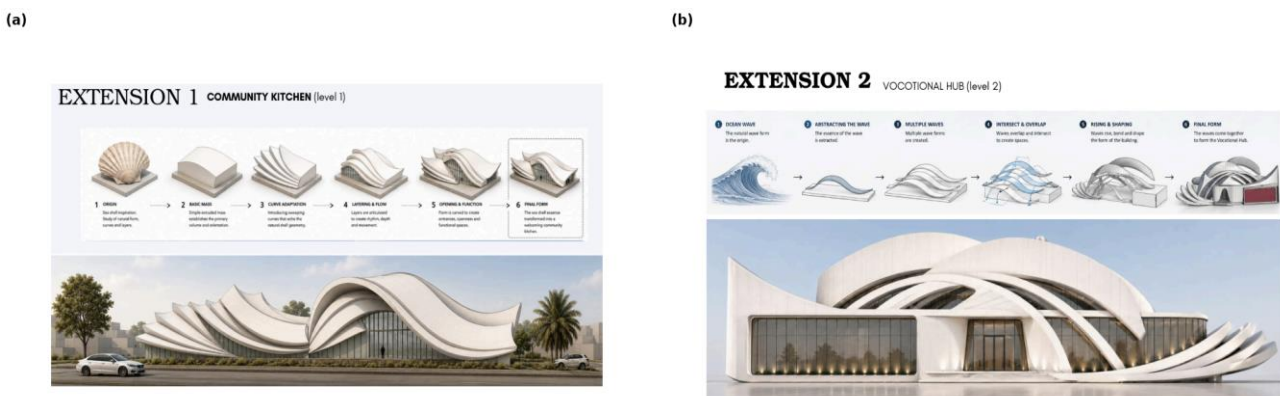


Figure 4. Architectural proposals derived from gameplay choices in the circularity project.

Note. Studio documentation and design outputs generated during the study.

This case illustrated a game that integrates awareness and preference elicitation with a design

briefing. One important limitation was also identified; the quality of the output was related to

the quality of the choices given to players. Participatory consultation is not just interactive, it must be participatory in terms of what options are offered, the rules and the interpretation.

6.3 Gamified Calligraphic Form-Finding

The third case, Gamified Architecture Through Square Kufic Rules: The Bannai Geode, was an investigation into an application of the calligraphy of the square kufic as a system of rules and computations for a porous Jaali's and pavilion. The intervention site was Shalimar Gardens, Lahore. Square Kufic uses a grid to separate letters into vertical and horizontal parts, suitable for modular translation. The team didn't look at the

script as a decoration –rather, as a rule system that could produce 3D mass and void.

The project was a mix of historical and formal study and an interactive Unreal Engine prototype. A word or a phrase was initially turned into a Square Kufic glyph. The glyph was then rendered onto three orthogonal side of a voxel grid. Boolean intersection identified the voxels common to all three inscriptions and any voxels that didn't intersect with any of the three inscriptions could be removed from the surfaces or treated as void. This operation produced forms that were also still bound by calligraphic logic but that would vary based on the text input, the direction of the form and the proportion of the cube.

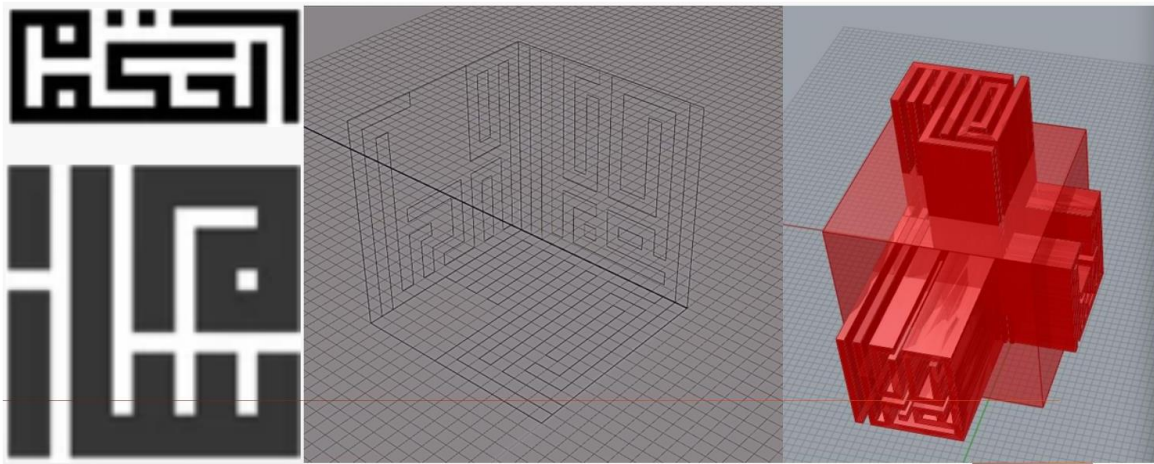


Figure 5. Bannai Geode progression from a Square Kufic glyph to a wireframe study and solid volume.

Note. Studio documentation and design outputs generated during the study.

The playable sequence consisted of the following operations: Text in Square Kufic: A word or short phrase was resolved into a grid-based glyph.

Write on cube: The glyph was projected onto one face of a subdivided voxel volume. Write on three axes: Different inscriptions were placed on the front, side, and top faces. Three-axis intersection:

The engine identified voxels shared by the three projected inscriptions. Delete or preserve: Non-intersecting cells were removed or used to define solid and void. Generate output: Players produced either a solid massing study or a porous jaali structure.



Figure 6. Methodological sequence from a Square Kufic glyph to a three-axis voxel intersection.

Note. Studio documentation and design outputs generated during the study.

The user interface enabled the player to switch between front, left, top and three-dimensional perspectives; move the axes; paint or destroy cells; restore selections; and create other outputs. This

interaction allowed the computational rule to be made visible and editable. Instead of taking a one-size-fits-all answer from the algorithm, players were able to review the changes in the form that occurred on the basis of each of the inputs and to compare different options as part of the design process.

(a)



(b)



Figure 7. Resulting voxel form and the Unreal Engine interface. *Note.* Studio documentation and design outputs generated during the study.

The same intersection logic has resulted in two architectural conditions. Selected cells were filled to produce solid volumes for massing studies and the void spaces inside the volumes allowed for a calligraphic shell to be retained, to become a Jaali,

a facade or a pavilion structure. This second condition linked computational and environmental, screened enclosure techniques that filter light and air.

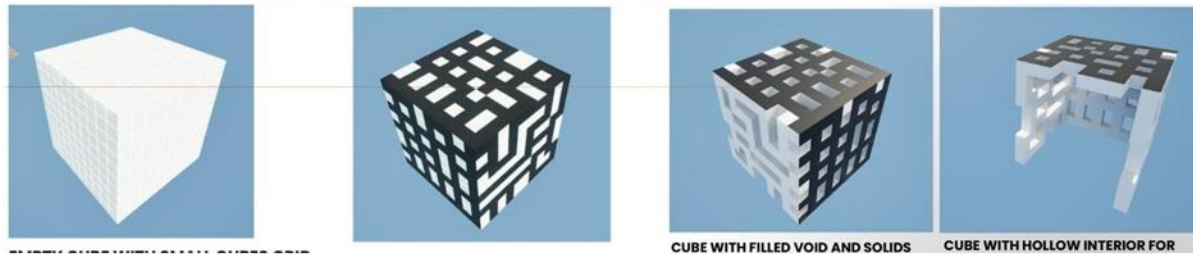


Figure 8. Sequence from an empty voxel grid to massing and a hollow jaali structure.

Note. Studio documentation and design outputs generated during the study

Various word orientations and proportions resulted in a family of similar but not identical outputs. Every successful result maintained a clear internal solid-void rhythm but did not have a fixed

building form. So, the game became a generative game with constraints: calligraphic rules provided continuity, player decisions provided variation.

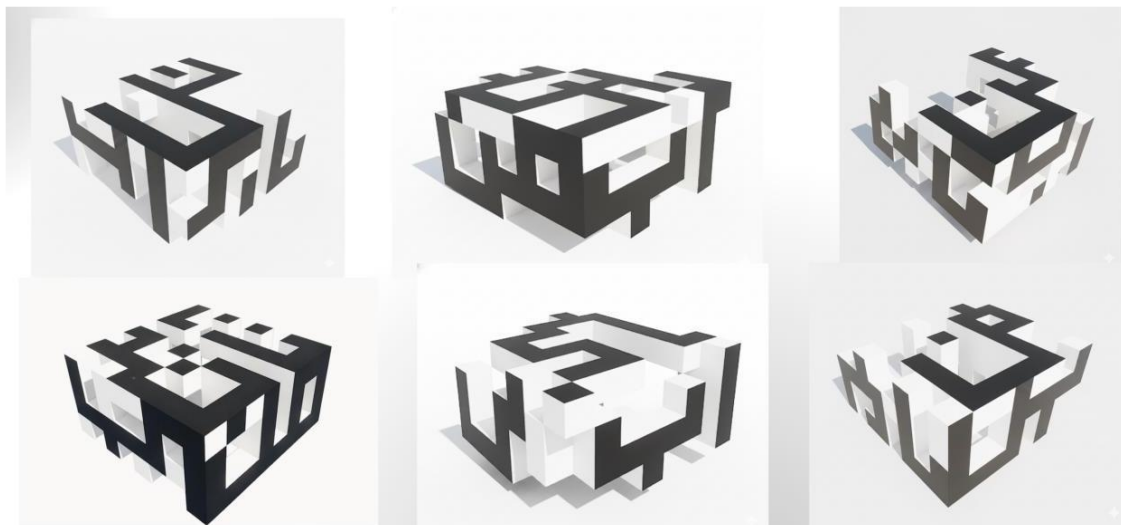


Figure 9. Representative massing studies generated from different Square Kufic inputs.

Note. Studio documentation and design outputs generated during the study.

7. Discussion

Across the three cases, gamification functioned as more than a strategy for increasing attention. It facilitated architectural inquiry by way of rules, actions and feedback. The Liberty Market game transformed local movement into circulation patterns, the circularity game transformed sequential choices into a programmatic brief, and the Bannai Geode transformed calligraphic constraints into mass and void. While the projects were on different subjects and interfaces, all of

them had a clear trajectory that started with interaction and culminated in architecture.

Results validate the proposed link between game mechanics, immersion, participation and creativity. The rules set the limits for what could be done, feedback made the consequences clear and iteration let players try out their alternatives. This is the structure which confirms the opinion that meaningful goals and feedback are essential and more important to effective gamification than superficial rewards (Hamari et al, 2014). It also is related to design cognition as the process of

creating new possibilities through representations and constraints (Gero et al., 1993).

The cases are additional examples of reflection-in-action. Students created a rule system, watched the game and adjusted the game and the architecture, instead of using a completed theory in a predefined form. The design problem evolved with the emergence of new evidence from the system. The iterative relationship is particularly crucial in open-ended studio work, where the worth of a method is based to some degree on its ability to bring in questions that were not apparent to the beginning (Schön, 2017). Gamification also transformed digital media. VR, real-time engines and computational modeling were not merely used to make things look pretty. They turned into spaces for filming action and for testing of relationships. This addresses research focus on the analysis of design behavior in VR instead of just final images (Wang et al., 2024). The projects' greatest contribution was procedural; that is, digital tools were integrated into the decision-making, rather than attached to the end of the studio process.

The approach provides a means to bring systems thinking into architectural education. Many problems can be complex and difficult to communicate verbally, particularly ones involving decentralized movement, cycles of resources and geometric limitations. A playable model lets students 'do' the model, thereby experiencing how one variable change the other and negotiate those changes with teammates. It can also lead to more specific critiques, since discussion can be about the link between a rule and an outcome, instead of about personal taste.

The method could be used in the field. Gamified environments can help participate in urban areas by providing an opportunity to test alternatives before construction and to document the reasoning behind the choices. But interactivity is not necessarily inclusion. The number of actions, the scoring and the interpretation of the results are still to be decided by the designers. A participatory application should have clear rules, easy to use interfaces and opportunities for participants to question the rules for the game.

There are a number of limitations to be noted. The study only focused on 3 cases and 6 students in an academic setting. The projects were documented in a variety of ways and the analysis was qualitative. A direct comparison to a traditional studio was not made and proposals for the architecture were not project into the full scale. Future studies should adopt greater number of participants, standardized assessment tools, systematic analysis of the game logs and pre- and post-testing of learning achievements. Future studies might also use comparative and longitudinal approaches to determine if collaborative experiences, spatial reasoning or design quality benefits from the use of gamification over time.

8. Conclusion

This study reframes architecture as an evolving system produced through interactions among people, rules, technologies and environments. In three experimental studio activities, gamification not only engendered engagement but it also enabled research frameworks that allowed students to model behavior, document decisions and turn abstract systems into architectural actions. Urban circulation, a community program and computational massing and porous enclosures were informed by biomimetic movement and circular choices, respectively.

The results indicate potential for bridging participatory design and computational thinking with the use of playable systems. Explicit constraints and consequences promote iteration, negotiation, and reflective learning through gameplay. It also helps place students as designers of architecture and the systems that produce it. While it is preliminary research, it offers a practical model for further research in the field of architectural education and participatory practice. The potential of digital technologies for design is not about novelty but about relationships. Gamification is one method to structure those relationships in a responsible way. Designing such a participatory, adaptable and transparent architectural system may be a part of the future of architectural inquiry that includes designing the architecture that can evolve. The findings of this

study provide a preliminary basis for extending gamification from an experimental studio strategy into a more systematically evaluated approach to architectural design education. Future research should involve larger student cohorts and multiple design studios to determine whether the observed relationships between game mechanics, participation, iterative decision-making, and architectural outcomes remain consistent across different educational settings.

9. Future Work:

Future studies should further investigate gameplay as a source of architectural data. Player choices, movement patterns, interaction sequences, voting outcomes, and design iterations could be digitally recorded and analyzed to establish clearer relationships between gameplay behavior and resulting architectural decisions. This would strengthen the methodological position of gamification as a research and generative design tool, rather than primarily an engagement or visualization technique. The approach should also be tested beyond the academic studio through real-world participatory design applications. Community members, users, architects, and other stakeholders could interact with playable environments to explore alternative spatial configurations, programs, circulation systems, and resource strategies before design decisions. Particular attention should be given to accessibility, transparency of game rules, and the extent to which participants can influence both the available choices and their architectural interpretation. Such work could contribute toward developing a more comprehensive pedagogical framework for integrating playable, participatory, and computational systems into architectural design education.

10. Contributions:

Quratulain Asghar conducted the fourth-year architectural design studio during Fall 2026, supervised the students' design and gamification work, and guided the development of the projects in accordance with the research objectives. She was responsible for interpreting and deriving the research findings from the studio outcomes and

was substantially involved in the writing and preparation of the manuscript. Dr. Fatima Javeed contributed to structuring the architectural design studio, refining its pedagogical and research approach, and developing the conceptual and methodological framework used to examine gamification and playable systems within the studio. Madiha Zaman contributed to the proofreading, language refinement, and editorial review of the manuscript, helping improve its clarity, consistency, and overall presentation.

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