Common Ground—Online Platforms for Bottom-Up Collaborative Decision Making in Design Education

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Abstract. Co-creation and real-time collaboration have always been an integral potential of digital design methodologies and have been accelerated by the rapid digitalization of teaching due to current societal developments. This paper discusses the prototype of a real-time multiplayer building platform as a video game developed for a first-year design studio impacted by pandemic-related teaching restrictions. The aim was to develop a methodology that enables first-year students to meet peers, build models collaboratively, and teach implicit design knowledge such as aesthetics and formal analysis while allowing individual creativity within the populous class. Through a combination of a step-by-step iterative design system and a real-time decentralized multi-player platform, students can work collaboratively on common digital designs. The design method is based upon building units and individualized strategies of aggregation and differentiation that are built up into larger structures. Special focus is paid to how new online platforms created for architecture education can migrate the advantages of physical intuitive design methods to a digital setting and eventually fill the gap of lacking implicit knowledge pedagogies.

Keywords: Co-creation in design · Collaborative design · Real-time platform · Crowdsourcing · Game engine · Mass-customization

1 Introduction

With a 170-students-large design class of first-year students who do not know their peers amid the 2020 Covid-19 lockdown, we, as instructors, wondered how we will offer a studio culture experience during a 5-week workshop while communicating both explicit and implicit/tacit knowledge fundamental to the architecture discipline [14].

1.1 Explicit and Implicit Skills

To teach how to develop “good” design is to impart two forms of skills: explicit and implicit/tacit [16] skills. Explicit design intentions are easy to articulate and summarize in written form or drawings, as opposed to implicit design criteria which cannot be

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objectified or explained precisely, such as aesthetic preferences. In the discussed workflow, explicit knowledge encompasses disciplinary concepts such as typology, scale, and building blocks. The aim of the studio framework was that students understand that the design process of a building involves multiple steps, with various levels of detail, from small scale to large scale and vice versa.

The teaching of implicit/tacit knowledge is usually done via a design studio system where students design as a team and regularly meet the instructors to evaluate the results in a conversation. The process of learning how to design involves complex skills and decision-making (e.g., articulating design intentions through words and visuals, synthesizing often conflicting design intents and translating concepts into spatial elements and effects, abstracting specific ideas into abstract design diagrams and techniques) and is, to a large part, supported by a tacit acquisition like observing peers and tutors during designing. Even the surrounding studio filled with models, images, and artifacts play a major role [1]. According to Nigel Cross, design knowledge resides in people, processes, and products of design [3]. Consequently, it is necessary to learn in situations where all three of them are around or can be observed. A common understanding of design knowledge is that it is "person- and situation-orientated" [11], especially in the Anglo-American understanding [10] (which has been adopted also in most Austrian Architecture faculties), it is encapsulated and expressed in a "studio culture."

This well-established teaching method of learning by observing and reenacting was not fitting to the new teaching challenges: a very large class of first-year students who have never entered an architecture school, during online teaching. Despite these problems, we wanted to ensure the students' acquisition of implicit knowledge and a high level of individuality within their projects. We wanted to train their ability to self-evaluate design decisions and recognize the moment when "design" happens [4].

1.2 Teamwork in a Virtual Teaching Environment

The progress of remote and open-source collaboration in design and the consequences for production, decision-making, authorship, and concepts like authenticity or originality is not a new discourse [7, 17], but it has been accelerated by the Covid-19-related shift to remote working. Despite recent advancements, more intuitive hands-on processes such as collaborative model-making in environments that enable the transfer of tacit knowledge are hard to implement. We propose that online platforms specifically created for architecture education can transfer many advantages of in-presence design studios to a digital setting.

1.3 Project Intention

To address the challenges of virtual teaching in Covid-19 lockdown, we decided to develop our collaborative building platform in the form of a video game (Fig. 4.) and a corresponding design methodology (Fig. 1). The game had to be decentralized, accessible, easy to use, and motivating, enabling students to work collaboratively and facilitate social contact with peers. It was intended to be embedded into a consistent iterative design system that still allowed students creative exploration.

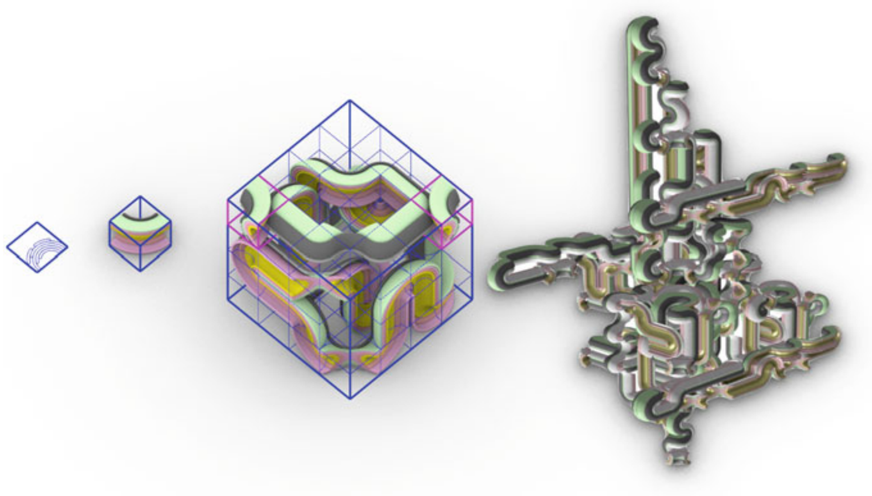

Fig. 1. A four-step process: 1. Curve → 2. Voxel → 3. Module → 4. Aggregation

2 State of the Art

Collaborative online games have been successfully adapted in science education and research: A prime example is “Foldit”, an online puzzle video game, which made laypersons find solutions for protein folding through a trial-and-error crowdsourcing approach [2].

In architecture, real-time building platforms are developed mostly as experimental design tools: Urs Hirschberg and his team at ETH Zurich developed a web-based system allowing users to work simultaneously on a common design project while being separated across three continents [7]. At TU Graz, Alexander Grasser and Alexandra Parger introduced concepts of configuration into the real-time building to inform the collaborative design process with three-dimensional reinterpretations of structuralist geometric operations [5]. Valerie Messini, Damjan Minovski, Dominik Strzelec, and Dominic Schwab developed a multi-user painting platform, where players use personalized brushes to “paint” collaboratively on a spatial “canvas” and tested it with students at the University of Innsbruck [12].

These platforms are great advances in collaborative design, but they lack certain qualities needed for an application in architecture education: 1. A mechanism within the application itself or its context to evaluate design decisions. 2. Integration in a larger pedagogical methodology. 3. The possibility to implement unique user-made objects. They consequently do not address the users’ engagement with aesthetics, missing out on the potential to let the users develop their approach towards design and form analysis.

We would like to fill this gap by focusing on the potential of real-time building platforms to teach implicit/tacit knowledge in an architecture design studio. This research process is based on three guiding principles: *collaborative bottom-up decision making*, a *grid-based design strategy*, and *gaming in architectural education.*

3 Concept

To elaborate on the three guiding principles and identify possibilities of implementing them in the game and design methodology, we set up a theoretical framework, which is briefly highlighted in this chapter.

3.1 Collaborative Bottom-Up Decision Making

Collaboration in Architecture: In their book "Open-Source Architecture" Carlo Ratti and Matthew Claudel advocate for the future of architecture discipline to become more collaborative, inclusive, and network-driven, based on the current online-technological advancements, such as open-source culture, crowdsource, and open-access principles [17]. The notion of open-source architecture is a novel way of designing, as opposed to the "starchitect" culture. Here, the architect serves as a curator and educator to many other people, designers, or non-experts. This inclusive approach to spatial design enables collaborative use of design tools by both professionals and laypersons: the term "citizen-centered design" emerges. The citizen-centered design movement is a key aspect of collaborative design at the intersection of design and public policy.

Decentralized Real-Time Collaboration: Urs Hirschberg acknowledges that collaboration across continents is flourishing with the accelerated development of internet-based open-source software and his research enables shared platforms for collaborative projects, opening up new avenues for collective authorship [8].

Findings for the authors' tool and methodology: The core intentions for *Common Ground* were based on Carlo Ratti's concept of open-source architecture. Urs Hischberger's decentralized multi-author approach proved to be a suitable way of implementing these intentions in a practical tool. Online collaboration and a free, accessible, and customizable platform were postulated as necessary and very valuable in this situation. Further, we saw the potential to open the platform to non-experts, in this case, first-year students, to expand the "citizen-centered design movement" within the setting of video games.

3.2 Grid-Based Design Strategy

Grid-Based Geometric Transformations: An early example of a grid-based design system is the educational practice of Jean-Nicolas-Louis Durand, who made his students draw on squared paper. Durand started by letting them design a catalog of stylized building elements, like porches, vestibules, halls, staircases, or courtyards, to develop a range of geometric vocabulary. The grid allowed precise positioning of standardized elements to be composed [15, p. 44].

Encapsulation of Design Decisions: When using tools and, especially, computers for design education, there is a potential of focusing on specific design decisions within the discussion with the students, by embedding pre-made decisions within the software. When operating the software, users automatically build on these decisions and use the design knowledge already embedded within the system. Andrew Witt calls this "encapsulated knowledge." Users do not need the design knowledge encapsulated in the tool, but only need to know how to access it [20].

Findings for the authors' tool and methodology: Like Durand, the authors' design methodology uses a grid to situate and measure compositions. To guide students through the complex process of designing, setting up a structure removes weight and leads the students faster towards creative work. This structure is especially relevant in large classes to guide the thought process of many students. Encapsulating knowledge and decisions within the tool helps strengthen this structure.

3.3 Gaming in Architectural Education

Component-Based Games in Architecture Education: Although component-based games have become popular within the last years in architecture, they have been used in education for centuries [13, p. 83]. An early architectural example is the "Riesenspielzeug" ("Giant Toy"). It was invented by German architect Gustav Lilienthal in the 1880s after seeing prefabricated houses in Australia. The game consisted of standardized wood elements and metal wedges, designed to accurately represent the elements and systems of technical building construction. Their large size allowed for constructions up to 1 m high and offered various connection possibilities. The system was intended for children and architects alike to create miniatures of real buildings [13, p. 99].

The Logic of Continuity: In the 1970s graphic designer Ken Garland developed "Connect," a game of 140 cards with red, blue, and black lines and curves of different colors. Players had to place the cards on the floor in a way that the curves formed a continuous loop while winding them around furniture or other obstacles. "Connect" is a great example of how a design language and aesthetics can be embedded in a game while allowing autonomous decision-making; it was adapted for design education [6].

Video Games as Educational Tools: Today, there are countless architecture/city planning-themed video games, but most are not suitable for architectural education. City-building games usually depend on a strict set of rules and relationships, forcing the player to build a "realistic" city. To develop and teach original architectural design, it is more suitable to leave the outcome unpredictable and let the players decide if the outcome is successful. As architect and educator Damjan Jovanovic puts it: "Play does not have to be always goal-oriented, and although most games do have a goal (the 'win' state), more and more the inherent specificity of experience leads to the player being content with merely 'existing' within a game. Immersion does not depend on and is more likely even disturbed by direct calls for action towards reaching a goal." [9, p. 33].

Findings for the Authors' Tool and Methodology: "Gaming" as a didactically premeditated methodology, which allows to channel design options and increases the students' understanding of their design decisions and consequences [19]. The component-based system of the "Riesenspielzeug" is a great precedent for the building logic because it allows for three-dimensional aggregations in many configurations. "Connect"'s logic of continuity became one of our main principles when developing the design logic for the studio. We wanted to implement these two aspects into the framework of an open non-goal-oriented video game.

4 Practical Implementation of the Concept

4.1 Design Methodology

Based on these three key features, we developed a design methodology, including a step-by-step design and evaluation process, wherein groups of students collaboratively designed their building components and used those to build large aggregation in an online video game setting. To break down the complexity of large aggregations, the design method is made of steps that build upon the last step, gradually increasing the level of detail. Breaking the task down into smaller steps helps slowly move towards an implicit knowledge of designing complexity. The game helps communicate this form of knowledge playfully while simultaneously providing the fun part of playing the video game with peers. In the next paragraphs, this process will be explained in detail (Fig. 1).

Step 1 "Curve": The process starts with a simple 2-dimensional curve drawn in Rhinoceros 3D, fitting a 3-by-3 m bounding area. Students were encouraged to develop different versions of curves for further testing and evaluation in Step 2 (Fig. 2).

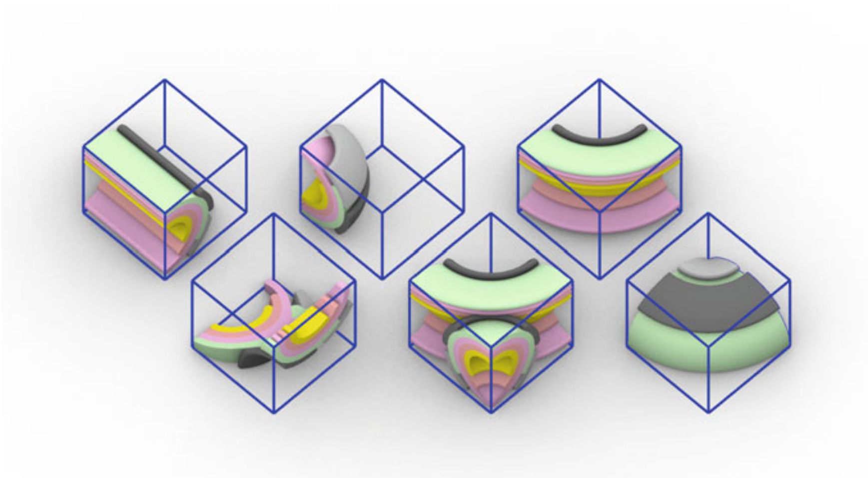

Fig. 2. A minimum set of different voxel types are needed to fill the modules: straight, left angle, right angle, multiple connections, up, down

Step 2 "Voxel": Students three-dimensionalized their previously developed curves with various manipulations, such as linear and non-linear extrusions, rotations, and boolean operations to fit a $3m^3$ bounding box. They had to make six different voxel typologies that can be rotated to ensure the continuous connection between the voxels for the next step: a straight connection, left corner, right corner, joint right and left corner, down corner, up corner (Fig. 3).

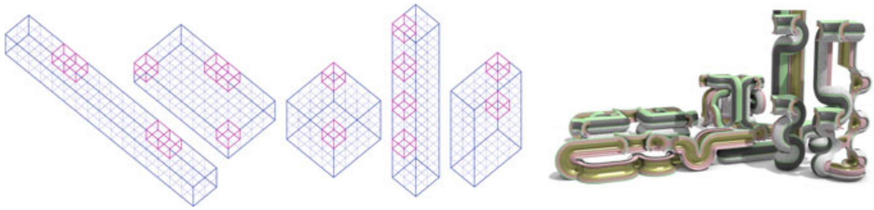

Fig. 3. The five-module types with connection blocks and the same modules are made of continuous voxels, leaving open ends for module-module connection

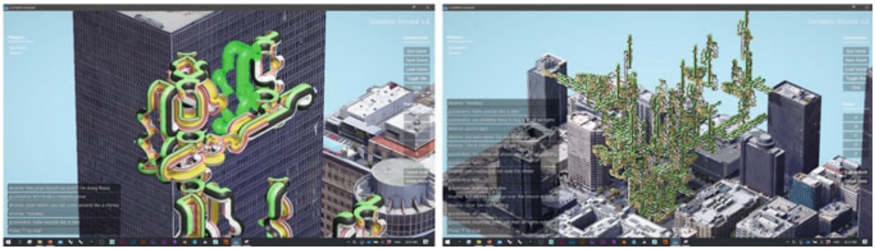

Fig. 4. In-game collaborative aggregation process

Step 3 "Module": To achieve a diversity of possible decisions for the final aggregation, we defined five larger "module" bounding volumes in different dimensions based on a 3 m x 3 m 3D grid. Each module contains 64 voxels. The modules have several connection blocks needed for future continuous assembly in the final step. Students now used their previously designed $3m^3$ voxels to fill the space between the connection points inside the module in a continuous procedure, leaving loose ends only at the connection blocks. Not every empty position has to be filled with a voxel object. Meanwhile, it is challenging to select the correct "corner voxel" to create continuity within the tight limitations of the bounding volume (Fig. 4).

Step 4 "In-game Aggregation": The modules from Step 3 are uploaded to the game engine and form a 5-piece collection of building elements within the game. Students then log in as a group and choose from the modules to assemble them collaboratively and evaluate their results in the context of a city environment. Connection blocks on the modules guarantee continuity between modules as well as a range of aggregation possibilities due to their alternating position within the module (Figs. 5 and 6).

Co-Evaluation of Design Outcomes: In between each step, students are encouraged to follow an evaluation cycle that starts with the design, then evaluates its eligibility for the next step. Design choices like low density vs. high density or simplicity vs. complexity were left to the students. If it succeeds, the design continues to the next step. If not, it will be redesigned, re-evaluated, and so on until it is declared eligible for the next step.

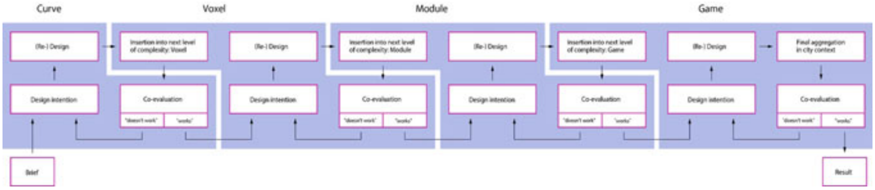

Fig. 5. Diagram of the iterative design method

Fig. 6. Evaluation renderings of the same project in various stages. (*Credit* Miriam Meyer, Matti Schlenther, Noel Melmer, Maximilian Rieder, Julia Muschler)

Hence students get to slowly integrate how to design best, which feeds their implicit knowledge. Designing is a quality that cannot be taught as straightforward as a history class which is why such methods of self-evaluation and re-adaptation are necessary.

4.2 Game

The name "Common Ground" suggests that users share the same site, basic building elements, and game rules. Important aspects are the multi-player feature, the in-game communication through the chat, and the realistic representation of the 3D city environment through shadows and materials. The players are given a free-roaming camera from an aerial viewpoint to view the whole scene.

Preparation & Export: Users need to design assets in a 3D modeling software of their choice, within the predefined bounding boxes of the modules, their size, and the location of the connection blocks. (Fig. 3) Next, they export the modules and add them to the game engine.

Download & Installation: The game can be made publicly available and downloaded from a conventional server or file-sharing site such as OneDrive, Wetransfer. After unzipping the file, the application is operative.

Login & Group Selection: Upon starting the application, the users enter a log-in screen. They can choose a nickname and the number of their group, which is linked to their five previously designed modules. They then proceed to a lobby room where they can create new groups of collaborators or join already existing groups. After pressing "start," they enter the virtual building environment.

Navigation & General User Interface (GUI): Inside the building environment, players can use their mouse to navigate around the virtual construction site, pan left and right, and zoom in and out. The GUI of the game includes a set of buttons, which can be used to select the desired modules for the construction or deletion of modules. Selecting a part from the catalog activates the building mode and moving the mouse cursor points to the desired building location. Further options include “Quit Game”, “Save Scene”, “Load Scene”, “Toggle Site”, “Chat”, and “Cancel Build”. Players can see a list of their collaborators and a chat window for communication.

Design & Communication: The real-time aspect is key for users to react rapidly to their teammate’s new placements. When building, new blocks quickly appear in different places. Some users concentrate on one area, others try to build higher, wider, more compact, horizontal slabs; every player has their unique playing and building behavior. In addition, users can communicate verbally as well over the chat function (Fig. 7).

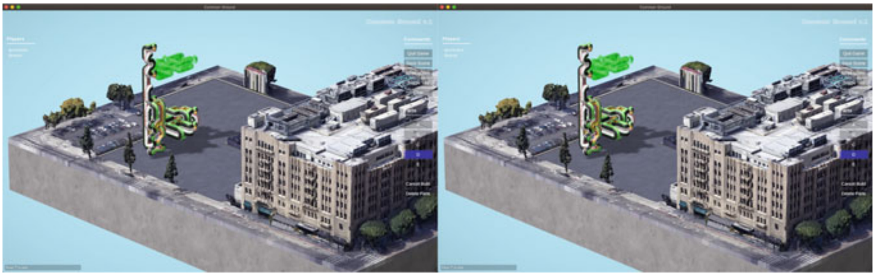

Fig. 7. Possible positions are rendered green, impossible ones are rendered red

Progress Saving & Logout: Users can save their progress using the corresponding button in the GUI. They can then log out of the game and continue working on their saved progress in a later session.

4.3 Implementation of Guiding Principles

The game is set up to allow collaborative bottom-up decision making, a grid-based iterative design system in education, and gaming in architectural education.

Bottom-Up Decision Making: The game space hosts up to 100 players simultaneously, who get real-time updates when new parts are added or deleted by other users. This makes communication essential and encourages collaborative decisions about the development of the structure.

Grid-based Design Strategy: To condense the learning experience, specific design decisions and geometric operations, which would usually require a high understanding of 3D software, were embedded into the game. This enabled the students to focus on the essential tasks, without having to deal with too much complexity.

Gaming in Architectural Education: The simplified GUI and playful art style of the game encourage students to experiment without the fear of being wrong. Choices on aesthetics and grade of abstraction were made by the students, allowing them to approach the design problem more pragmatically or experimentally. Even though these decisions were discussed intensively, the game did not judge them (Fig. 8).

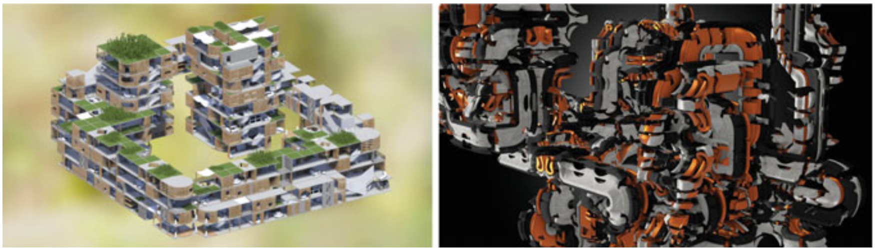

Fig. 8. The workflow allows for the expression of subjective design preferences and different degrees of abstractness. (*Credit* Antonia Hornauer, Hannah Rainer, Irinia Radeva, Katharina Rauch, Christian Rehnisch and Leander Gasteiger, Mara Ruperti, Vincent Reichardt, Bert Landsmann, Samuel Schmid)

5 Survey

Survey Setup: To evaluate the effectiveness and learning experience of our pedagogical method and tool, a survey was sent to the 170 participating students. The questions were directed towards the performance of the method and tools used in the context of distance learning, collaboration, imparting of explicit and implicit design knowledge, and the general group working experience. The survey was structured as a written interview including questions such as: "Are you satisfied with the way distance learning was handled?", "How is it a restriction or an improvement against physical class?", "Do you have any feedback on the course material and structure? What was the most successful part?".

Survey Results: 70% agreed that in the context of distance learning, the teaching method was comparable to the advantages of physical group work. Examples of answers are "I have been feeling extremely lonely and isolated this semester and this course was the one exception." or "In our group, we could work together at any time and place. That was efficient." Regarding the online pedagogy, one reply was: "Really great that you can get a project going in this short time only via Zoom, Miro, and Vimeo". The final video game was successful as the questionnaire showed 80% satisfaction with the game as a design-pedagogical tool. Students replied: "The most successful parts were the game and in the beginning the design of each voxel.", "I like the idea of starting simple and increasing the project to a large building." or "Most successful part—to see the whole project "grow" and create different aggregations in the game".

The feedback indicates that students enjoyed seeing the project grow by starting with simple voxel designs, increasing the scale, and finally creating in-game aggregations. They were also excited about having their own designs as actual building elements in a video game that they played together with 5–10 players. Chatting in-game and video calling while playing nurtured peer contact (Fig. 9).

Fig. 9. Two examples of teams of five students aggregating the elements together into architectural figures in real-time in the game Common Ground. (*Credit* Andreas Lederbauer, Ariana Gosalci, Chiara Koch, Lena Jenn, Sophie Gruner and Dominikus Schlögl, Theresa Riedmann, Sarah Rieder, Kilian Rietzler, Poledt Cedillo Peralta)

A suggestion for improvement was a clearer outlook on the final product of the studio to help the students improve their objects' fitness progressively.

6 Conclusion

The three key features of this project are *collaborative bottom-up decision-making*, a *grid-based design strategy*, and *gaming in architectural education.* Addressing the combined factors of Covid-19 lockdown, a class of 170 spatially separated first-year students, while teaching online, the project successfully fulfilled its pedagogical aim: to develop a method and tool for collaborative design decision-making for a large class, teaching implicit skills and effectively establishing a virtual studio culture.

The students developed a series of designs implemented in the online multi-player real-time video game "Common Ground". The game is accessible as a multi-user tool in the design context. Thanks to the user-friendly nature of its interface, it is ideal for distance education, facilitates student–teacher and student–student communication, allows students to simultaneously design complex aggregated structures, and encourages them to communicate through the in-game chat function. This step-by-step design cycle method improves the students' implicit skills while the boundness to the 3-dimensional grid structure, the voxels, and the modules, helps open a framework for creativity and freedom. In the end, the students produced 36 unique sets of 5 modules made of continuously attached voxels and even more aggregations in the game.

The project is a continuation of the use of game engines in the architecture field. In this case, the game was the last step at the end of the semester while the rest of the design process focused on creating the assets for the game with conventional 3D modeling software. In the future, it would be interesting to weave 3D assets earlier in the game as a constant back and forth manner to test how they perform in the final environment. The learner could evaluate its fitness through the game itself.

Finally, the step-by-step process in combination with the game initially developed for educational purposes could be used for "citizen-centered design with "real world" communities. It allows people with no background in architecture education to evaluate their own design decisions in collaboration with their peers.

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