

# Investigating Digital, Tangible, and Paper-Based Room Design at a Small Scale

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## Abstract

Miniature representations, like CAD and blueprints, are useful for designing a larger physical space. While experts are trained to use these methods, non-experts often lack this training. Nonetheless, non-experts can benefit from designing with miniature representations, yet their interactions with these tools are not well understood. In our work, we observed participants designing two rooms using three tools: an online planner, pen and paper, and Lego. We collected and analyzed data from the Desirability Toolkit, a semi-structured interview, and observations of their design sessions. Our findings suggest that participants found each tool engaging and satisfying for different reasons, but paper more empowering and Lego more familiar, efficient, and unconventional. Participants also suggested that these tools had value at different design stages. We also identified that participants often had difficulty scaling objects to match realistic expectations in the paper and Lego miniature representations.

## CCS Concepts

• Human-centered computing → Empirical studies in HCI.

## Keywords

Miniature, Design, User Experience, Mixed Methods

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## 1 Introduction

Worlds-in-miniature (WiM) have been around for a long while. These miniature models are common in architecture, engineering, and construction (AEC) [17, 23, 32], but their use has been expanded into other applications [15, 22, 28]. However, tools based on these concepts are mostly designed for and used by a small proportion of the general population, primarily experts, and often neglect any form of tangible experience.

Trends like do-it-yourself (DIY) and democratizing design activities like software design and AR/VR/3D content authoring have gained popularity and are empowering non-experts to engage in design activities [42, 46]. Despite this popularity, digital tools for

miniature representation (e.g., CAD tools) are often not designed for non-experts. As a result, non-experts are often left to use simplified design processes, like drawing on paper when planning their room layouts or using tools like the IKEA room planner. However, it is unclear if these simplified miniature representations are adequate and what the non-expert experience of using them is like.

Additionally, physical 3D representations (e.g., scaled architectural models) are currently inaccessible to non-experts and, while there have been efforts made to integrate haptic experiences [4, 17, 32, 43], tangible interaction is still nascent. In this paper, we address these gaps by investigating how non-experts use tools (both tangible and traditional) for design tasks.

This paper presents findings from a mixed-method study where we observed participants designing a room layout using miniature representations of larger physical spaces with existing tools (paper and digital), as well as tangible Lego blocks. We collected video data to observe the design process with each of these tools and used the Desirability Toolkit [5] with a follow-up semi-structured interview to collect participants' affective experience with the tools. Our analysis shows that while the online tool benefits from the constraint of having correctly scaled selections of furniture, it can limit creativity. On the other hand, paper and pen and physical Lego bricks offer flexibility, promoting personalization and customization. These findings suggest that future designs could combine tangible interaction (e.g. Lego blocks) with digital experiences, such as AR/VR, to further democratize design activities for a broader audience, including non-experts.

## 2 Background

Our contribution focuses on understanding user experience when interacting with miniature representations and how they utilize widely available methods. We discuss miniature representation and how we position this paper.

### 2.1 Design in Scale

Designing in scale, using miniature representations of larger physical spaces, is common practice in architecture, engineering, and construction (AEC), as well as in design. The HCI community has also explored the use of miniature and scaled objects as interactive objects. World in Miniature (WiM) [40] extends the use of miniature models from a means of representation to an interaction method. Miniature models provide an overview of large areas and allow users to interact with and manipulate scaled objects. Urp [43] also uses the advantage of miniature representation for urban planning, which is impossible at a one-to-one scale. Miniature design tools [17, 23, 32] leverage small objects to represent larger ones, which can be especially useful for large-scale projects, including urban



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planning and architecture design. The miniature concept is also used in media production by researchers, for character animation [22], theatrical work [15], large public interactive displays [28], and car showrooms [39]. Miniature-based design tools excel at providing spatial information directly on the objects associated with the location. The AEC and design domains have been using miniature design tools extensively, but how less experienced users perceive such interfaces and how we can improve these are underexplored.

## 2.2 Non-experts as Designers

Psychologists began investigating how designers design as early as the 1960s [45]. Understanding designers' cognitive processes is crucial because it can provide generative ideas for designer tools that are eventually available to them, ultimately improving the quality of work. Researchers have started investigating how less experienced designers approach design problems and work, compared to more experienced designers [1]. Similarly, the effort to understand non-experts has been made by highlighting the differences based on experience level and expertise. Given a design problem, experts (architects) tend to analyze it more deeply and identify it more than students with the same problem [41]. A similar attempt in the engineering sector to compare behaviours based on different expertise has been made. The main difference is that less-experienced designers tend to implement a solution as soon as it is found, showing a tendency to use "trial-and-error" [1].

**2.2.1 Mass Architecture.** "Mass Architecture," which promotes architecture as more accessible to the general public, has been a growing phenomenon in recent years [29, 46]. Bringing non-experts into the design process is not new and has apparent benefits, accelerating the overall process and bringing high satisfaction to the client [14, 36]. Currently, AEC is mainly done by experts, a tiny percentage of the population [33]. The discipline is still considered "closed" to the general public [44], even though most residents of architecture projects are non-experts.

**2.2.2 Demand for Democratized Design.** There is an increased demand for personalized homes [11]. Recent technological leaps in virtual and augmented reality allow us to develop a non-expert-centric system. Interest in VR and AR for architecture is growing [3, 11, 35, 47], yet the adoption rates are slow in architecture compared to other industry sectors [29]. Still, the demand has been consistently increasing [27].

Democratizing technology and design activities made a significant footprint in HCI and CSCW [42]. However, studies on the general public—rather than apprentices or students in related fields—tackling design problems with miniature representation have been underexplored. Thus, our definition of a non-expert is one without formal training or education but interested in doing *the activities*. It is challenging to close the gap between experts and non-experts because of a gap in domain knowledge [30], yet the importance of active participation from all stakeholders is often mentioned [38]. As self-design and DIY trends become popular, we see a surge in building materials and the demand for appropriate tools. The general approach to providing needed tools to the general public is the abstraction of complex processes and concepts [48], but this kind

of abstraction implicitly limits non-experts' creativity, preventing customization and personalization.

## 2.3 Tangible Interfaces for AEC

Architecture and interior design tools require users to have extensive training because they offer various features for complex design work. Tangible interfaces, rather than using a mouse and keyboard, introduce new ways to interact with objects. Bricks introduced a graspable user interface with physical objects that can be mapped to virtual objects [13]. It suggested a baseline for tangible user interfaces and later literature, which is also heavily used in design tool research. Similarly, Urp uses the concept of a graspable user interface in an urban planning tool that can be used on a table [43]. Schubert et al. [37] used tangible interfaces for the early stages of architectural design. They use object recognition of the simplified and scaled physical model to represent the design. Salim et al. [34] proposed a similar concept using physical models for urban design on a table.

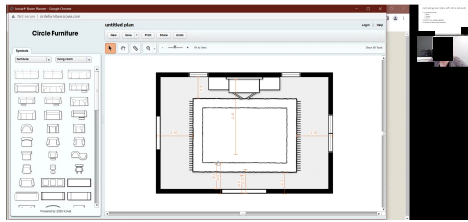
**2.3.1 Leveraging Physical Interfaces.** The lack of skills and design training is a significant setback, making novices reluctant to be active participants [6]. Physical interfaces, such as Lego, help non-experts to be more active participants and generate more elaborate and creative ideas during the design process [7]. Physical interfaces and props are used during prototyping and are standard practice in the AEC sectors. This is also accepted as an essential step in various design stages [10].

While prototypes for tangible interfaces for AEC have been studied, our work builds on this research by investigating how non-experts interact with tangible (Lego) miniature representations, compared to paper, pen and digital representations.

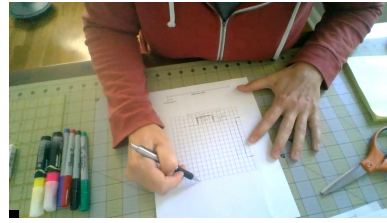
## 3 The Study

Our study investigates the use of physical and digital media for the creation and design of physical spaces. While architectural and interior design has a wide variety of miniature representations of physical spaces (e.g., architectural scale models, drafting documents, etc.), we focus on the application of room layout for several reasons: (1) it is a miniature representation of a physical space that many people are familiar with, (2) there are already online tools available for non-experts for this process, (3) it has both 2D and 3D aspects to the design process, and (4) there are examples already in HCI literature that use this task that this work can build on.

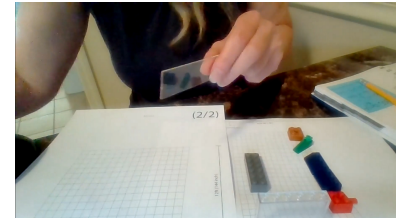
As this work is an early exploration of miniature representations of physical space, we opted for a mixed methods approach that leans more toward qualitative analysis when possible, because we did not have clear hypotheses. Nonetheless, we wanted specifically to contrast the experience of using physical 3D media (Lego), physical 2D media (pen and paper), and digital tools. On the quantitative side, we used a validated scale to collect data about flow experience, but our primary data collection was a combination of the Desirability Toolkit [5] and interview data.



(a) Participant with Online condition



(b) Participant with Paper condition



(c) Participant with Lego condition

Figure 1: How we recorded the videos. Participants working on the design.

Employment	N	Design Exp	Arch Tools	Skill	3D Tools	Skill
Educational services	8	4				
Professional, scientific or technical services	8	6	3	6.0	4	5.7
Other services (except public administration)	5	4	2	4.0	1	3.0
Health care or social assistance	3	3				
Construction	2	2	1	5.0	1	5.0
Real estate or rental and leasing	1	1				
Utilities	1	1				
Retail trade	1	1				
Arts, entertainment or recreation	1	1				
	N=30	N=23	N=6	M=4.3 (SD=2.3)	N=6	M=5.2 (SD=1.2)

**Table 1: The breakdown of participants by profession. While most had planning or design experience with architecture or interior design, this included simple tasks like laying out a room (which we consider common for non-experts). Additionally, six participants had experience with architectural and 3D modelling tools, respectively (5 of these were the same participants), though typically skill with architectural tools was rated lower than for 3D modelling tools.**

### 3.1 Participants

We recruited 30 participants (21 identified as women, 9 as men, 0 as non-binary; age: 21–79,  $Mdn = 42$ ) from UserInterviews.com<sup>1</sup>, a third-party participant recruiting service. We did not set specific inclusion or exclusion criteria for background (knowledge, education, profession), though we aimed to recruit interested individuals for rich outcomes and analysis, as our study advertisement included the description of designing interiors and room layout. As a result, most participants (23 out of 30) indicated they had been involved in these activities in some way, including basic room planning (arranging and moving furniture) or related gaming experiences like The Sims. Six participants had experience using 3D modelling tools like 3DS Max and Maya and described their skill level on a 7-point scale from beginner (1) to expert (7) with a mean of  $M = 4.3$  ( $SD = 2.3$ ). Five of those six also indicated experience with architectural tools and similarly rated their skill ( $M = 5.2$ ,  $SD = 1.2$ ), indicating a small subset of participants had related knowledge of and interests in interior and room layout activities (Table 1). All participants reported having at least a college credit or a Bachelor’s degree, including 13 postgraduate degrees (Master’s, Ph.D., professional degree).

**3.1.1 A note on sample size.** There are a number of methods for determining sample size in qualitative studies. We used a purposive

<sup>1</sup><https://www.userinterviews.com>

sampling technique based on advice from Malterud et al. [25] that uses information power rather than saturation. This model suggests five dimensions: study aim, sample specificity, established theory, quality of interview dialogue, and analysis strategy to determine information power. We determined that we had a narrow study aim (fewer participants), but our sample was quite general, with no exclusion criteria (more participants), with a theoretical foundation that was neither especially strong nor absent (neutral), a novice interviewer whose shyness might have affected the ability to establish a good dialogue (more participants), and our analysis crossed three conditions rather than focusing on one (more participants). Nonetheless, the interviewer’s experienced supervisor has conducted many similar studies that have led to rich data with as few as 8 participants. Based on these considerations, we cautiously appraised our case to require about 30 participants (10 per condition).

### 3.2 Method

The study was conducted online using the video conferencing platform Zoom, due to the risk of COVID-19 at the time of the study. All participants were asked to prepare and set up a webcam prior to the session. After a brief introduction, ensuring the webcam and materials were set up properly, and obtaining informed consent, participants designed two rooms (a living room and a kitchen) for a family with two parents and two children (one teenager and one toddler). For each room, they were given a list of fixtures to place, and the dimensions and shape of the room, but no other constraints were suggested (i.e., specific furniture selection, size, colour, etc.). We also prompted participants with examples of what could be placed in each room and asked participants to choose and design features such as doors, windows, walls, and entryways. Participants were asked to think aloud while designing the rooms. Each session lasted about an hour, and participants were given a remuneration digital gift card valued at 20 USD.

Participants began with designing the living room, followed by the kitchen. The specifics of each room were as follows:

- The *living room* had a rectangular shape of 18 by 12 feet (5.49 m × 3.66 m) and participants were prompted to add a door, window, and lighting and furniture as they desired. We also provided the example of a play area for the toddler.
- The *kitchen* was 12 by 12 feet (3.66 m × 3.66 m), and participants were prompted to add a cabinet and major kitchen appliances (refrigerator, stove, etc.) and countertops/islands as desired.

Following the design activity, participants were asked to complete the FSS long version of the flow scale [21], and were then asked to complete the Desirability Toolkit [5], followed by a short interview. After the interview, we collected demographics.

**3.2.1 Conditions.** We had participants design the layout of a room in one of three conditions:

- **Online:** We used a publicly available online planner<sup>2</sup>, that was less likely to be used by our participants than other more popular tools (e.g., Ikea). This tool uses a 2D top-down view and provides comprehensive options, such as room shape, size, and lists of furniture and objects based on sections of a home (living room, bedroom, garden, etc.), essentially acting as a CAD tool for the non-expert. Before completing their design, we provided participants with a brief demonstration of the basic operations of the online planner, such as placing objects, rotating, scaling, and browsing.
- **Paper:** We included this option as a more traditional and accessible way to design the interior, using common household items, such as pen, pencil, paper, and ruler. While we did not limit the selection of objects used in each session, participants still needed to bring our base grid paper (provided as two printable digital documents, one for the living room and one for the kitchen) and a drawing tool (pen or pencil). Participants could also bring an eraser, ruler, and scrap paper.
- **Lego:** We asked the participant to bring at least 100 Lego pieces (specifically, “Bricks”<sup>3</sup>). Participants would assemble a variety of pieces on the same piece of grid paper used in the paper condition.

We provided participants with two separate portable document format (PDF) files for the grids for the living room and kitchen. Each cell was approximately 8 mm × 8 mm and corresponded to 23 cm × 23 cm (9 inches × 9 inches) in real-world conversion. One cell was designed to fit one bit of Lego brick. In the online tool, we instructed participants to manually adjust the size of the room (by typing numbers). The online tool used a responsive design, so we could not easily control the physical size of the miniature representation. With the online tool, participants could also zoom in/out dynamically as needed. On a 1080p, 21-inch monitor, this would correspond to a 1:26.6 scale on the default view, at 100% zoom level (in contrast to the 1:28.7 scale for paper and Lego).

### 3.3 Measures & Data Collection

We used several measures to gather qualitative and quantitative data covering both breadth and depth. We elaborate on collection methods, including the Flow Scale, the Desirability Toolkit, the follow-up interview, and observation:

- **Desirability toolkit:** The Desirability Toolkit [5] was initially created to collect data about “desirability”, but more generally, can be used to elicit a participant’s experience using a tool. We included 30 descriptive words (e.g., innovative, time-saving, ineffective, irrelevant) and first asked

participants to select as many words from this list as they wanted to describe their experience. Then, they were asked to select their top 5 words from that shorter list. The order of words in the list was randomized for each participant.

- **Interview:** An important part of the Desirability Toolkit is to follow this selection with an interview to discuss the experience. We used a semi-structured interview that began with, “How was your experience in general?” Whenever possible, we asked follow-up questions related to the previous question, even if the question was not on the question guideline. We also requested a specific rationale for their five words from the Desirability Toolkit.
- **Observations:** The design sessions by each participant were recorded, and the webcam was positioned so that the experimenter could observe the participant and the tool (online: screen capture + webcam on participant; paper and Lego: webcam pointing down to see paper/Lego during the design process).
- **Flow Scale:** The Flow Scale measures the responder’s flow state, indicating the balance between their skills and the task’s challenges, thus showing how deeply users are engaged in the task. Specifically, we used the FSS Long version [21], retrieving the original wording and question order for all participants.

## 4 Findings: Observations

In addition to the interview data, we analyzed the video recordings from the design sessions, borrowing concepts from reflexive thematic analysis [8, 9], such as familiarizing ourselves with the dataset and using multiple passes to identify recurring patterns. Specifically, the experimenter did a first pass to review the videos, taking note of interesting patterns. In a second pass, the experimenter labelled interesting segments of the videos. In the third and subsequent passes, patterns of behaviour were identified.

### 4.1 The Disparity in Object Scaling

When representing furniture and other objects in their room layouts, there was a clear pattern of notable variation in scale representations in the paper and Lego conditions, unlike the online condition, which had predefined sizes that were common in real-life scenarios. To demonstrate this discrepancy, we picked a sofa (which all participants represented) and converted the scaled representation to its actual length in centimetres. A boxplot and dot plot for each participant’s sofa length is shown in Figure 3. When reading this plot, it is useful to consider the online condition as “standard” in order to see the variety in the other two conditions.

To demonstrate how we determined these calculations, Figure 2 shows an example of sofa representation in each condition. The sofa in the paper condition (middle) was counted three deep as seating and 12 in length (longer, back of the couch). In the Lego condition (Figure 2, right), we can count 2 in depth and 14 in length. As we provided the same grid paper for both the paper and Lego conditions with the dimensions and conversion noted directly on the PDF (living room and kitchen), we can see the varied sizes of the same functional objects. In our grid paper, one cell converts to a 9-inch square (appx. 22.86cm on every side) in real-world size.

<sup>2</sup><https://circlefurniture.icovia.com/>

<sup>3</sup><https://www.lego.com/en-ca/pick-and-build/pick-a-brick?page=1&filters.i0.key=variants.attributes.subcategoryId&filters.i0.values.i0=1>

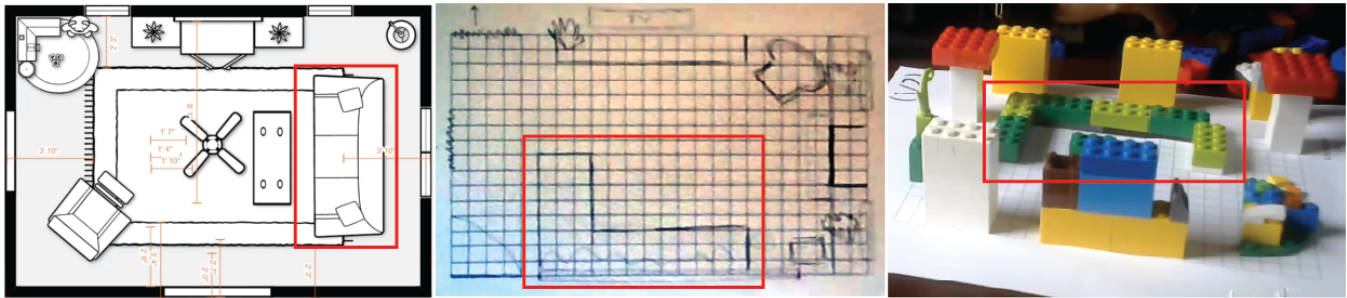


Figure 2: Sofa in three different design tools, highlighted with red

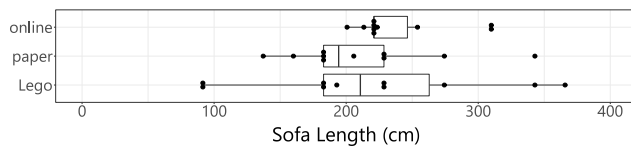


Figure 3: Size (length) comparison of participants' sofa sizes.

**4.1.1 Online.** In the online condition, participants used the supplied objects on the website we provided. All of the objects had dimensions ( $W \times L \times H$ ) noted in a separate window, so the participants had access to the exact size. The default size of the objects was close to what is considered “standard” sizing in real life.

**4.1.2 Paper and Lego.** In the paper and Lego conditions, participants showed a large gap between their size and the standard size of objects. In the example in Figure 2, a participant in the online condition placed a three-seater sofa. In contrast, the paper and Lego participants placed a sectional sofa but represented it as too small.

Because we did not ask how many people could be seated on the sofa they were placing, there is some room for interpretation of the intention of the participants. It seems clear that both when drawing or using physical props to design an interior, participants experienced difficulty converting their scale perception onto grid paper, even though the dimensions were provided. This scale perception difficulty might lead to other issues when designing. We occasionally see participants using an eraser in the paper condition and similar methods in Lego, such as reassembling into a different size or unusual scaling relative to other objects in the same design. For example, in Figure 2 with Lego (right), white blocks with red tops represent floor lamps (next to their sofa, red circled). Considering the “standard” floor lamp size, we can interpret that the scaling is difficult, or we can infer a limitation using Lego bricks since Lego bricks are provided “as-is” in their sizes and availability at hand, limiting flexibility.

## 4.2 Freedom of Expression

In the online condition, participants were limited to selecting only the objects available, but in both the paper and Lego conditions, they had more freedom to express their own intentions. This was, in some cases, intimidating, but they spent time creating objects matching their real-world counterparts.

**4.2.1 Paper.** In our semi-structured interview, several participants mentioned they felt incompetent in drawing, even though we noted that we did not intend to test or evaluate their drawing skills or final drawing at the beginning of the study. In most cases, participants tried to draw the objects instead of using abstract geometrical shapes, such as rectangles or circles. This suggests that feeling less competent in drawing skills could impact the design process, making them passive rather than active participants.

**4.2.2 Lego.** Participants with Lego bricks showed a similar way of representing or replicating objects with their Lego bricks. Since we asked the participants to bring enough pieces (100+ pieces) for the session, many participants brought pieces with different shapes and colours. Participants then assembled them into a similar shape or colour, resembling their real-life counterparts. For instance, they used green pieces to represent plants and clear (transparent) pieces for windows. We infer this as participants wanting to show higher fidelity so they could conceive the design better. Thus, high fidelity and instant feedback might be empowering, especially for non-experts.

## 4.3 Design Processes with Each Tool

We found that participants exhibited different behaviours when designing with each tool. In this section, we describe in detail how participants approached the design problem in each condition, looking both at how they set up the space around them as well as additional details about how they did their work.

**4.3.1 Online.** Participants frequently changed their minds about what furniture or features they wanted and replaced objects in their room layout. Since the online tool allows for easy editing, participants used this feature extensively. Once they decided what type of object to add (usually “landmark,” the largest object), the participants navigated through lists of objects provided by the online tool. While browsing each object, they often placed them in the room to get more detail, such as exact measurements.

After initial browsing and navigating, participants decided on the object type (e.g., TV or Sofa for the living room) and its variations (e.g., loveseat or three-seater). Space dividers or landmarks were placed first, and minor features, such as tables and lighting, were decided later. We also noticed frequent relocation of objects as participants leveraged the benefit of having a digital tool. Participants repeatedly replaced their objects with the same type in a different size or variation. These actions were chained into other objects'

Word	Online	Paper	Lego	Total
Engaging	7	10	10	27
Satisfying	5	8	7	20
Organized	7	5	7	19
Innovative	6	4	7	17
Intuitive	3	7	5	15
Empowering	3	9	2	14
Accessible	5	5	2	12
Efficient	2	4	6	12
Motivating	1	6	5	12
Comprehensive	5	3	3	11
Effortless	1	4	5	10
Time saving	5	3	2	10
Familiar	1	3	5	9
Confident	2	3	3	8
Unconventional	1	3	4	8
Complex	3	2	1	6
Collaborative	1	0	3	4
Intimidating	1	2	1	4
Time consuming	1	1	1	3
Difficult	1	1	0	2
Frustrating	2	0	0	2
Hard to use	2	0	0	2
Predictable	2	0	0	2
Too technical	2	0	0	2
Confusing	1	0	0	1
Irrelevant	0	0	1	1
Overwhelming	0	0	1	1
Unpredictable	0	1	0	1
Inconsistent	0	0	0	0
Ineffective	0	0	0	0
<b>Total</b>	<b>70</b>	<b>84</b>	<b>81</b>	<b>235</b>

Word	Online	Paper	Lego	Total
Engaging	7	9	8	24
Satisfying	5	7	5	17
Empowering	1	8	1	10
Motivating	1	5	4	10
Organized	5	2	3	10
Innovative	4	1	4	9
Intuitive	3	4	2	9
Comprehensive	5	1	2	8
Familiar	1	2	4	7
Efficient	1	1	4	6
Time saving	4	1	1	6
Accessible	2	2	1	5
Complex	3	1	1	5
Unconventional	1	1	3	5
Confident	0	1	2	3
Intimidating	0	2	1	3
Collaborative	0	0	2	2
Effortless	0	0	2	2
Frustrating	2	0	0	2
Confusing	1	0	0	1
Difficult	1	0	0	1
Predictable	1	0	0	1
Time consuming	1	0	0	1
Too technical	1	0	0	1
Hard to use	0	0	0	0
Inconsistent	0	0	0	0
Ineffective	0	0	0	0
Unpredictable	0	0	0	0
<b>Total</b>	<b>50</b>	<b>48</b>	<b>50</b>	<b>148</b>

**Table 2: Frequency tables (left: from initial 30-word list, right: top 5 words) of word choices by condition.**

replacements as they wanted to “match” their style or balance the available space.

**4.3.2 Paper.** Participants who used paper with drawing tools often began with light sketches or thin lines before committing to solid lines or noticeable colours. Non-committal drawing included hovering over the paper without making a thin line. Once they determined what objects to draw, the participants changed tactics and drew more solid lines by changing colour or using more pressure on the drawing tool. When the participants decided to add detail to an object, they either added a label to mark what the object represents or added details to the object, such as armrests on a sofa. Participants rarely replaced or removed the drawn objects, especially compared to online tool participants. Most participants used the eraser attached to the back of their pencil, if available. We also noticed that participants extended the line over their objects to make them bigger rather than using an eraser to remove and redraw them.

**4.3.3 Lego.** Lego participants were always actively thinking about what to build and how to collect the necessary pieces to achieve their design goals. Generally, we observed two types of builders during our study: batch builders and one-by-one builders. Batch builders decided on an object and then placed the necessary pieces in front of them for later assembly. One-by-one builders considered the basic structure of the object and connected each piece as they collected the necessary pieces. This one-by-one process is similar to the participants using pen and paper, as they needed to actively think about the required object and how they could achieve it.

We rarely saw any detailing work from Lego participants, adding small pieces to existing finished Lego objects. This may be due to participants not having enough Lego pieces or not feeling the need for a detailed model.

## 5 Findings: Desirability Toolkit

Table 2 shows word frequencies, with initial selections at the left and the top 5 words at the right. “Engaging” was the most frequent word from our list of 30 words across all conditions, though the rationale varied based on the condition. All participants in the Paper and Lego conditions chose “engaging” as one of their initial words, but only 7 of 10 participants in the online condition did. Interestingly, all 7 of these online participants kept the word “engaging” as one of their top 5, but in both the paper and Lego conditions, 1 and 2 participants, respectively, dropped the word “engaging” for their top 5 words. While word frequencies provide a surface-level, holistic understanding of participants’ experiences, we provide interview context for their top 5 words.

### 5.1 Engaging

Online participants selected “engaging” for two main reasons: their own motivation to continue or because of the tool’s features. Participants felt compelled to “keep going until it’s complete” (p5, online) or “keep kind of doing it” (p9, online). The online tool’s features and ease of revising were seen as engaging to online participants: “because it was kind of fun to do just moving things” (p3, online). These experiences suggest that the online tool’s instant feedback and user agency contributed to the engagement.

Participants in the paper condition found their thinking process engaging, emphasizing the need for planning and creative problem-solving. They noted that “*I have to think, you know, where I would place the items*” (p13, paper). This feeling stemmed from the permanency when drawing on paper, which encouraged thoughtful planning before committing to drawing. Participants also described “*thinking through the parameters*” (p11, paper) and said “*I activated the part of my brain. That’s the creative part, the imagination*” (p16, paper), further demonstrating the root of their rationale.

In contrast to the other two methods, Lego participants mentioned various engaging experiences, highlighting the physical, hands-on, play-like nature of the tool or the challenge of assembly and problem-solving. They described “*building things ... by hand*” (p22, Lego) or similarly, “*to play around with it [Lego]*” (p29, Lego). The challenge of assembly, “*to think and get more in tune*” (p25, Lego) and the “*process of elimination or, problem-solving*” (p30, Lego), also contributed to the engaging experience.

## 5.2 Satisfying

Participants across all conditions found the design process “satisfying.” They described the experience as “*a simple blank canvas to a room*” (p3, online), “*you get to see ... the end result*” (15, paper) and “*seeing how things came together*” (p24, Lego). Lego participants also noted the tactile experience, as it “*zones everything else out, and it’s super satisfying*” (p21, Lego).

## 5.3 Empowering

Paper participants predominantly selected “empowering,” noting accomplishment in designing without professional experience. They felt they did “*better than [they] thought*” (p16, paper) and enjoyed “*seeing it on paper*” (p17, paper). They also felt empowered “*as opposed to hiring a professional*” (p11, paper) because they “*can be a part of that design process, which makes it empower*” instead of being “*subject to someone else’s ideas*” (p18, paper).

## 5.4 Motivating

Participants with Lego and Paper more frequently selected “motivating” than participants with the online condition. Paper participants found the design thinking process motivating with a similar remark: “*making them think in a design way*. They described the experience “*to be more involved in design*” (p14, paper) and “*motivating [them] to want to make it happen*” (p16, paper). Whereas Lego participants were motivated by the playful aspect of building and assembling to “*continue to do it*” (p25, Lego) and “*to take on some projects*” (p26, Lego), suggesting Lego’s potential as a playful introduction to the design activity.

## 5.5 Organized

Online participants selected “organized” more frequently than participants with Paper or Lego conditions. They appreciated the interface and the categorization of objects, found “*the program itself was very organized*” (p1, online) and that it made “*categories and like subcategories, ... easier to find*” (p10, online). Lego participants, on the other hand, described “organized” in different ways, noting they “*can see exactly where each piece is going to fit*” (p23, Lego) and “*the squares [the grid] ... you can fill however you want*” (p29, Lego).

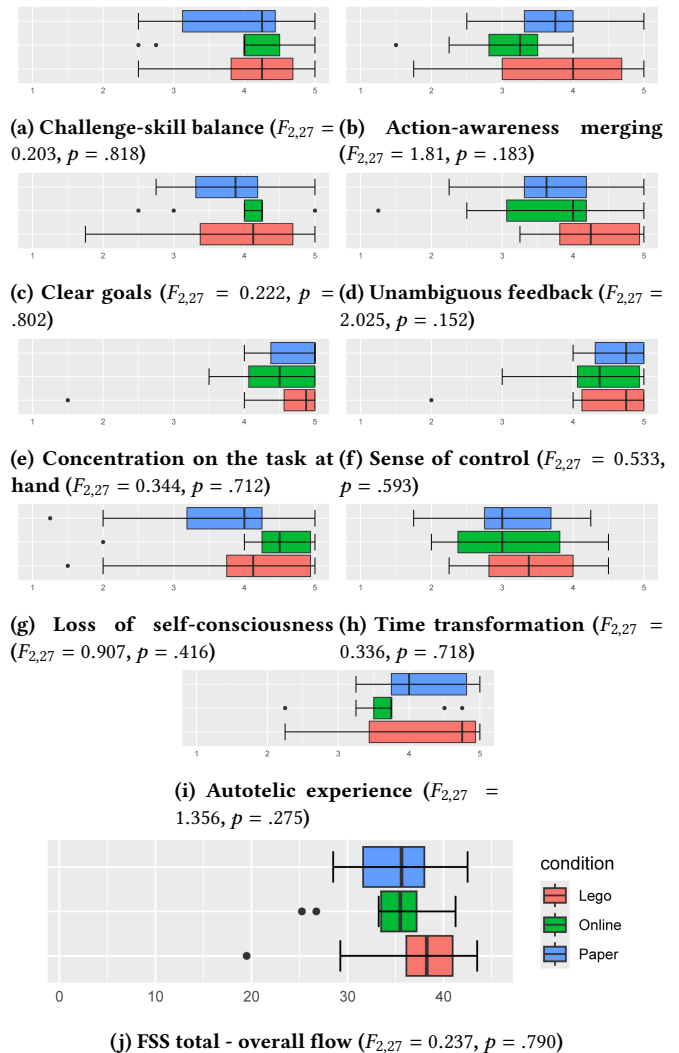


Figure 4: Boxplots for each dimension and FSS

## 6 Findings: Flow Scale

We used a one-way multivariate analysis of variance (MANOVA) with condition (paper, Lego, online) as the independent variable and the nine dimensions of the flow scale as dependent variables. There was no significant difference found between the three conditions (Pillai’s Trace = .84,  $F_{2,27} = 1.6, p = .11$ ). We, therefore, cannot reject the null hypothesis. We show univariate ANOVA results and boxplots for each dimension and the overall flow score (FSS total) in Figure 4. This result is not surprising considering our low sample size and the lack of reported difference in engagement between conditions in our Desirability Toolkit results.

## 7 Findings: Interview

Semi-structured interviews revealed two notable patterns beyond word choice comments and rationales. To identify these, we underwent multiple passes of the recordings: Initial familiarization followed by quote labelling and pattern grouping in the second pass.

While our analysis resembles reflexive thematic analysis methodology [8, 9], our focus was on the methodology suggested by the Desirability Toolkit, resulting in topic summaries rather than themes.

## 7.1 Choosing the Right Tool for Each Stage

Participants favoured the paper condition for a quick draft to get a sense of the overall design, claiming it was useful for a “*very, very high level*” design stage (p13, paper) and “*rough sketch*” (p20, paper). Many wanted to transition from paper drafts to digital formats to “*visualize and make a really nice rendering*” (p20, paper). They valued digital convenience for instant visual feedback and precise measurements, noting paper’s limitations in measurements and proportions: “*take measurements of all the like appliances or the cabinets, but on the piece of paper, it’s, it’s hard to do*” (p13, paper).

## 7.2 Need for Different Perspectives

Participants desired different perspectives to judge object proportions, particularly as paper and online conditions offered only 2D top-down views. They expressed a need for their designs to be transformed into “*VR or 3D view*” (p1, online) to see “*how it looks within the room*” (p13, paper). Participants noted that 3D views would help those “*who sort of lack the vision of being able to see what something would look like*” (p11, paper). Despite the between-participants design, they recognized the benefits of other unseen methods, reinforcing the need for different perspectives.

## 8 Discussion

Our study explored the current state of the design process and how non-experts perceive and use different tools in a familiar interior design scenario. We conducted the study to examine how people’s experiences with miniature representations of large physical spaces vary based on tools both commonly used as non-expert tools (online planner, pen and paper) and physical objects with potential design utility (Lego). Our results revealed that the online tool offers convenient features, such as easy deletion and object measurement, but presented usability challenges for some participants. On the other hand, physical tools, such as paper-pen and Lego, can offer rich, engaging experiences, allowing participants to focus more on design than the tools. Furthermore, our observations yielded deeper insight into how people use each tool for design and factors that contribute to inaccuracies in scaled design, suggesting further investigation. These findings underscore the current state of such design tools and point to the potential for future solutions that combine the benefits of both digital and physical approaches. As technology advances, AR/VR solutions could be combined with tangible interaction to enable some of the benefits of physical miniature representations together with digital convenience.

### 8.1 Design Implications

Table 3 shows a summary of how our findings suggest what stage each of the tools can be used in and some of the advantages and disadvantages of each that we identified. We discuss how future tools can be designed to incorporate these insights.

**8.1.1 Different Workflow.** The different workflows observed in our study highlight where each method excels at different design stages.

This suggests that each method can be combined, complementing each other effectively.

For instance, a suitable interior design process for non-experts might begin with a quick sketch and ideation phase, allowing freedom of expression (Table 3d), which promotes personalization and customization. However, these methods can be intimidating for some users [6] and might encounter underlying requirements like scale perception (Table 3g). In contrast, online tools often provide a list of available objects which can be placed. However, this heavily deters personalization and customization (Table 3h), which contradicts the recent DIY trend where users seek self-design opportunities for customization and personalization. This hints that freedom of expression is more important in the early design phase than producing accurate, high-fidelity designs. A digitalized tool can be developed to satisfy this expectation, similar to how current sophisticated CAD programs operate.

Once the initial ideation phase is completed, these sketches and ideas can be translated and transformed into a format that is accessible for detailed and heavy editing, taking advantage of *digital convenience* (Table 3e). In this stage, integrating a tangible interface can further assist in the design process to promote engagement and familiarity (Table 3f). One promising approach is integrating tangible interfaces to lower the barrier to entry for design activities. For example, using passive haptics, such as haptic retargeting [4], can compensate for the need for every object to be mapped to digital objects in physical forms (Table 3i).

**8.1.2 Using Tangible Interfaces.** As shown in previous work [6, 7], our findings also show that physical interaction and haptic feedback are great candidates for developing tools for non-experts. Responsive feedback and fidelity are both vital in the creation of supportive tools (Table 3f). The concept of “I’ll Know It When I See It” (IKIWISI) resonates well within the design sector, particularly among less experienced users. Our study participants’ responses emphasized the demand for high fidelity in tasks such as Lego assembly, colour matching to real-world objects, and the creation of realistic-looking drawings. This underscores the necessity for a tool that offers high fidelity while remaining user-friendly, nurturing creativity, and promoting ideation.

For urban planning, the interactive system Urp [43] demonstrates exceptional use of tangible user interfaces [13, 20]. Bringing together technologies, such as traditional paper drawing with physical interfaces [26] or augmented reality [2], has the potential to improve the design experience. It’s worth noting that both VR and AR have reached a stage where they can produce photorealistic representations with minimal differences in size and shape compared to real-world objects [3, 16, 31]. This suggests an opportunity to leverage these technologies to create a physical experience that enables miniature representations of larger physical spaces (Table 3c).

**8.1.3 Self-Confidence in Sketching/Design.** Despite our participants expressing intimidation from their lack of drawing ability, previous research suggests that sketching skills are not a significant factor in engineering design [49]. While sketching skills are not directly relevant to the final design, the skills are often emphasized to make the individual participating in the design process more creative during ideation [6, 24].

	Pen and Paper	Online tool	Lego
Design stages	(a) initial planning for quick sketch	(b) editing-heavy stages	(c) used as interface with online
Advantages	(d) complete freedom	(e) accessible easily modifiable	(f) intuitive, familiar
Disadvantages	(g) requires scale perception	(h) less freedom using predefined objects	(i) limited by availability of Lego

**Table 3: Summary of our results and recommended design stages for each tool**

Novices without related training often make inaccurate drawings with pen due to the misperception of the objects intended to be drawn [12] (Table 3g). As we saw in our study, the participants mentioned the need for a different perspective (3D or VR) to *check* their designs, and this suggests inaccuracies and *the disparity in scaling* may have the same underlying cause: misperception. This may be why participants felt the necessity for an extra validation tool such as a 3D viewer or digitally transformed design from using sketching on paper (Table 3a): the need for *the multiple design stages* (Table 3b,e).

## 8.2 Envisioning Future Tools for Everyone

The main tasks in our study centred on designing scaled worlds or, in other words, miniature worlds. Space design, such as this interior design task, requires an understanding of space and the relationship between objects. The birds-eye view benefits the participants by showing relative positions between objects, thus helping users further optimize the space. While miniaturization helps the planning phase of the space, experiencing these spaces at full scale remains a challenge.

Some of our findings, such as the “desire for 3D visualization after sketch” from the participants, underscore the need for further exploration. Future tools, especially incorporating immersive technology, hold promise for delivering highly interactive experiences with the convenience of digital workflows. AR/VR specifically offers tremendous potential as it allows for the seamless integration of digital information directly from existing software (CAD, BIM) conveniently in an immersive and interactive environment.

This hybrid approach using AR/VR together with physical interaction is rapidly emerging as a *new* standard in the AEC industry [27]. The three methods we employed in this study—Lego, paper sketching, and online interfaces—can serve as effective tools for initial sketches in low fidelity, then transition to immersive technology for enhanced interaction and visualization. Combined with the tangible interface, this approach can be introduced for not only experts alike but everyday users as well, bridging physical and digital interfaces.

Integrating with advanced computing technology naturally addresses scalability in spatial design. While our study focused on limited spatial design tasks, such as room layout and object placements, transitioning and integration with computer-aided tools can enable users to design at any scale of spatial design, from room layout, interior, architecture, and facade to urban design. Interactive technology allows users to seamlessly navigate between multiple scales, views, and designs, ultimately fostering a dynamic

and adaptable design process and enabling more informed design decisions.

## 8.3 Understanding Our Users

While some participants in our pool reported some experience with architectural (e.g., CAD) and 3D modelling tools (7 in total), we consider the majority to still be non-experts (and even some of these 7 to have low expertise, given their self-ratings of skill with these tools). While many more participants rated some planning or design experience with architecture or interior design, we explicitly highlighted “planning your room layout or playing a game” as such an activity, so we expect this group to still be considered non-experts (and to be similar to participant pools from related studies), and thus think that our participants were representative of a general population (albeit a highly educated one).

Nonetheless, these experiences and education levels may have influenced participant experiences and responses during our interview. Despite having a different group than *typical* novices, our analysis and results still provide valuable insights. Because our ad for participation was sent broadly, we expect the nature of the study interested some participants more than others, so it is also reasonable to expect our pool to be a target audience of the types of tools we are proposing, and our results can help inform developers and designers of related architecture and interior design tools.

## 8.4 Implication of Full Remote Study

We conducted a fully remote study due to the risk of COVID-19 at the time it was run. In addition to the typical tradeoffs between remote and in-person studies, our study required physical components (Lego bricks and pen and paper), which limited our participant pool and necessitated individual differences in setups. This choice may have also affected our findings, as participants that have Lego at home, presumably, are already familiar with those specific Lego blocks, and similarly, a participant’s regular use of their own pen and paper may have affected their word choices, for instance, the “familiar” word in the Desirability Toolkit. Nonetheless, Lego bricks are versatile in nature, and pen and paper are common household items, so we found the participants to have comparable setups, even if they were not identical. The remote setup also forced the research to be as simple as possible. While our research can be supported on applications with head-mounted displays (AR/VR), we necessarily determined not to use AR/VR integration in our study to streamline the sessions with participants.

## 9 Conclusion

In this paper, we present the results of a mixed methods study comparing room layout design experiences with a digital online tool, paper and pen, and physical Lego blocks. Our vision aligns with previous research [18, 19] that integrates physical objects into existing concepts. This study provides fresh insights into how tools can be designed for a broader audience. Our results give a better understanding of users interacting with miniature representations of larger physical spaces. Our findings highlight the benefits of each tool. The digital experience allows quick editing and precise measurements, while tangible tools (paper-pen combo and Lego) are familiar and intuitive, offering the flexibility of physical media. Moreover, participants experienced difficulties with the physical media to properly scale objects within a room which is an opportunity for future work. We envision that future design tools could integrate tangible interaction to leverage the benefits of digital tools (e.g., measurement) with the benefits of the physical experience.

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