KIT-OF-PARTS DESIGN FOR ARCHITECTURE CO-CREATION GAMES

Provides Ng[1], Yuechun Li[2], Shutong Zhu[3] And Jeroen Van Ameijde[4]
[1,2,3,4] *School of Architecture, The Chinese University of Hong Kong*
[1]*provides.ng@link.cuhk.edu.hk, 0000-0001-6975-4642*
[4]*jeroen.vanameijde@cuhk.edu.hk, 0000-0002-3635-3305*

Abstract. In the planning of built environments, participatory design can help to tailor spaces and facilities that are better suited to residents' needs. Through the use of new digital tools in sandbox games and collaborative virtual environments, participants can express their needs in a spatial language and better understand the implications of their collective design decisions. However, the kit of building parts and 3D assets with which they can interact to create spatial proposals can impose limitations on design explorations, by being overly prescriptive or open-ended. This study explored ways in designing novel kit-of-parts (KoP) systems that can enable collaborative architectural production. It employed participatory methods in which local communities co-create a public space through a tailored videogame to test three types of KoP systems: modular-integrated, modular, and discrete. The initial findings show how the levels of discretization and abstraction affect the amount of knowledge needed for participation, time required to initiate collaboration and creative thinking, and potential to generate meaningful and implementable design proposals. Reflecting on these lessons, the paper presents insights on the implications of KoP (granularities, stacking methods, and self-similarity) on spatial design (technical possibilities, spatial arrangements, and activity scenarios) to better assist co-creation processes. In midst of an accelerated digital transformation, this study reflects on the evolving role of new collaborative tools in architecture.

Keywords. digital common(s), kit-of-parts, architecture co-creation, sandbox games, combinatorial creativity, modular and discrete

1. Introduction

Co-creation is a method that engages stakeholders and end-users, to cooperatively generate innovative ideas, which can activate the subsequent design processes (Ind & Coates, 2013). In architecture, it is increasingly mediated by digital sandbox games to stimulate playfulness, spontaneity, and creativity (Sanchez, 2021). 'Play' is a participatory and experiential form of learning (Abt, 1978). However, the design of the building parts, which participants can engage with, is a major challenge in designing architecture sandbox games. The parts should assist participants to learn architectural rules, express their varying needs, and be playful and creative towards implementable solutions. Such parts are often referred to as a Kit-of-Parts (KoP) (Fuster et al., 2009).

Although there has been an increasing number of studies looking at architectural co-creation, few have been dedicated to understanding the relationship between KoP and how it can drive collective creativity. Creativity can be combinatorial, exploratory, and transformational; for instance, in sandbox games, players often combine ready-made pieces to generate new creations - a form of combinatorial creativity, which ‘produces unfamiliar combinations of familiar ideas’ (Boden, 2009). The combinations can be problem-, similarity-, or inspiration-driven, which highlights the importance of designing KoP in relation to the gameplay (Han et al. 2017). Digital gameplay provides the benefits of simulation, allowing players to explore different part arrangements and various architectural scenarios through iterative testing. Moreover, networked multiplayer platforms accelerate the generation of designs. Despite increasing studies on architectural co-creation, few have been dedicated to understanding the relationship between KoP and how it can drive creativity.

To address this question, the study presented in this paper experimented with different granularities of architectural parts, testing modular-integrated, modular and discrete architectural systems (CiC, 2020; Claypool, 2019). A networked-VR sandbox game was developed to articulate aspects of the co-creation agenda: collect community preferences, improve quality of space, and generate new ideas for shared facilities. In this study, the term “user” is used to refer to the end-user of public spaces, whereas “participant” is used to describe the users who participate in co-creation.

2. Sandbox Games & Learning through Playing

Sandbox games are games without predetermined goals, thus, allowing a greater degree of freedom for players to interact with creatively. The practice of applying such games to urban co-design had been around for at least two decades. Initial experiments used the platform Second Life as a virtual open world simulator, which enabled user-generated game contents (Gordon & Koo, 2008). Nonetheless, this required a significant amount of skill to 3D model and customise virtual objects. In contrast, Minecraft is much more accessible and user-friendly, and has become a more sophisticated tool for co-design (UN-habitat, 2016).

Sandbox games that are popular worldwide with well-streamlined user interfaces (UI) are easier to be adopted by the design thinking sprint of ‘empathise, define, ideate, prototype, test’. For instance, Block'hood employed a block-oriented method, but unlike Minecraft, the blocks were more tailored to the architectural agenda through a set of custom designed KoP (Sanchez, 2021). Each block was defined as an architectural component (e.g. apartment, office space, park, playground, a set of solar panels, etc.), and a catalogue of over 200+ blocks was designed with eco-sustainable features. The strength of this video game was that it could be used as an education, planning, or design game with its three modes: Story, Challenge, and Sandbox.

The game Block'hood illustrates the difficulties and complexity in balancing planning and design, activities which vary in their job nature and use different forms of reasoning that can every so often result in contradictory findings. It simulates principles of resources management in urban planning, but also reveals how doing the bare minimum can already keep the game going - just as how planning guidelines can sometimes lead to projects preoccupied with ticking boxes (Zallio & Clarkson, 2021).

Seen together, these precedents highlight a few key aspects of KoP: granularities, stacking methods, and self-similarity between parts. These aspects drive the combinatorial qualities of design outcomes, especially their technical possibilities, spatial arrangements, and activity scenarios. Take spatial arrangement as an example, the in-between spaces from the stacking method of Block'hood by Jose Sanchez and Block by Block by UN-habitat performed regularities, whereas Platform Sandbox by Damjan Jovanovic and Playable Planning Notice by Bartlett RC12 were more playful as they were abstracted from a real-world understanding. For technical possibility, too many parts to choose from can be overwhelming, too little can be restricting - a challenge for all sandbox game designers (and BIM architects) (Figueres-Munoz & Merschbrock, 2015). The scale threshold is dependent on the given duration and complexity of the gameplay and activity scenario.

Concurrently, researchers have found that phygital (physical + digital) gameplay in community engagement can complement physical face-to-face communications. It should be inclusive to differently-abled participants so everyone can feel relevant in a technologically driven process (Wang et al., 2022). Accordingly, appropriate tools should be provided to facilitate creativity. In digital craft, thoughts must be given on the granularity that is designed into these tools, given the time constraint of workshops.

3. Methodology: Kit-of-Parts & Building System Design

In review, the relationship between part size, customization, and design implications in a KoP are crucial. The design of a KoP should encourage larger outcomes by assembling smaller parts. As such, designers must consider how the size of the parts can influence the level of detail, how much can be designed into the outcome, the time and energy required from participants, and the customization options available. Additionally, the impact on communication, the meaning of the parts on participants' knowledge requirements, browsing time, and the potential for imagination in the design process must be explored. Considering the role of designers and users in a cooperative process, to what extent can the provision of ready-made solutions in KoP kick-start creativity, facilitate flexibility, and enhance phygital (physical + digital) interactions:

- How are technical possibilities, spatial arrangement, and activity scenario affected?
- What are the implications of different granularities, stacking, and self-similarity?

The proposed framework (Figure 1) integrates a spectrum of granularity design for KoP, from high to low threshold, including modular-integrated, modular, and discrete parts. The research gap on the relationship between creativity and KoP design limits our understanding of enhancing cooperative outcomes in complex problem scenarios and design solutions. Thus, the framework was used to design part systems for tests with local communities.

A video game was designed with Mozilla Hubs, with a game mechanism that integrated sandbox gameplay with role play.

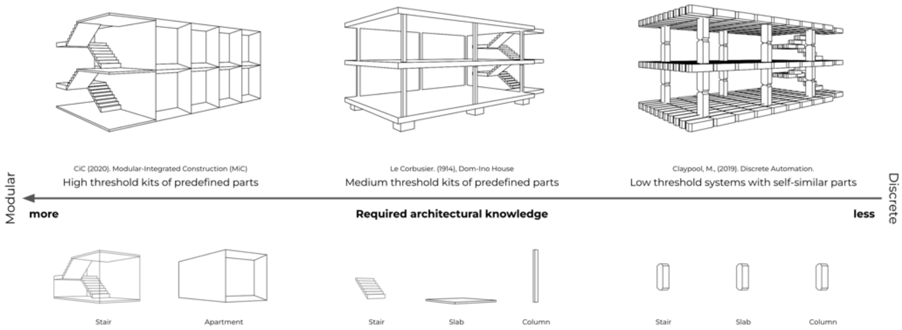

Figure 1. An integrated framework from modular to discrete ways of designing KoP based on the amount of required architectural knowledge to understand

Through participatory action research, the study engaged residents of public housing in Hong Kong, 1) to understand their preferences of intergenerational community activities through focus-groups and thematic analysis. Based on the emerging themes, 2) three sets of KoP were designed, respectively using modular-integrated, modular and discrete parts, and 3) tested in the game with end-users to study the combinatorial creativity generated in the process.

Four workshops were held, each using a different KoP system: game I (modular-integrated), game II (modular), game III (discrete), and game IV (mixed). Different participants were involved in each game, but in general, six participants role-played respectively as client, researcher, architect, social worker, developer, and resident, each had specific key performance indicators (KPIs) to fulfil (Figure 2).

The game comprised two rounds. In the first round, participants received KPIs for each role, ensuring the final design met residents' needs, including 20% greenery, 15% exercise areas, 10% commercial spaces, 10% playground spaces, and so on. They also had to include two barrier-free corridors, each over 1 metre wide. Using a 2D map, they planned spatial allocation, then used the sandbox game to prototype scenarios. In the second round, participants accessed each other's KPIs, allowing them to use lobbying tactics to influence decisions.

The documentation of the outcomes comprised 3D models, screenshots of the design's progression, and voice recordings of in-game discussions. Accordingly, researchers refined the 3D models by removing duplicates, replacing missing components, correcting misplaced items, and making necessary adjustments to accurately reflect participants' original design intentions.

Figure 2. Participants discussing and arranging KoP in the virtual sandbox during game 2

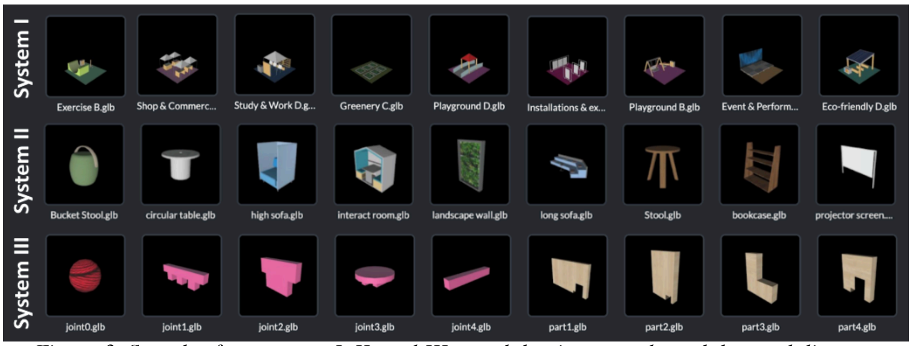

Figure 3. Samples from system I, II, and III - modular-integrated, modular, and discrete

4. Results: Kit-of-Parts (KoP) Design

The outcome of the KoP design encompassed the development of three distinct systems, each serving a purpose within the architectural framework (Figure 3).

System I, known as the modular-integrated system, consisted of high-threshold predefined parts (Figure 4). It comprised 16 distinct spatial programs, each containing four spatial typologies derived from over 190 activity preferences from user survey. The spatial programs encompassed greenery, exercise, shops, playgrounds, performances, installations, and more. The four spatial typologies within each program considered the figure-ground relationship between furniture and circulation. Typology A offered a flexible space arrangement, B included a 1.5m circulation corridor, C balanced layout with circulation in the middle, and D centralised furniture arrangement.

System II, known as the modular system, was crafted to incorporate medium-threshold pre-defined parts. These parts were assigned simpler functions and were smaller in granularity, requiring less time and knowledge to comprehend their architectural implications. Focusing on the individual facilities, system II aligned with the same spatial programs as System I. However, it introduced a new dimension by offering five distinct facility styles, each designed to cater to different aesthetic preferences and user experiences - neutral tone, colourful, biophilic, multifunctional, and technological facilities. For instance, neutral tone embraced a minimalist approach, utilising subdued colours and clean lines to create a sophisticated atmosphere. The colourful style embraced vibrant hues and playful patterns, injecting energy and liveli- ness into architectural compositions. The biophilic style drew inspiration from nature, incorporating green materials and organic shapes. The stylized parts provided a wide range of design possibilities, enabling greater diversity in spatial outcomes.

System III, known as the discrete system, was specifically designed to incorporate low-threshold self-similar parts. These parts were intentionally devoid of preassigned functions, focusing on their self-similar nature with slight variations in geometry and dimensions. The granularity of these parts was the smallest, allowing for intricate and detailed architectural compositions within virtual game spaces. The kit was also the smallest in size, consisting of a compact set of only 18 components, categorised into parts (made of wood) and joints (sprayed pink) for easy identification. The simplicity and minimalism of the kit ensured that users required the least amount of time and knowledge to understand each component and its potential applications.

These three systems carefully curated spatial programs and typologies, forming the foundation of the KoP design experiment. The integration of these elements into the VR game space aims to create a versatile and user-centric environment that can cater to a wide range of public space activities and preferences. By combining architectural knowledge and user insights, the KoP systems were designed to achieve a fusion of functionality and aesthetics.

5. Preliminary Findings: First Test with Public Space Users

In the context of the results from games I, II, and III, the technical possibilities, spatial arrangements, and activity scenarios were influenced by the different KoP systems used in the gaming workshops.

In Game I, the design outcome focused on negotiating land allocation for various user interests based on survey data (Figure 4). Participants realised that each module represented about 5% of the total land area, leading to a numerical and energy-intensive negotiation. Despite the design's coherence in the initial stage, it did not fully meet the surveyed user needs, prompting a shift towards fulfilling the KPIs and prioritising function accommodation within limited space. Round 1 resulted in a decline in spatial quality, leading to a high-density cluster of urban objects around a central green space. In Round 2, lobbying efforts led to minor changes as players negotiated for equilibrium. Despite not everyone meeting their KPIs, all parties preferred maintaining the status quo to avoid unpredictable actions from others, fearing a less desirable outcome. This fear significantly hindered the creative process, prompting reflection on planning practices in high-density contexts with limited spatial resources and diverse interests - planners often opt for "safe choices" to avoid unfavourable outcomes.

In Game II, the design outcome demonstrated greater creativity in arranging parts within the boundary, leading to the development of an activity scenario with vibrant colours and a mobile library (Figure 5). By incorporating the five facility styles within System II, the co-created outcome achieved a higher degree of design flexibility and user customization. With the modules no longer integrated, the negotiation shifted to determining how and where to place the selected facilities as a team. This sparked discussions on the types of arrangements that could support community-building activities, such as book-sharing and other second-hand exchanges. Finally, participants devised an idea for a local landmark with vibrant colours, aiming to strengthen a sense of identity, and proposed a mobile library to encourage active lifelong learning. Despite these positive aspects, there was a lack of overall spatial planning. The process of going through the parts individually, understanding their differences, orienting them in space, and collectively making decisions required significant energy and effort from the participants. Consequently, it took longer to complete the design, leading to only one round of the game being played.

Figure 4. Game I by participants, which utilised the modular-integrated system. As each module represented 5% of total land area, the creative process became a game of numbers

Figure 5. Game II results by participants, which utilised the modular system. The outcome showed participants were more conscious of the density between objects and their orientation

Figure 6. Game III results, which utilised the discrete system. Participants were a bit confused in the beginning with what to do with the parts; however, after some time of trial-and-error, they began to develop an understanding of how to form open or enclosed space from arranging the elements

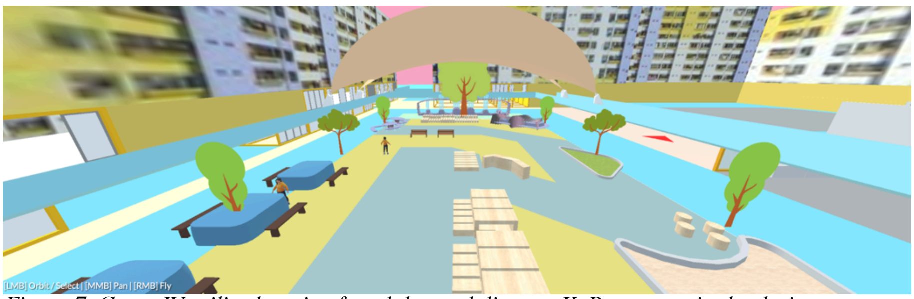

Figure 7. Game IV utilised a mix of modular and discrete KoP systems; in the design process, used open-source platforms to search for proxies that can help demonstrate ideas

Figure 8. Post-processed Game IV co-creation results, where vegetation, people, and other background details were added to visualise and approximate the implementation of the design

In Game III, the abstract nature of the parts, along with their granular character, provided participants with the freedom to manipulate, arrange and play, nurturing a spirit of creativity and discovery. The intricacy between parts and joints allowed for exacting adjustments, with the design being a product of meticulous fine-tuning. This enabled different technical possibilities, from stacking and interlocking, to parallel and diagonal orientation of parts to configure a sense of space. Also, the self-similarity of the parts facilitated the discernment of patterns and repetitions. Participants were able to split the design tasks amongst themselves and work in parallel to achieve efficiency, nevertheless, preserved a sense of visual coherence when their individual work comes together (Figure 6). However, it took a while before participants were able to grasp the potential of such abstraction, making it challenging to kick-start the design process, and they had to be shown with some reference images and examples with formal guidance. Additionally, while the outcome showcased diverse spatial arrangements, they began to exhibit visual similarities to each other as the game progressed.

In Game IV, the mixed KoP offered a wider variety of arrangement options for participants, which led them to dive into more diverse architectural configurations, yielding more elaborate and enthralling spatial arrangements (figure 7). Participants first used discrete parts to set apart different areas, resembling a figure-ground exercise; then, replaced some of the elements with modular parts to give variation of spatial quality, accentuating the social areas. The outcome comprised four distinct activity scenarios assembled into a public space design, each tailored to facilitate a community-building activity - a playground with a sandbox, a circular gathering space, a covered skill-building area with tables and chairs, and a lunch spot under the trees. The spatial quality of the outcome showed improvement, with more awareness towards density between objects and their orientation, resulting in interesting in-between spaces and facility arrangements. However, there were specific parts, like the tensile structure that spanned across the entire courtyard, that the participants wanted but not in the kit. As a result, designers had to 3D model those parts on the spot. Open-source platforms were also used to search for additional 3D assets that can help demonstrate the idea.

Overall, the technical possibilities, spatial arrangements, and activity scenarios were affected by the level of granularity, stacking methods, and self-similarity inherent in each KoP system. The modular/-integrated systems provided varying degrees of predefined parts and facility styles, impacting the spatial quality and creativity of the outcomes. Concurrently, the discrete system allowed for intricate and detailed spatial compositions, fostering creativity and exploration within the virtual environment. When these systems synthesised, participants were able to select and combine stylized parts according to their desire, resulting in a diverse range of architectural compositions that catered to their varied needs and aesthetic preferences. These demonstrate the influence of KoP systems on the outcomes of an architectural co-creation process.

6. **Discussion: Creativity, Flexibility, and Interactions**

The results revealed several advantages and limitations in the stimulation of creativity:

1. Granularities: The use of different granularities allows for precise adjustments and fine-tuning, enabling users to achieve their desired design outcomes with meticulous attention to detail. However, too many options can be overwhelming, while too few can be restricting, and the scale threshold is dependent on the given duration and complexity of the gameplay design.
2. Stacking methods: The stacking methods influence the figure-ground relationship between furniture and circulation, impacting the spatial quality and orientation. They can provide standardisation benefits while enabling enough freedom for variety in design to prevent generic outcomes, but they also present challenges in managing complexity and ensuring coherent design outcomes.
3. Self-similarity: The self-similar nature of the parts enables users to easily identify patterns and repetitions, facilitating the assembly of complex and visually captivating architectural compositions. However, the abstract and self-similar nature of the parts may become distant from a practical understanding of the real world, posing challenges in stimulating creativity and managing feasibility.

In summary, the different forms of granularities, stacking methods, and self-similarity offer flexibility but also present challenges in managing complexity, ensuring coherent design outcomes, and balancing standardisation with design variety. These aspects significantly impact the technical possibilities, spatial arrangements, and activity scenarios in spatial design, influencing the level of detail, customization, spatial quality, and overall creativity in the resulting architectural compositions.

As a next step, the subsequent research phases will involve the integration and advancement of the systems for further combinatorial testing with participants. By utilising VR as a means to navigate design abstraction, uncertainty, changes, and negotiation, the study will seek to employ KoP as a collaborative learning tool to initiate engagement, fostering public appreciation for spatial design via 3D interactions. By immersing in virtual environments, stakeholders can engage in iterative experimental processes concerning architectural elements as part of creative learning.

Furthermore, to cultivate macroscopic and higher-order thinking in design concepts, participants will be encouraged to go beyond articulating needs and formulating opinions towards basic spatial requirements. Also, the study will diversify and integrate phygital tools for more intuitive expression, such as clay-moulding and 3D scanning to foster more outside-the-box thinking.

7. Conclusions

This paper presents the outcomes of a sandbox game used as a co-creation platform, which aimed to enhance collective decision-making, improve public space design, and generate innovative ideas for shared facilities. The study focused on utilising Kit-of-Parts (KoP) in virtual environments to facilitate collaborative architectural production. It explored the integration of modular-integrated, modular, and discrete KoP systems to understand the relation between architectural elements and creativity in co-creation, as well as their technical possibility, spatial arrangement, and activity scenario.

In KoP design, the various granularities, stacking methods, and self-similarity offer advantages like precise adjustments, intricate compositions, and visual appeal. The levels of granularity influenced detail, participant effort, and customization options. Stacking methods affected figure-ground relationships, spatial quality, and orientation. Combinatorial qualities of design outcomes were driven by self-similarity, impacting variety and creativity. Self-similar parts make it easy to identify patterns and assemble complex designs, whereas the absence of predefined functions encourages creativity and experimentation, allowing users to explore different architectural configurations.

Modular systems required architectural understanding and provided specific spatial functions, while discrete systems allowed intricate compositions and fostered creativity. However, both systems require careful consideration to avoid generic outcomes and maintain a balance between guided variety and design abstraction. Limitations of KoP applications can include overwhelming options based on the number of parts, and a constrain on the scale threshold based on gameplay complexity.

In conclusion, this study contributes to knowledge in design, customization, and co-creation. It helps designers optimise KoP design by considering part size, options, and meaning. The findings can help guide the development of new digital tools to enhance cooperative processes, emphasising the role of collaboration in face of accelerated technological and societal changes. By leveraging KoP and virtual environments, designers can navigate these changes and shape the future of more human-centric and responsive built environments.

Acknowledgement

This project was supported by The CUHK Seed Funding Support for Thesis Research and ICARE Social Service Projects Scheme. We are grateful for the help of Ms. Bingge XU, H.K.F.Y.G. Jockey Club Jat Min Youth S.P.O.T., and all participants. We give thanks to CUHK Library and Prof. Adam Fingrut for lending their VR headsets.

References

Abt, C. C. (1987). *Serious games*. University press of America.

Boden, M. A. (2009). Computer models of creativity. *AI Magazine*, 30(3), 23-23 https://doi.org/10.1609/aimag.v30i3.2254

CiC. (2020). What is MiC. Construction Industry Council, Hong Kong. https://mic.cic.hk/

Claypool, M. (2019). The Digital in Architecture: Then, Now and in the Future. Space10

Figueres-Munoz, A., & Merschbrock, C. (2015). Overcoming challenges in BIM and gaming integration: The case of a hospital project. *WIT Transactions on the Built Environment*, 149(149), 329-340. https://doi.org/10.2495/bim150281

Fuster, A., Gibb, A., & Beadle, K. (2009). Newways: An Industrialised Kit of Parts. *Open Building Manufacturing*, 1.

Gordon, E., & Koo, G. (2008). Placeworlds: Using virtual worlds to foster civic engagement. *space and culture*, 11(3), 204-221. https://doi.org/10.1177/1206331208319743

Han, J., Park, D., Shi, F., Chen, L., Hua, M., & Childs, P. R. (2019). Three driven approaches to combinational creativity: Problem-, similarity-and inspiration-driven. *Proceedings of the Institution of Mechanical Engineers*, Part C: Journal of Mechanical Engineering Science, 233(2), 373-384. https://doi.org/10.1177/0954406217750189

Ind, N., & Coates, N. (2013). The meanings of co-creation. *European business review*, 25(1), 86-95. https://doi.org/10.1108/09555341311287754

Sanchez, J. (2020). *Architecture for the commons: Participatory systems in the age of platforms*. Routledge.

UN Habitat (2016). Using Minecraft for Community Participation.

Wang, C. M., Shao, C. H., & Han, C. E. (2022). Construction of a Tangible VR-Based Interactive System for Intergenerational Learning. *Sustainability*, 14(10), 6067.https://doi.org/10.3390/su14106067

Zallio, M., & Clarkson, P. J. (2021). Inclusion, diversity, equity and accessibility in the built environment: A study of architectural design practice. *Building and Environment*, 206, 108352. https://doi.org/10.1016/j.buildenv.2021.108352