Beta-Testing Architecture

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

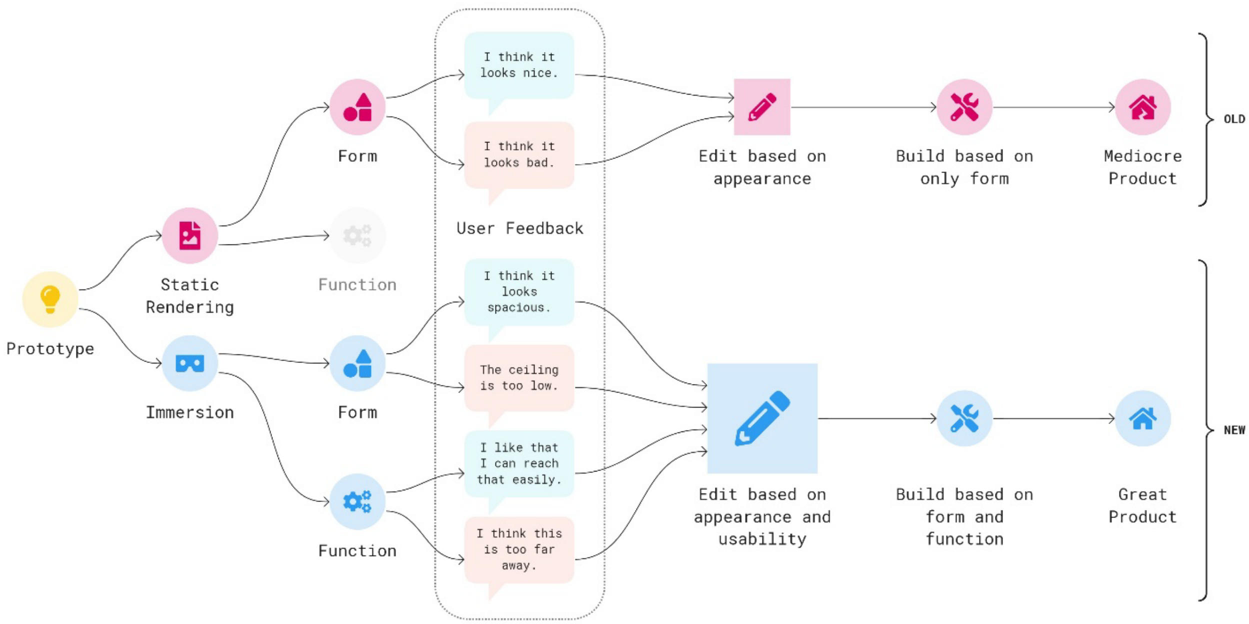

Figure 1. Diagram comparing traditional methods of testing and proposed methods of immersive testing. (Source: By Author)

In the field of architecture, designers traditionally show their building concepts for design analysis mainly through static renderings.[1] The problem with static renderings is that they don't show us how and if buildings work for the end-user.[2] Designers are currently working towards more immersive methods of representation in architecture through means of digital walkthroughs, virtual reality simulations, and augmented reality experiences, but it is still unclear how to use these methods to best allow a user to evaluate and give feedback on a building concept to improve the design.[3] This thesis looks at how we can develop a framework for beta-testing architecture; the best ways we can represent architecture to an end-user that allows them to experience the usage of space as a method of evaluation to provide feedback. I designed a series of digital experiences that attempted to allow the immersive experience of a hypothetical building by end-users, and ultimately explored this with my peers to get their feedback on a space I designed. I anticipate that this new method of evaluating architecture through beta-testing will allow us to implement end-user feedback as an integral part of the design process and shift away from static renderings as our main method of representation.

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[1] "Architectural Renderings Play a Vital Role in Architecture, Here Is Why," accessed January 13, 2021, https://www.easyrender.com/a/architectural-renderings-play-a-vital-role-in-architecture-here-is-why.

[2] Mark Minkjan, "What This MVRDV Rendering Says About Architecture and the Media," *Failed Architecture* (blog), accessed January 13, 2021, https://failedarchitecture.com/what-this-mvrdv-rendering-says-about-architecture-and-media/.

[3] "Immersive Technologies: How Architects Can Position Themselves For Future Success -," *Cuningham Group* (blog), January 15, 2020, https://www.cuningham.com/2020/01/15/immersive-technologies-architects-position-themselves-success/.

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0 [Prologue] New Tools, Same Old Mistakes

We have so many new ways to represent architecture. Why aren't we using them in new ways? We should be presenting architecture with our most immersive tools and using that to generate feedback to help us improve our buildings.

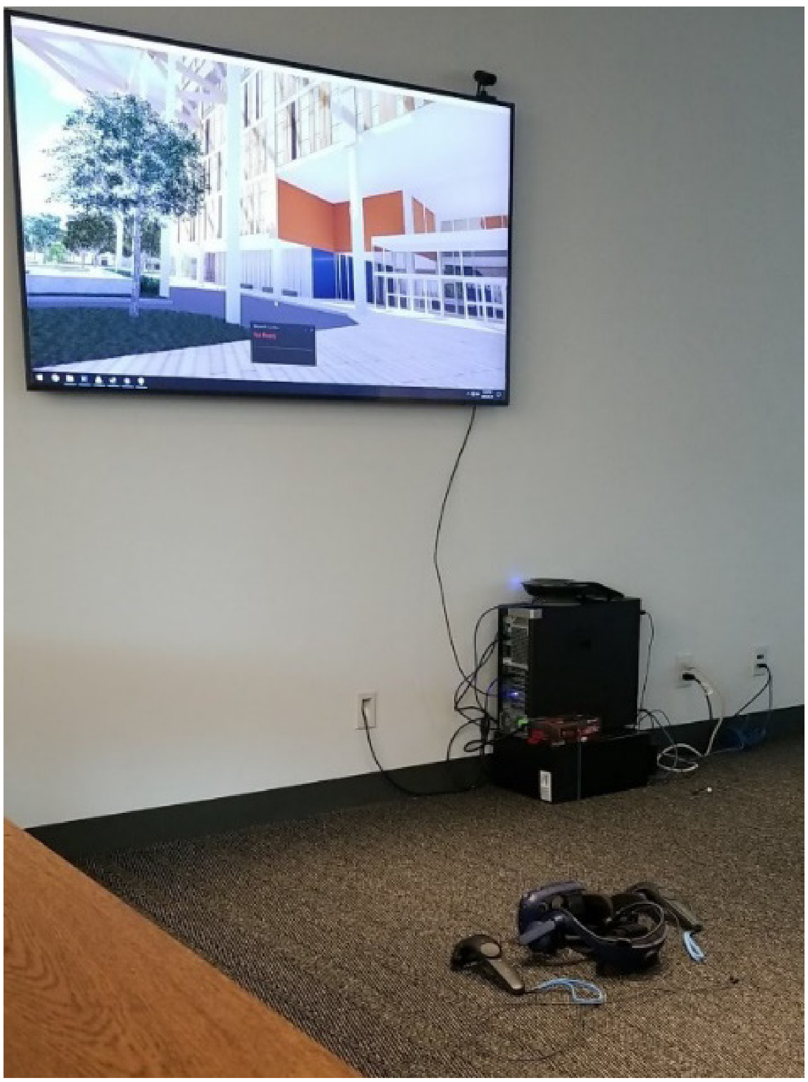

Figure 2. VR experience setup at my workplace. (Source: By Author)

When I was working at an architectural firm out west in Vancouver, BC, I was a Virtual Reality (VR) chaperone for an evening event that the company was holding for clients and consultants. As people started pouring in, a few people walked into the VR room. I tried to introduce them to the idea of VR for previewing some buildings we had in development. Some were familiar with the concept, but for many, this was a new experience. When people dropped into VR, they looked around a little and proceeded to ask me,

"Is that it? How do I use this space?"

I had no real answer for them since the experience was mainly for looking around the prototype. The clients didn't like the experience because it lacked depth, and they didn't have anything to say other than,

"Well, I mean I guess it looks nice."

It was then that I started to realize that we as architects needed to use immersive tools like VR differently. We need to get past the novelty of emerging immersive technologies and start using them as integral tools in the architect's drawing set.

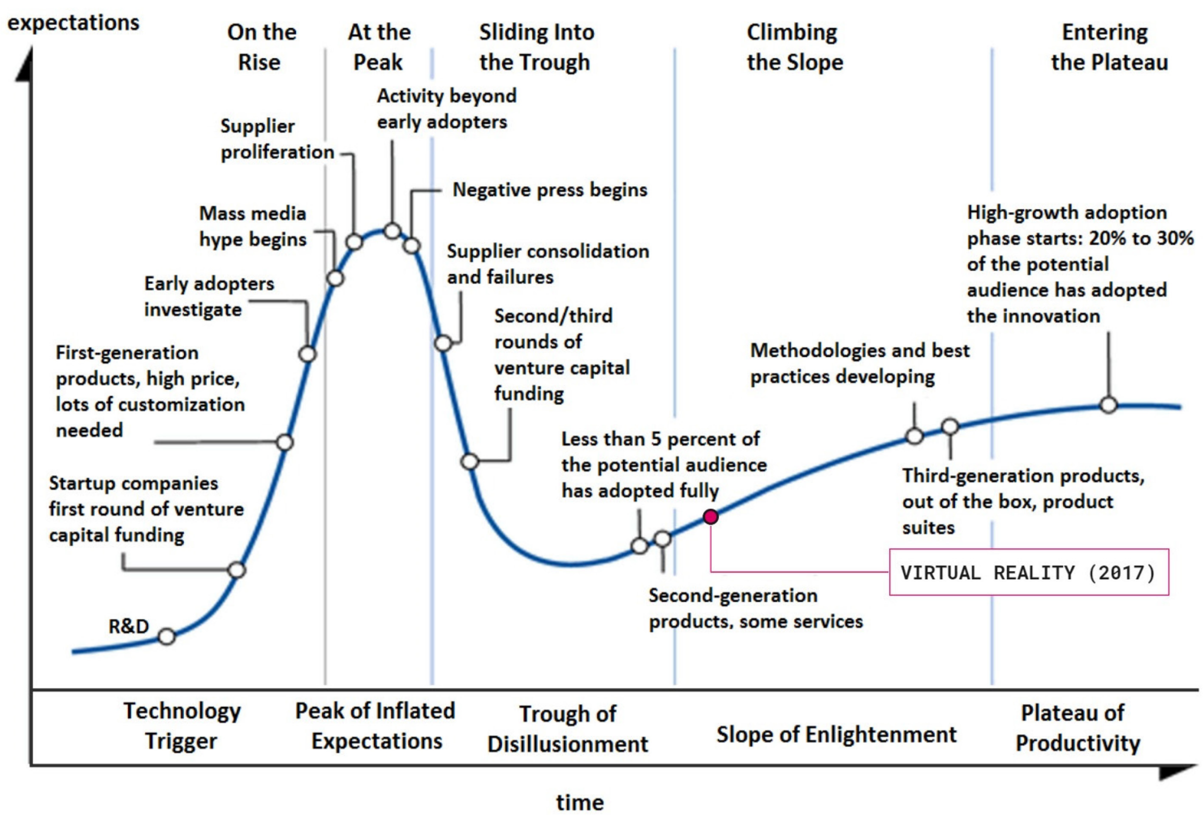

Figure 3. "General Gartner Research's Hype Cycle diagram." (Source: Olga Tarkovskiy / CC BY-SA 3.0, / Added data point for Virtual Reality in 2017)

The Gartner Hype Cycle for Emerging Technologies is a diagram that is released by Gartner every year indicating what technologies are emerging, and to what extent the technology is in its stage of novelty. In 2016, the Hype Cycle listed VR as a technology which was on the "Slope of Enlightenment."[4] This meant that it was on the verge of being adopted as a mainstream tool to be used in productivity. In 2017, it was still on the same point on the chart just before the

[4] "Hype Cycle for Emerging Technologies, 2016," Gartner, July 19, 2016, https://www.gartner.com/en/documents/3383817/hype-cycle-for-emerging-technologies-2016.

"Plateau of Productivity."[5] In 2018[6], 2019[7], and 2020, VR does not appear again on the cycle.[8] This may have occurred because the cost of a VR headset had not gone down since then, and VR headsets mostly failed to sell to the mainstream audience. However, according to TDG Research, the way that VR can make a come back is through the usage of easily accessible hardware. This meant that the product would have to be relatively inexpensive and easy to use. In addition to this, the product needs to have a proper enterprise level application to encounter mainstream usage.[9]

We show still renderings to end-users to get comments on what we should change about the building's looks but using immersive technologies for testing with end-users will require a different approach to presentation as well as feedback. We must have a solid reason to use immersive tools in architecture. Currently we are using new tools with old methods, and it's time that we find the 'plateau of productivity'.

[5] "Hype Cycle for Emerging Technologies, 2017," Gartner, July 21, 2017, https://www.gartner.com/en/documents/3768572/hype-cycle-for-emerging-technologies-2017.
[6] "Hype Cycle for Emerging Technologies, 2018," Gartner, August 6, 2018, https://www.gartner.com/en/documents/3885468/hype-cycle-for-emerging-technologies-2018.
[7] "Hype Cycle for Emerging Technologies, 2019," Gartner, August 6, 2019, https://www.gartner.com/en/documents/3956015/hype-cycle-for-emerging-technologies-2019.
[8] "Gartner Identifies Five Emerging Trends That Will Drive Technology Innovation for the Next Decade," Gartner, August 18, 2020, https://www.gartner.com/en/newsroom/press-releases/2020-08-18-gartner-identifies-five-emerging-trends-that-will-drive-technology-innovation-for-the-next-decade.
[9] "AR and VR — Back from the Dead," *TDG Research* (blog), May 27, 2020, https://www.tdgresearch.com/ar-and-vr-back-from-the-dead/.

1 [Purpose] The End-User Can Play Too

How can we incorporate the end user as an integral part of the architectural design process? We can tackle this in two parts: how can we immerse an end-user in an architectural prototype, and how can we gather information about the experience?

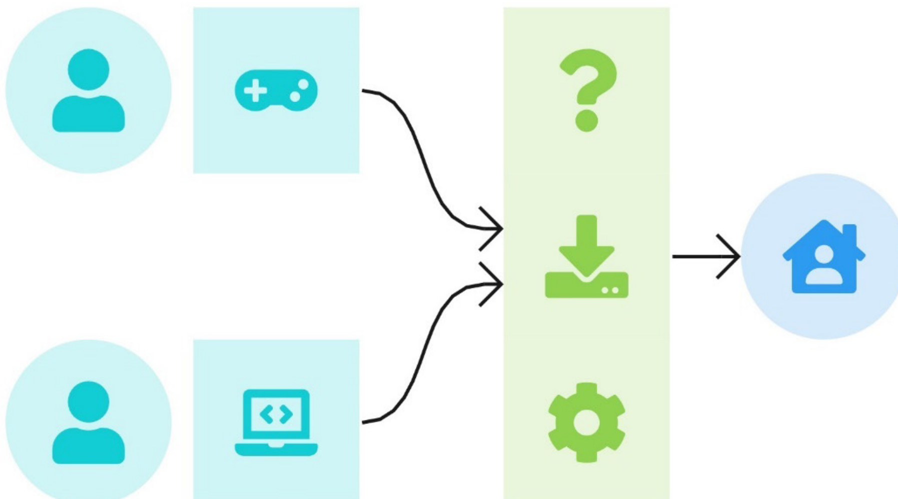

Figure 4. Designers and play-testers each take on an integral role of creating a building. (Source: By Author)

When we design buildings, we start with the client's needs, and we craft a set of concept documents and drawings to describe our proposals. End-user involvement in the design process typically involves public design reviews where users comment on these static drawing sets. Most comments are focused on how the project looks, and comments about usage are speculative since there are no parts of the typical drawing set that accurately depict space usage. We then make changes based on this feedback and send the building proposal off to be built in the real world. The spaces we build like this may look great, but often we fall short on addressing the intricacies of how end-users want buildings to function. For example, a designer might think that an open-concept floor plan for an office space looks great but talking to an end-user of the space may reveal that the lack of compartmentalization and spatial hierarchy may lead to a distracting workspace with a difficult to navigate floorplan. Video game development is a field where end-users' feedback is critical to developing the final product. Video games are first developed into a minimum playable state where they are tested by the developers themselves and are edited as needed. This is known as alpha-testing. Though this does allow them to test their product through using it as intended, it falls short in learning about what the end-user wants in the product. Developers are limited to their own knowledge. To address this, they can send out functional copies of the game before release to end-users to try and work out flaws in functionality. This process is known as beta-testing. End-users can then provide feedback based on their immersive experiences in the game, and developers can use this information to make edits to their product. Beta-testing allows the developer to acquire knowledge about their product that they did not previously anticipate. In the field of architecture, we lack a form of beta-testing. Beta-testing is critical in video game design because it allows the inclusion of the end-user experience in the design process.

The goal of this thesis is to explore how we can incorporate the end-user as an integral part of the architectural design process. Incorporating the end-user into the design process can help architects understand what users want out of architecture, as well as how users will use spaces. What if we could show end-users an experience which gives them the illusion of not only being in a space, but taking part in activities within the space? In addition, how can we gather feedback from the end-user that would allow us to edit our designs to their benefit? Learning from users is difficult and time-consuming, so this method must add value to the conversation to justify using it.

The idea of the end-user being included in the design process can be seen prominently in the field of video game development. The end-user is brought into the design process after a game has been developed into a playable version ready for release. The end-user helps test the product and gives feedback to the developer to help adjust the game based on how people will play the game in the real world. The end-user is seen in this field playing a vital part of the design process.[10] First, the end-user is presented with an immersive experience which is nearly identical to the final product. The experience for a beta-test is both visually and functionally compelling. Second, the end-user can then provide valuable feedback based on this immersive experience.[11]

With the progression of architectural design into more immersive media, the idea that we can immerse an end-user in architecture that is not yet built doesn't seem so far off. Additionally, we must find a way to generate meaningful feedback from the user that allows us to revise our architectural proposals to better suit the needs of end-users. With these two parts in mind, how can we create an effective beta-test for architecture?

[10] Simon Egenfeldt-Nielsen, Jonas Heide Smith, and Susana Pajares Tosca, *Understanding Video Games: The Essential Introduction*, Third edition (New York; London: Routledge, 2016).
[11] Bob Bates, *Game Design*, 2nd ed (Boston, Mass: Premier Press, 2004).

2 [Relevance] Showing and Knowing the End-User

2.1 How Designers Show Their Work

2.1.1 Hand Drawn

Orthographic drawings are abstract representations of things we already know. They are great at showing spatial relations that are built into building concepts.

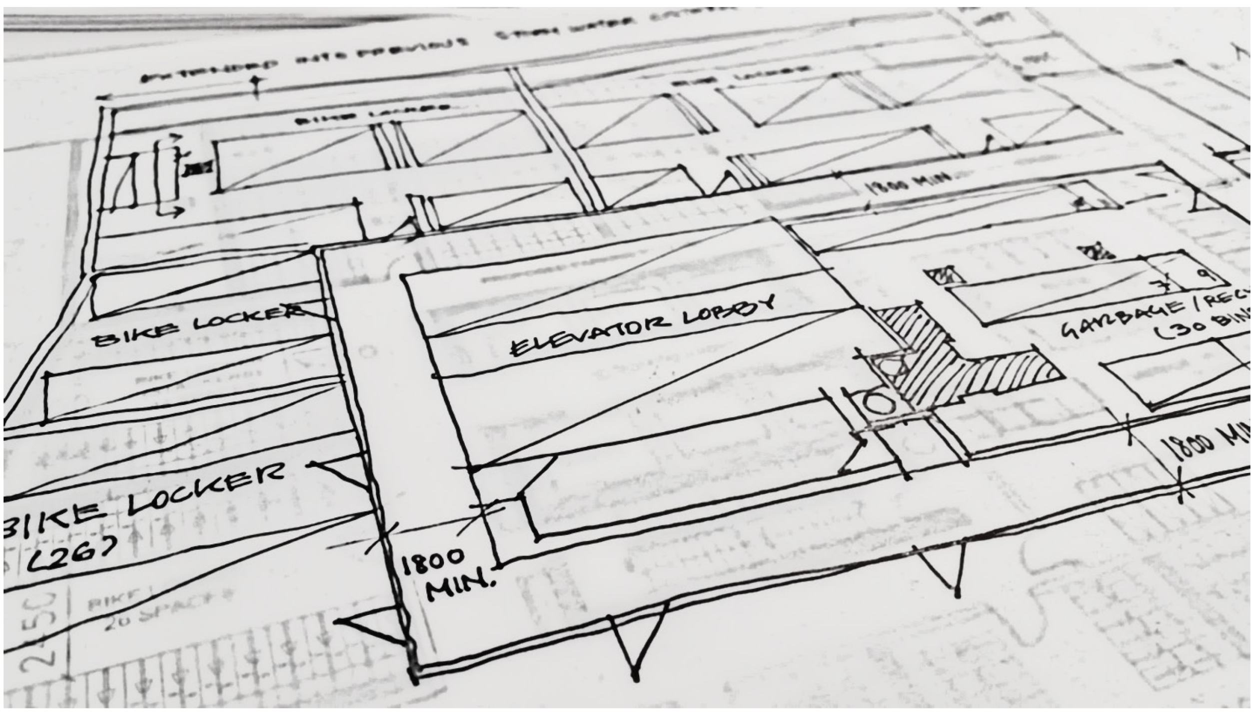

Figure 5. Hand drawn floor plan of condominium basement layout. (Source: By Author)

Throughout the years, we've been using various technologies as architects to communicate our building designs. These methods include orthographic drawings, perspective drawings, and physical models both to scale and one to one.

Drawings are different from media such as painting and colouring since we are using the technique to represent an object, scene, or idea.[12] We use orthographic drawings as a very necessary tool to communicate things like dimensions and geometry. These are critical in the creation of a building since it allows the construction of it to be accurate. For a trained architect, it can be very easy to imagine the experience of a space just by looking at the floor plan, but for a layperson, client or end-user, this may not be the case. The act of imagining what the space would be like in real life requires a lot of speculation, and the ability to imagine the space will differ from person to person depending on skill level. Even though these drawings are mission critical in drafting up a building, they don't do well in trying to communicate experience of space to end-users. The main role that these drawings play instead is to draw attention to the relationships between elements in a design rather than experience.[13] Orthographic drawings are abstracted versions of what we know about the spaces we try to convey; we are drawing what we already know. They do not reference an observer occupying the space.[14] Trying to get user feedback from orthographic drawings relies a lot on speculation about the geometry on the page and does not always tell the full story about the building. The end-users would then be giving feedback on the

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[12] Francis D. K. Ching, *Design Drawing*, Third Edition (Hoboken, New Jersey: John Wiley & Sons Inc, 2018).
[13] Sonit Bafna, "How Architectural Drawings Work — and What That Implies for the Role of Representation in Architecture," *The Journal of Architecture* 13, no. 5 (October 2008): 535–64, https://doi.org/10.1080/13602360802453327.
[14] Ching, *Design Drawing*.

building solely based on its form rather than its function, and this would result in a building that has not been tested based on real world usage.

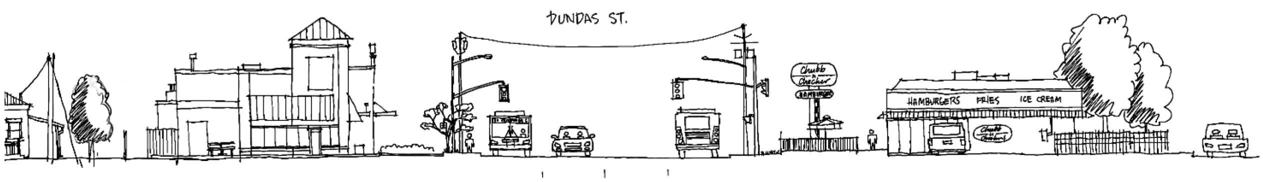

Figure 6. Orthographic section drawing of Dundas Street, Cambridge, Ontario. (Source: By Author)

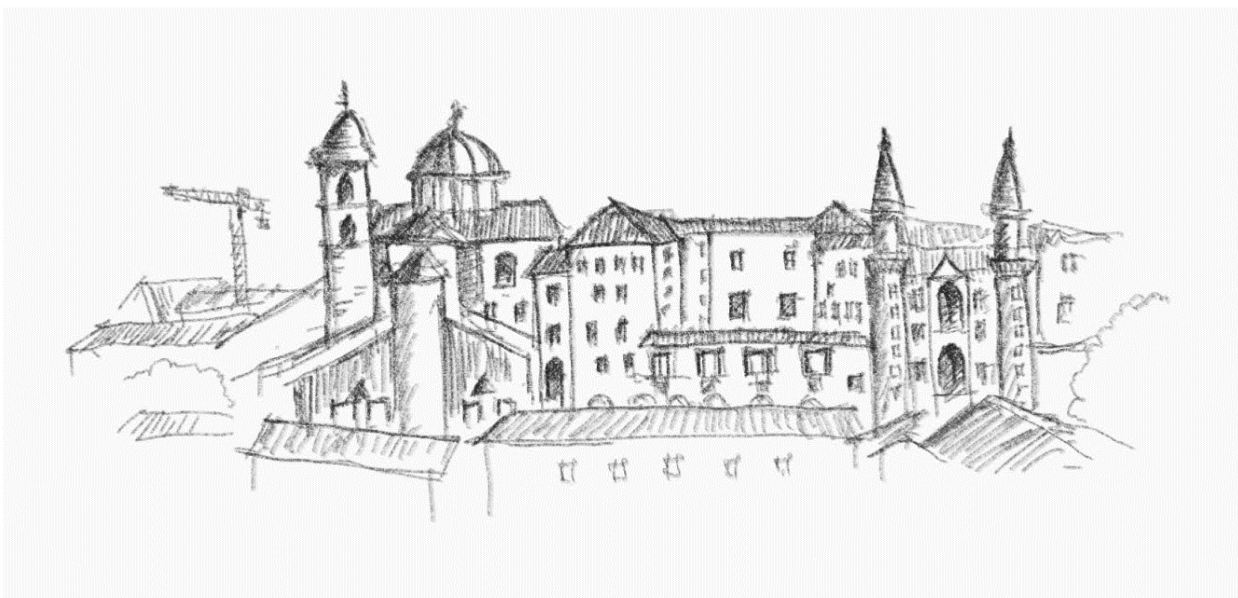

Figure 7. Drawing of distant buildings from Urbino, Italy. (Source: By Author)

Figure 8. Drawing of a plaza experience from Piazza Castello, Mantua, Italy. (Source: By Author)

Perspective hand drawings try to convey the experience of space and spatial relationships on paper to the end-user.[15] The limitations presented by perspective hand drawings are that they don't tell the full story of the space, and only capture still frames from selected viewpoints of the project. For example, in the above drawing of an Italian plaza, the story of the space is only partly told from one view. The experience of the space is missing. The designer selectively showing only a few views of a project is a way that the designer's bias interferes with how the project is received.

[15] Francis D. K. Ching and Corky Binggeli, *Interior Design Illustrated*, Fourth edition (Hoboken, New Jersey: Wiley, 2018).

2.1.2 Hand Built

We build our scale models of our designs to get a better understanding of their volumes. They work great as design tools and help us what a built version of our drawings would look like.

Figure 9. Side view of laser-cut physical model. (Source: By Author)

Another way we can represent architecture is using physical architectural models whether they're scale models or one to one.[16] Scale models allow the architect to communicate the project in physical space at a low cost. This communication can be used as a method to interface with the client regarding design decisions that need to be made or be used as a marketing tool to showcase building proposals to the public.

[16] Nick Dunn, *Architectural Modelmaking*, 2nd ed (London: Laurence King, 2014).

Figure 10. "Mock-up of seating on Liverpool Overhead Railway. On display at the Museum of Liverpool, England." (Source: Rept0n1x / CC BY-SA 3.0)

Full scale mock-ups such as showrooms for condominiums and building envelope design can serve different functions in the design process. Some of these functions include conveying volume, material and colour testing, assembly testing, and performance.[17] In the case for showrooms presented to customers, these are often finished products, and what the end-users see is what they get.

[17] Minjung Maing, "Physical or Virtual?: Effectiveness of Virtual Mockups of Building Envelope Systems," no. 54 (2012): 17.

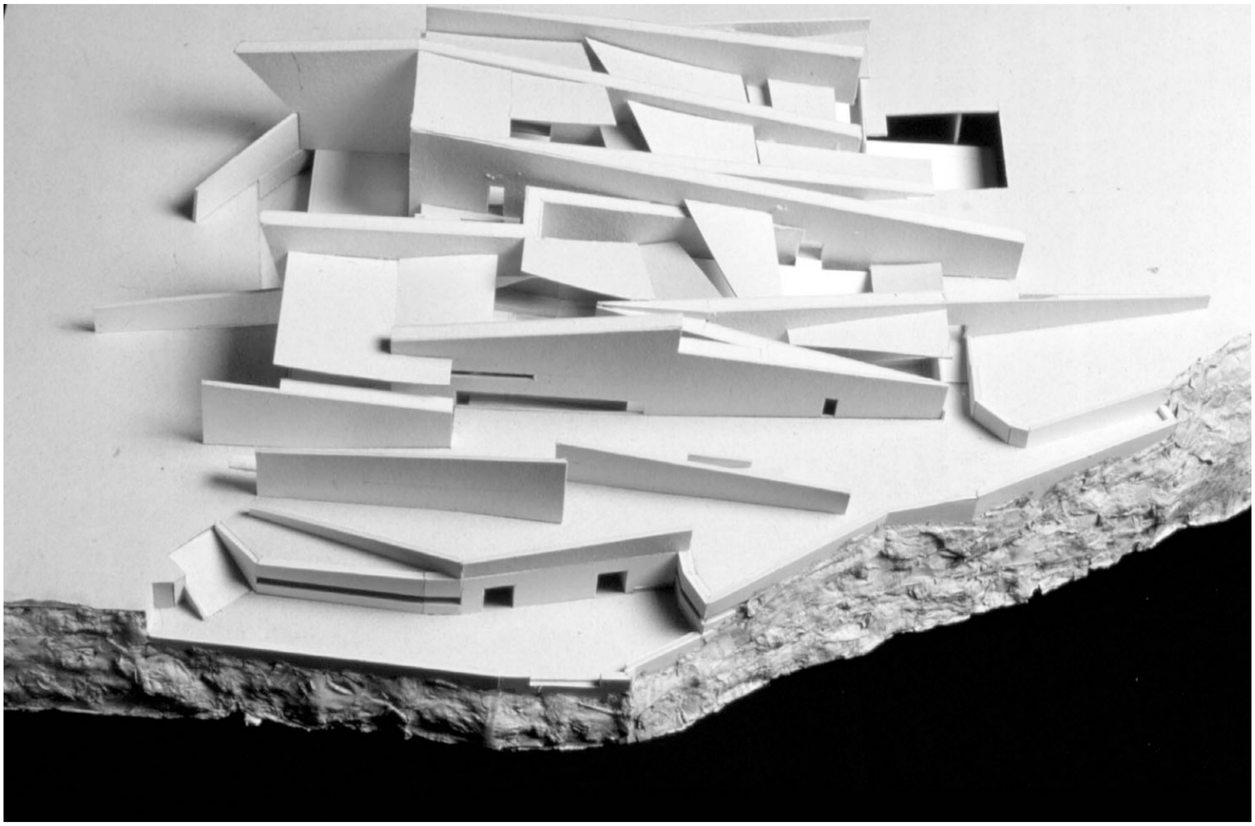

Figure 11. "MuseumMOM, Salzburg, 1998." (Source: Maximilian Manfred Rieder / CC BY-SA 3.0)

Physical scale models can be useful as a method of exploring new ideas because of how quickly they are able to provide tactile visuals.[18] The style of the scale model can also be a strategic variable depending on who the audience viewing it is. Developers, investors, and larger scale urban planners may prefer to see duotone conceptual models which outline the scale of the project in context with other geographic information. Property buyers on the other hand may prefer colour models which show a higher focus on materiality and details. According to RJ Models, in their experience buyers from North America tend to prefer models which have a less saturated colour scheme, whereas buyers from East Asia prefer more saturated colours.[19]

[18] Francis D. K. Ching and James Eckler, *Introduction to Architecture* (Hoboken: Wiley, 2012).
[19] *This Chinese Factory Makes $100,000 Architectural Models!*, accessed November 12, 2020, https://www.youtube.com/watch?v=fvwwYeDVAqk.

Scale models can give the end-user a better understanding of the project with a lesser amount of speculation needed. Physical models can help build a common ground between the architect and the end-user to talk about the volume of space which the building occupies.[20]

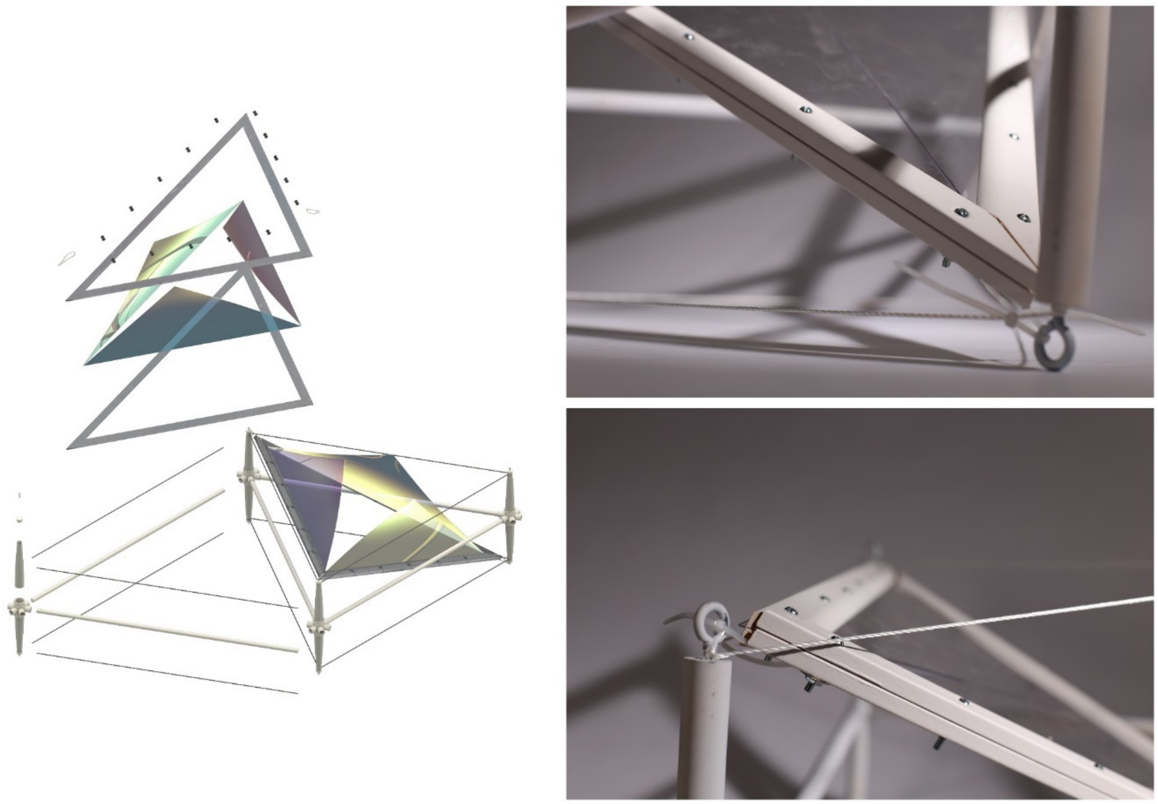

Figure 12. Left: Digital model illustrating the construction of a building module. Right: The physical mock-up of the building module at one to one scale. (Source: By Author)

Materiality, form, and space can be easily communicated by the architect through a scale model. The disadvantage of this is the inability to experience the space. This is resolved with one to one physical models. These are full-scale prototypes of architectural projects and are typically only a part of a larger project. These can typically be found in showrooms for potential homebuyers showing off

[20] Tom Cheng|, "Architectural Models: The Ultimate Guide," *RJ Models* (blog), April 11, 2018, https://www.rjmodels.com.hk/architectural-models-guide/.

the condo units or homes that are being sold new. These are expensive, but they do well in communicating what it's like to occupy the space. What they don't typically account for is the movement of a user between spaces if they’re only building part of the whole project for the showroom. The feedback that an end-user would be able to provide in this case would still only be based on form, but in this case, it would be more accurate to real life than two-dimensional drawings.

In the manual methods of representing architecture, we still lack ways to immerse end-users in our design proposals. These methods account for architectural form, but not always its functionality.

2.1.3 Computer Drawn

We use technology like CAD to help us create digital models of the spaces we design. We can create renderings that can help us visualize what it would be like to be in the space.

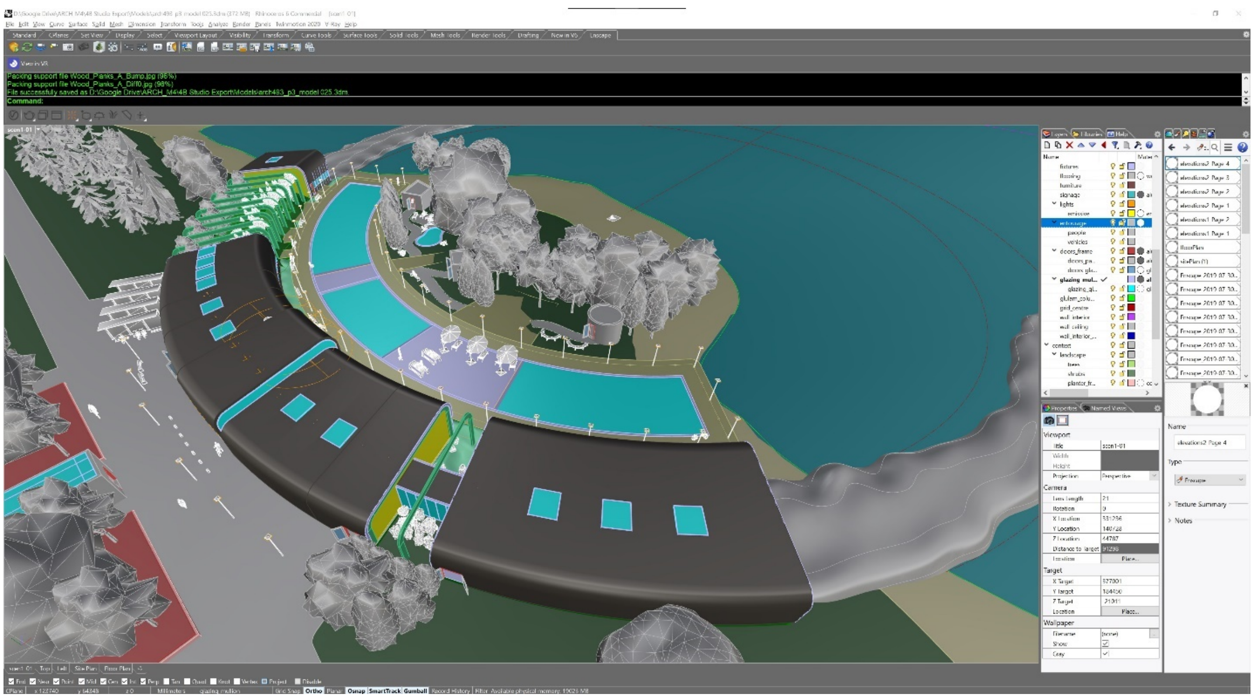

Figure 13. Screenshot of a project made in the CAD software Rhinoceros 3D. (Source: By Author)

More recently, the usage of computer aided design has helped expedite this process of creating drawings. Orthographic and perspective drawings can be quickly generated using the same digital model.[21]

The orthographic drawings generated digitally present the same issues as the hand drawing equivalents, but the usage of digitally rendered perspectives allow a designer to quickly find views within

[21] "What Is Computer-Aided Design (CAD) and Why It's Important," accessed January 15, 2021, https://www.procore.com/jobsite/what-is-computer-aided-design-cad-and-why-its-important/.

the project. Still renderings generated in this way are like walking into a building and taking photographs. They can help capture and communicate qualities of architecture such as form, and lighting. While this method does help illustrate what it's like to be in the space, ultimately the framing of each shot is decided by the architect. This method lacks immersion since it only gives snapshots in space framed by the designer's hand. The information provided to the end user this way is typically viewed on a monitor; therefore, the perception of the 3D data set is ultimately 2D.[22]

Still images are framed in and are cropped versions of the larger concept or project they represent. This limits the feedback and engagement of the end-user to the still rendering. Immersion, being more open ended, would allow an end-user to experience space over time. This would help determine qualitative issues in architecture. Using immersive methods of representation allow the shift in the philosophy of how we design and perceive space. Instead of creating objects that define what spaces are, we can start crafting spaces in themselves.[23]

Immersion requires the direct involvement of an end-user to give the illusion that they are part of the system of space that is presented before them. Architectural renderings carry the designer's bias in its framing, and do not allow for an end-user to fully understand space and what it's like to occupy it.

[22] Ching and Eckler, *Introduction to Architecture*.
[23] Antonieta Angulo, “Rediscovering Virtual Reality in the Education of Architectural Design: The Immersive Simulation of Spatial Experiences,” *Ambiances*, no. 1 (June 9, 2015), https://doi.org/10.4000/ambiances.594.

Figure 14. Still renderings showing points in space, but not the path in between the places. (Source: By Author)

Traditional static renderings end up being misleading for three main reasons. The first reason is that they only tell part of a story of the architecture being proposed since they are only snapshots of space. The act of moving through space is difficult to communicate through the usage of still images. Static renderings do not describe how a space is traversed, as well as how it is used. Secondly, the appearance of space is sometimes edited to look better than real life. Camera optics will alter the perspective of the image; therefore, altering the perception of space. An example of this is in interior renderings or photographs where the technique of tilt-shift photography is used. This gives the illusion that the space is larger than it is. This means the medium is not always accurate to real life.

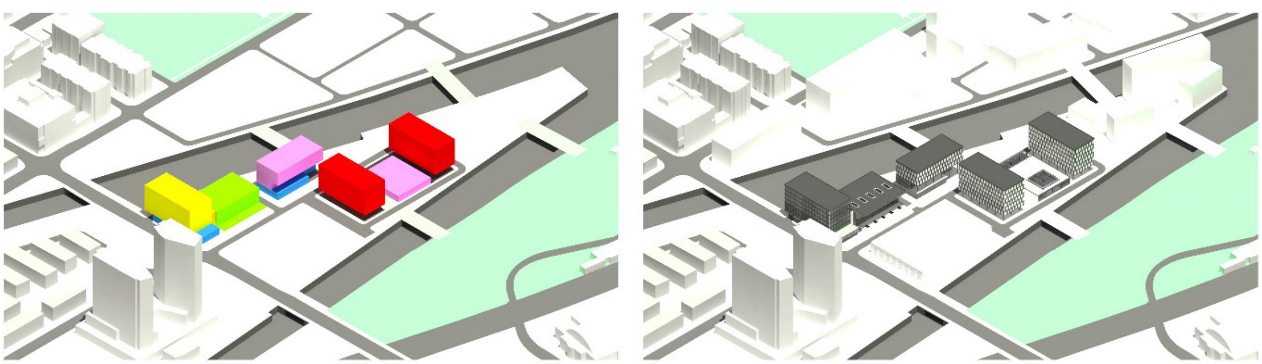

Figure 15. Bird's Eye View renderings of a master planning project. (Source: By Author)

Renderings may be taken from a bird's eye view, and not representative of what it's like to be in the space. These may be beneficial to clients in determining the scope of the project but are not helpful to end-users in determining what it's like to be in the space as well as how it's used. A designer may choose to add lots of vegetation to the drawing to make it seem more desirable an end-user, effectively “greenwashing” the experience.

An example of this is MVRDV’s *Valley* in Amsterdam, where all the promotional material presented to the public depicts lush greenery on rooftop balconies with vegetation spilling over the sides. The argument against this is that vegetation covering the building in this manner never looks as luxurious as their rendered visions. The pedestrian experience at ground level is akin to walking past “another glass box”.[24]

MVRDV provides the counterargument that renderings can be used as a tool to generate interest for a proposal. Getting the municipality and the general public excited about a project can help fuel its development and help achieve funding that allows it to meet its initial ambitions. In this way, setting up high ambitions with highly artistic renderings can lead the way for more architectural and urban quality.[25]

[24] Minkjan, “What This MVRDV Rendering Says About Architecture and the Media.”
[25] “In Defense of Renders and Trees On Top of Skyscrapers,” ArchDaily, March 2, 2016, https://www.archdaily.com/783045/in-defense-of-renders-and-trees-on-top-of-skyscrapers-mvrdv.

Figure 16. Rendering by Vero Visuals of MVRDV's 'Valley' depicting lush rooftop vegetation, and cascading balconies. (Source: Vero Visuals, MVRDV / Downloaded from https://www.mvrdv.nl/projects/233/valley?photo=17058 on January 2021)

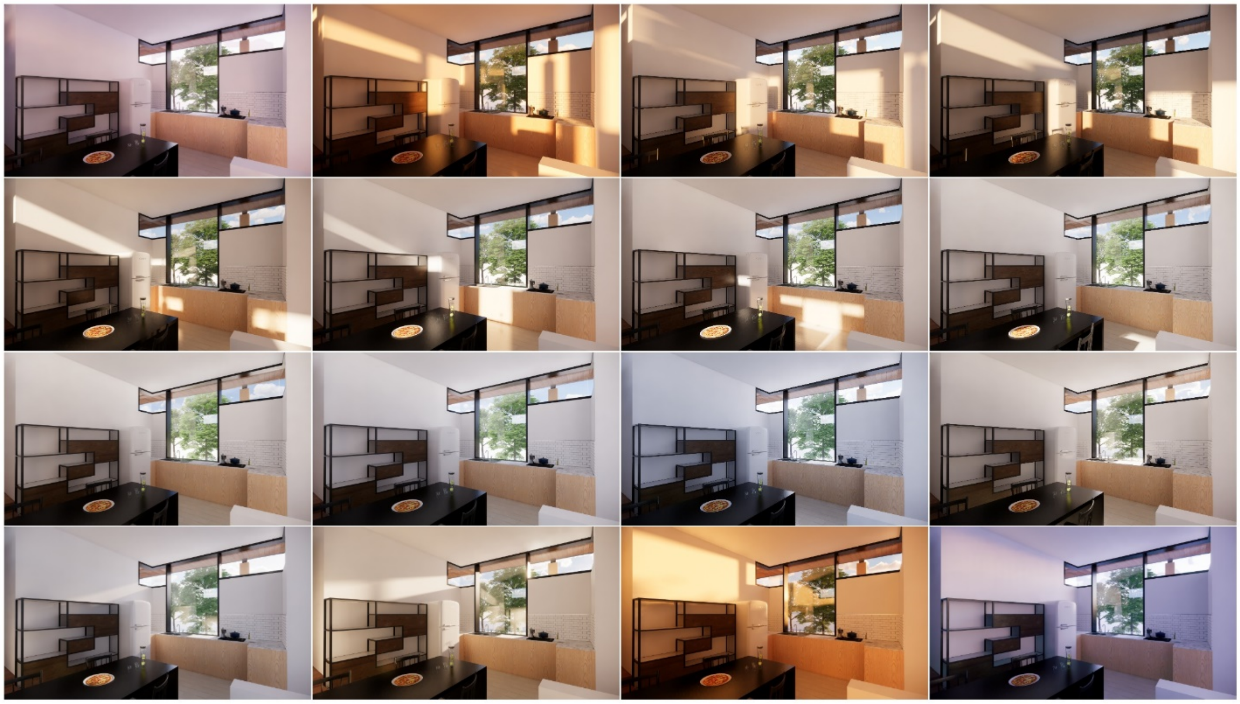

Figure 17. Time-lapse renderings exported in under five minutes from Enscape. (Source: By Author)

With the advent of real-time rendering technology in architecture, we can preview our three-dimensional digital models with not only more accurate lighting and material, but also through time. This is made possible with greater computational power, and newer software. What this allows us to do is quickly preview architecture with a client or end-user in a way that is representative of how the building would look like in real-life. The architect can then use these methods to make animations or virtual walkthroughs that simulate moving through a space. The importance in the step of moving through space to understand it can be seen in *Space and Place: The Perspective of Experience* by Yi-Fu Tuan when he talks about the relationship between time and experience of place. He states that time and place are related in three main ways, *"… time as motion or flow and place as a pause in the temporal current; attachment to place as a function of time, captured in the phrase, "it takes time to know a place"; and place as time made visible, or place as memorial to times past."* Focusing on his first argument, we can look at places as *"pause(s) in the temporal current."*[26] Renderings are depictions of places, but they should not be left without the counterpart of time. To help with the end-user's understanding of space, the movement or flow through space along with pausing in space to capture place should be implemented in representing architectural prototypes. This is what real-time visualization of architecture can help us achieve.

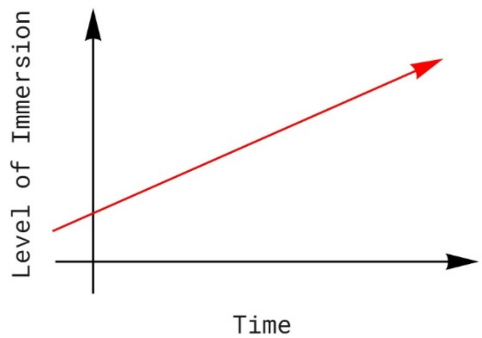

Figure 18. Increasing level of immersion in architectural representation over time. (Source: By Author)

Looking at the three main methods of representing architecture mentioned previously, we can see a trend towards being immersed in architecture during the design process of architecture. Starting off from orthographic drawings, we have low immersivity since the drawings do little to represent the experience of the space but do well in illustrating the dimensions and geometry of space. Moving towards static renderings, we have what are essentially photographs of a building before it's built. These work well in illustrating key viewpoints for the end-user, but do not present an element of time to view.

[26] Yi-Fu Tuan, *Space and Place: The Perspective of Experience*, 7. print (Minneapolis, Minn.: Univ. of Minnesota Press, 2011).

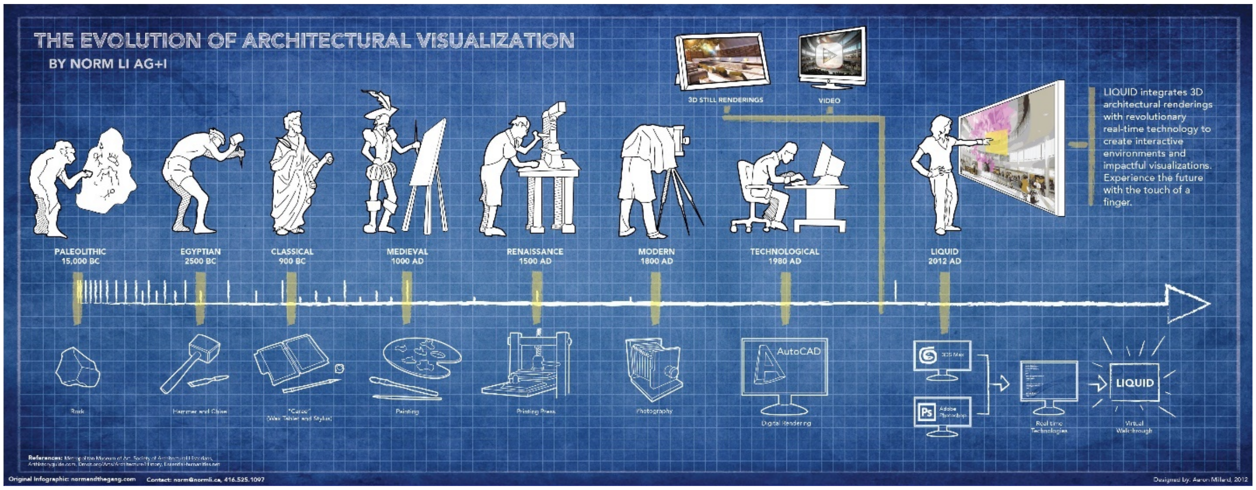

Figure 19. The Evolution of Architectural Visualization. (Source: NORM LI AG+I, Aaron Millard / Downloaded from https://i.pinimg.com/originals/25/35/da/2535dad1c807476354d1c1df4fc886c3.jpg on January 2021)

Finally, with innovations in hardware and software, we can represent architecture in a way that is realistic and interactive. The lighting and materials are almost true to life, and the experience is walkable and not just a painting to look at. The deeper and more integral the experience is, the more the end-user will gain a greater understanding of what the architecture is.[27] This phenomenon is best highlighted in a quote by John Fillwalk, the senior director of hybrid technologies at Ball State University. He says that, "You remember a trip, but you don't remember a lecture."[28]

This is not to say that we would be eliminating 2D drawings in favour of immersive tools. Drawings still can show the overall design vision while incorporating ideas about sequence, proportion, and

[27] Daniela Faas et al., "The Influence of Immersion and Presence in Early Stage Engineering Designing and Building," *Artificial Intelligence for Engineering Design, Analysis and Manufacturing* 28, no. 2 (May 2014): 139–51, https://doi.org/10.1017/S0890060414000055.
[28] Lesley Weidenbener, "2018 Innovation Issue: Is Virtual Reality Already Dead? Or Just Getting Started?," 2018, https://www.ibj.com/articles/69026-innovation-issue-is-virtual-reality-already-dead-or-just-getting-started.

balance. The simplicity of drawing on a blank sheet of paper is yet to be surpassed by digital media.[29]

For the next step in immersion and integrating the end-user into the design process, we can look towards the field of video games. The video game development process is the perfect example of immersion and end-user feedback through beta-testing, since they require the direct involvement of an end-user to experience space. Video games can act as testing grounds for the designer as well as the end-user.[30]

[29] Miguel Baptista Tavares Carreiro, "The Evolution of Representation in Architecture," *1ST ECAADe Regional International Workshop*, 1ST eCAADe Regional International Workshop, 2013, 12.

[30] Thomas McMullan, "Architects Are Playing With the Future of Design in Video Games," Medium, December 9, 2019, https://onezero.medium.com/architects-are-playing-with-the-future-of-design-in-video-games-1352a2d3ae3f.

2.2 How Designers Know About the End-User

2.2.1 Personal Experience

The designer can design for the user based on personal experiences, but this will not encapsulate all the user's actual needs.

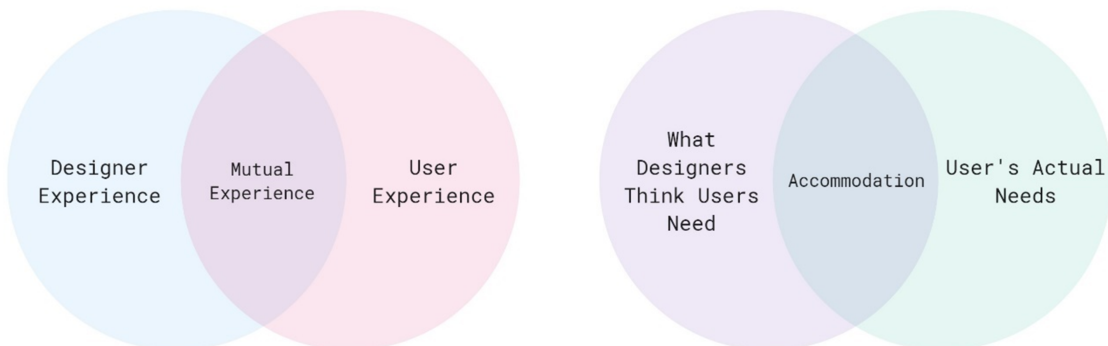

Figure 20. Diagram illustrating the gap between designers and users. (Source: By Author)

As designers, the first thing we use to initiate our designs is our personal knowledge. This seems like something that would be glaringly obvious, but it needs to be addressed if we are to start pointing out the shortcomings of this method. While relying on our personal experiences to make design decisions can be fruitful at times, it may cause designs to exclude user experiences that did not apply to the designer. The result of this design method may create a product that is unfit for people unlike the designer.[31] For example, an architect may prefer their workspace to be brightly lit by fluorescent lights, so they design an office space lit only by powerful lights. A

[31] Jen Heazlewood, "Combatting Unconscious Bias in Design," Medium, April 28, 2017, https://uxdesign.cc/combatting-unconscious-bias-in-design-bff4dfb013c3.

person that uses the office space may prefer a working environment with warmer lighting since the cooler brighter lights cause them eyestrain. Design decisions must be based on more than just our own knowledge because we are not only designing for ourselves, but everyone using the spaces we build. Although the designer may already know a lot about a user, it is valuable to test the designer's opinions and personal knowledge and contrast these to real-world people. This can help validate these existing views as well as change and add new views for future work.[32]

2.2.2 Existing Literature

We can expand on our own knowledge by referencing literature when making design decisions. Most coarse grain problems in architecture have already been solved by other designers and should give the architect a head start in a new project.

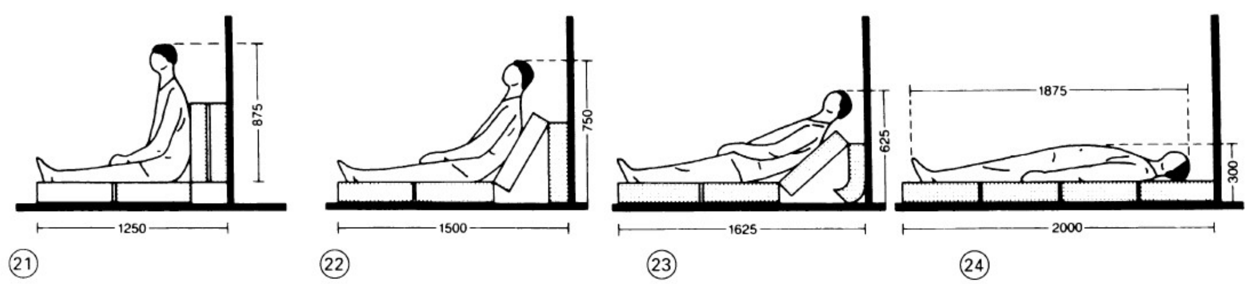

Figure 21. Diagram of various body measurements and space requirements. (Source: Ernst Neufert, Architect's Data 3rd Edition, (Massachusetts: Blackwell Science, 2000), 16)

Architect's Data by Ernst Neufert and *Modulor* by Le Corbusier are examples of existing literature that architects may base their

[32] Xiao Zhang and Ron Wakkary, "Understanding the Role of Designers' Personal Experiences in Interaction Design Practice," in *Proceedings of the 2014 Conference on Designing Interactive Systems - DIS '14* (the 2014 conference, Vancouver, BC, Canada: ACM Press, 2014), 895–904, https://doi.org/10.1145/2598510.2598556.

designs on.[33] These are references which contain information about dimensions and design strategies that have been verified previously. Examples of these references include dimensions for certain building features such as doorways, hallways, and rooms, as well as information regarding building component standards such as bricks, posts, and windows. The advantage of this initial standardization was that it helped unify the design community on certain aspects of design. It allowed all designers with access to the book to have a common foundation to work from.[34] While these references are good to base initial design drafts from, they mainly account for the "average" person, and are slow to update.

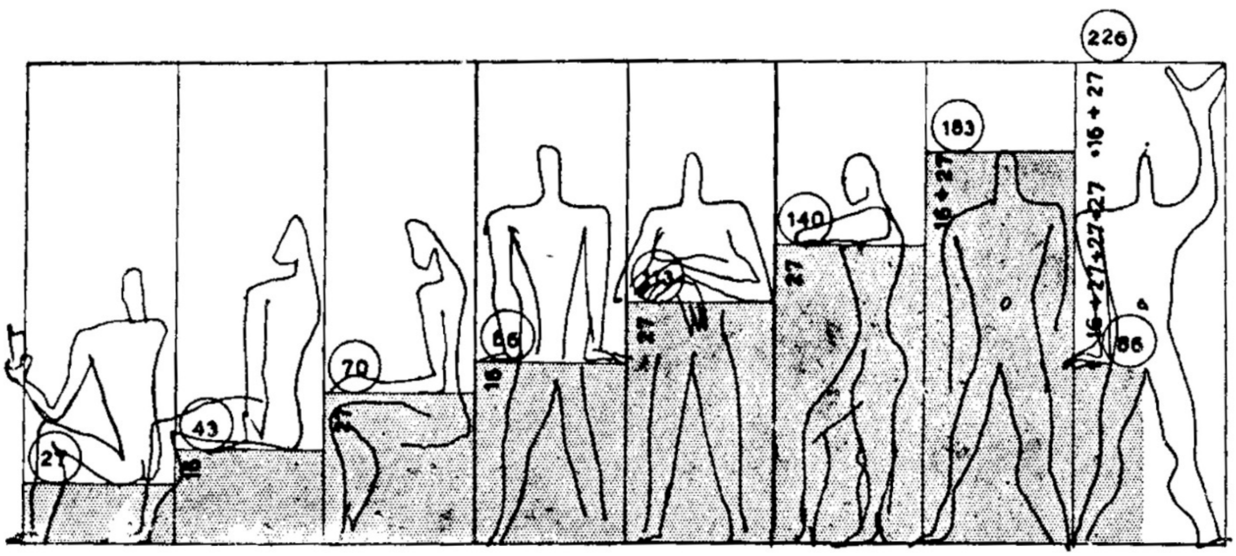

Figure 22. Diagram of Modulor showing all the different human positions and their related dimensions and ratios. (Source: Le Corbusier, El Modulor, (Buenos Aires: Editorial Poseidon, 1953), 62)

Modulor, an earlier work by Le Corbusier, outlined the geometric proportions of the human body to improve upon the ergonomics of

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[33] Ernst Neufert et al., *Architects' Data*, 3rd ed (Oxford; Malden, MA: Blackwell Science, 2000).

[34] "Neufert: The Exceptional Pursuit of the Norm," ArchDaily, October 30, 2017, https://www.archdaily.com/881889/neufert-the-exceptional-pursuit-of-the-norm.

architectural design.[35] The principles built into *Modulor* were based on pure mathematic ratios and proved to have certain limitations to represent the human body. For example, the form which Le Corbusier had settled on was the 6-foot-tall English male since the average French male was too short to fit the requirements of the geometry. Even Le Corbusier himself recognized the limitations and stated that its use should be limited by practical perception. In Le Corbusier's later projects, *Modulor* acted as more of an informational guide rather than a controlling rulebook.[36]

[35] Le Corbusier, *Le Modulor* (Buenos Aires: Editorial Poseidon, 1953).
[36] Michael J. Ostwald, "Le Corbusier (Charles Edouard Jeanneret), The Modulor and Modulor 2 — 2 Volumes. Basel: Birkhäuser, 2000.: Reviewed by Michael J. Ostwald," *Nexus Network Journal* 3, no. 1 (April 2001): 145–48, https://doi.org/10.1007/s00004-000-0015-0.

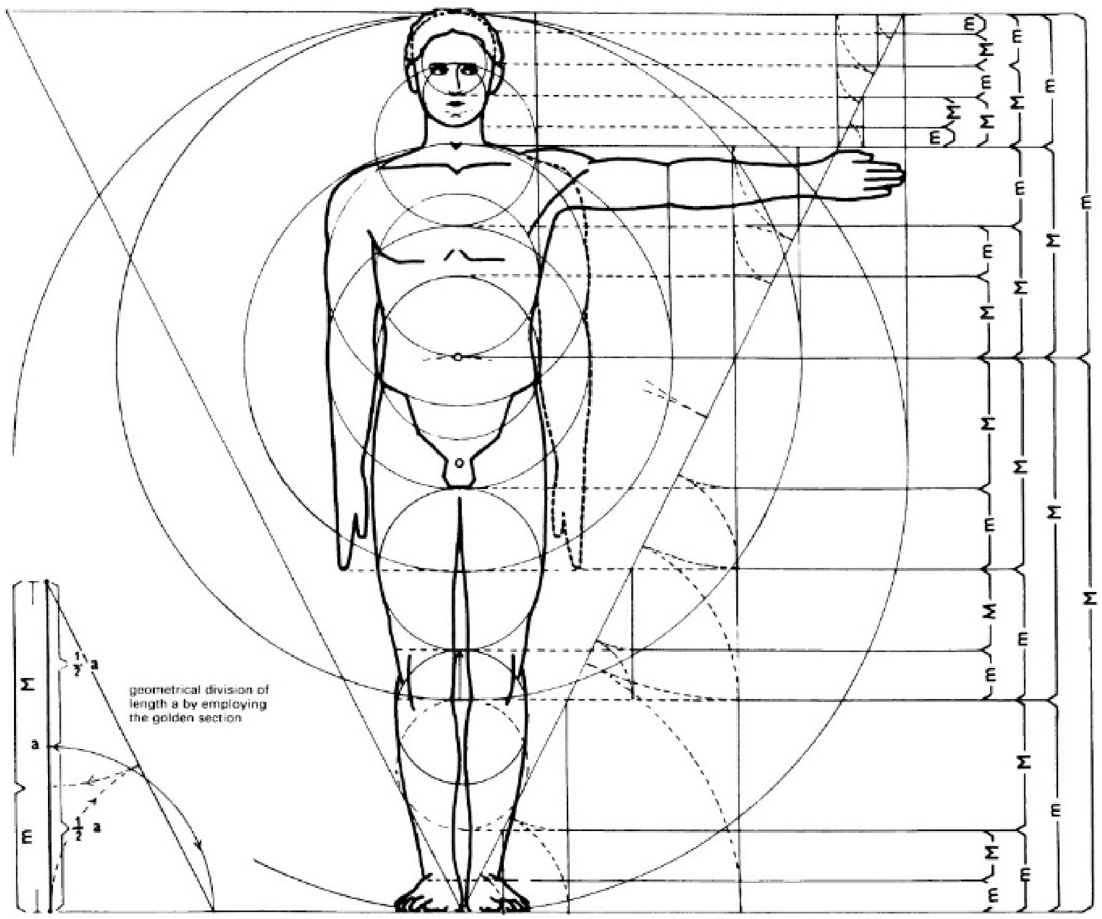

Figure 23. Diagram of man's dimensional relationships. (Source: Ernst Neufert, Architect's Data 3rd Edition, (Massachusetts: Blackwell Science, 2000), 15)

In *Architect's Data, 3rd Edition*, the universal standard that they use to define human dimensions is 'Man: The Universal Standard'.[37] The problem with this is that not every person is a 175 cm tall European male, and the limitation of literature becomes apparent as it cannot account for the diversity of humans.

Looking past ergonomics, we can also see that there is architectural literature referencing other scales of building occupancy. This includes daylighting requirements, acoustic design, psychology of space, as well as occupant space use and physical

[37] Neufert et al., *Architects' Data.*

activity design. They all address problems that a designer may encounter during the design process and propose a solution for said problem.

Daylighting references in architecture address how to naturally illuminate an interior space. Guidelines for how to use solar shading are included to reduce the need for a designer to start from scratch to achieve the same effect. An example of this is *Daylighting: Natural Light in Architecture* by Derek Phillips. The literature points out what aspects of lighting need to be addressed to reduce heat gain from the sun, as well as reducing sun glare.[38]

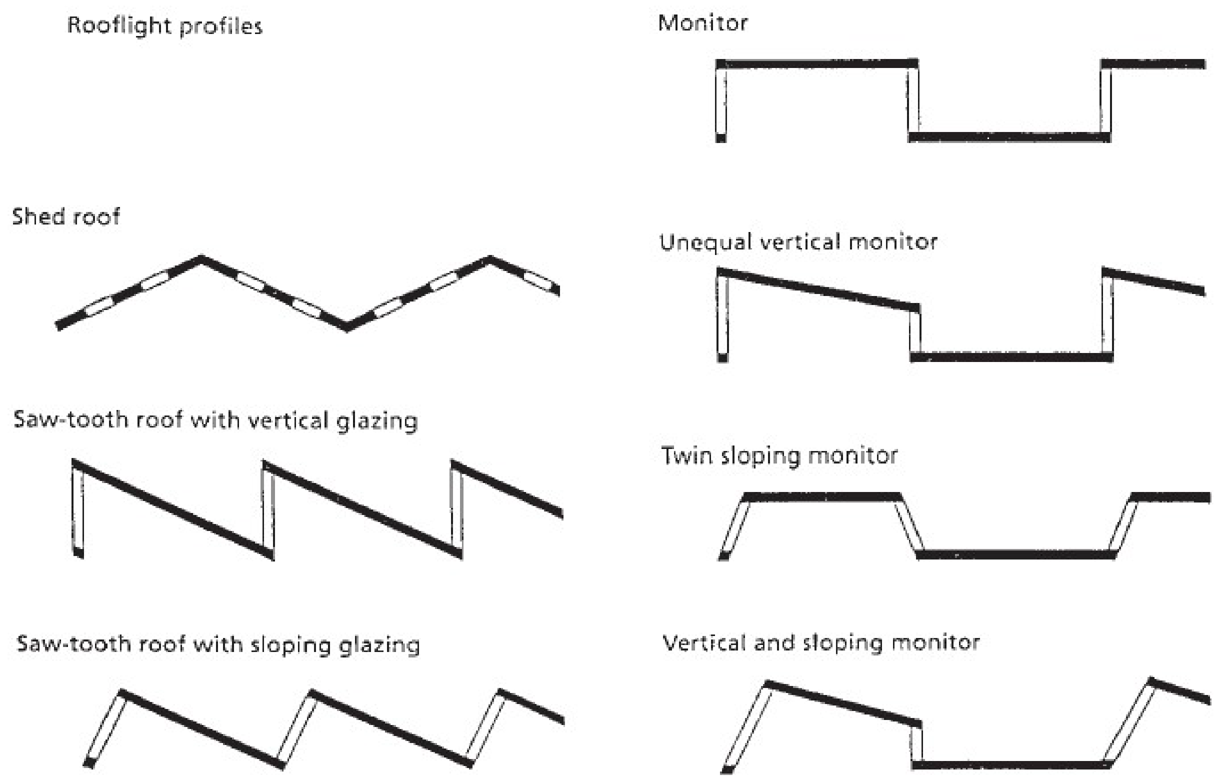

Figure 24. Various roof light profiles from Daylighting: Natural Light in Architecture showing the different types of roof lights a designer can use. (Source: Derek Phillips, Daylighting: Natural Light in Architecture, (Oxford: Architectural Press, 2004), 23)

[38] Derek Phillips, *Daylighting: Natural Light in Architecture* (Oxford: Architectural Press, 2004).

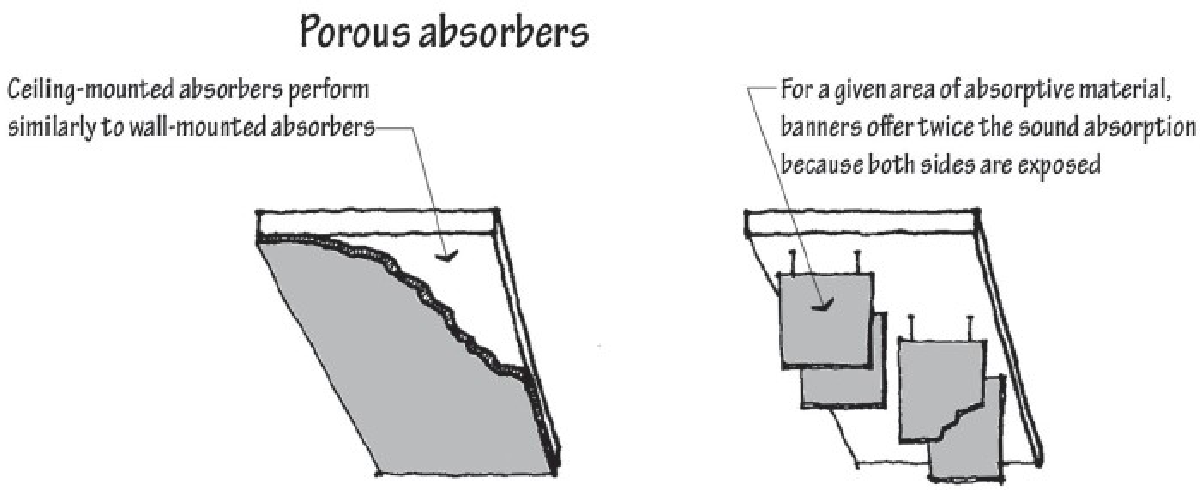

Figure 25. Material and layout-based solutions for sound control and noise mitigation. (Source: Michael Ermann, Architectural Acoustics Illustrated, (New Jersey: Wiley, 2014), 30)

Architectural acoustics literature points out cases where noise is needed or not. *Architectural Acoustics Illustrated* by Michael Ermann provides material and geometric solutions to tackle the requirements for a given project and quantifies the acoustic properties of common building materials. The room shape it recommends differs depending on the use-case for the given room. For example, a room shaped for speech needs elements which direct early arriving first-order reflections of sound to the listener, whereas a room shaped for musical performance needs elements that successfully reflect a wide range of frequencies for sound as well as large sound-reflecting volumes for reverberation and spatial impression.[39]

[39] Michael Ermann, *Architectural Acoustics Illustrated* (Hoboken, New Jersey: Wiley, 2014).

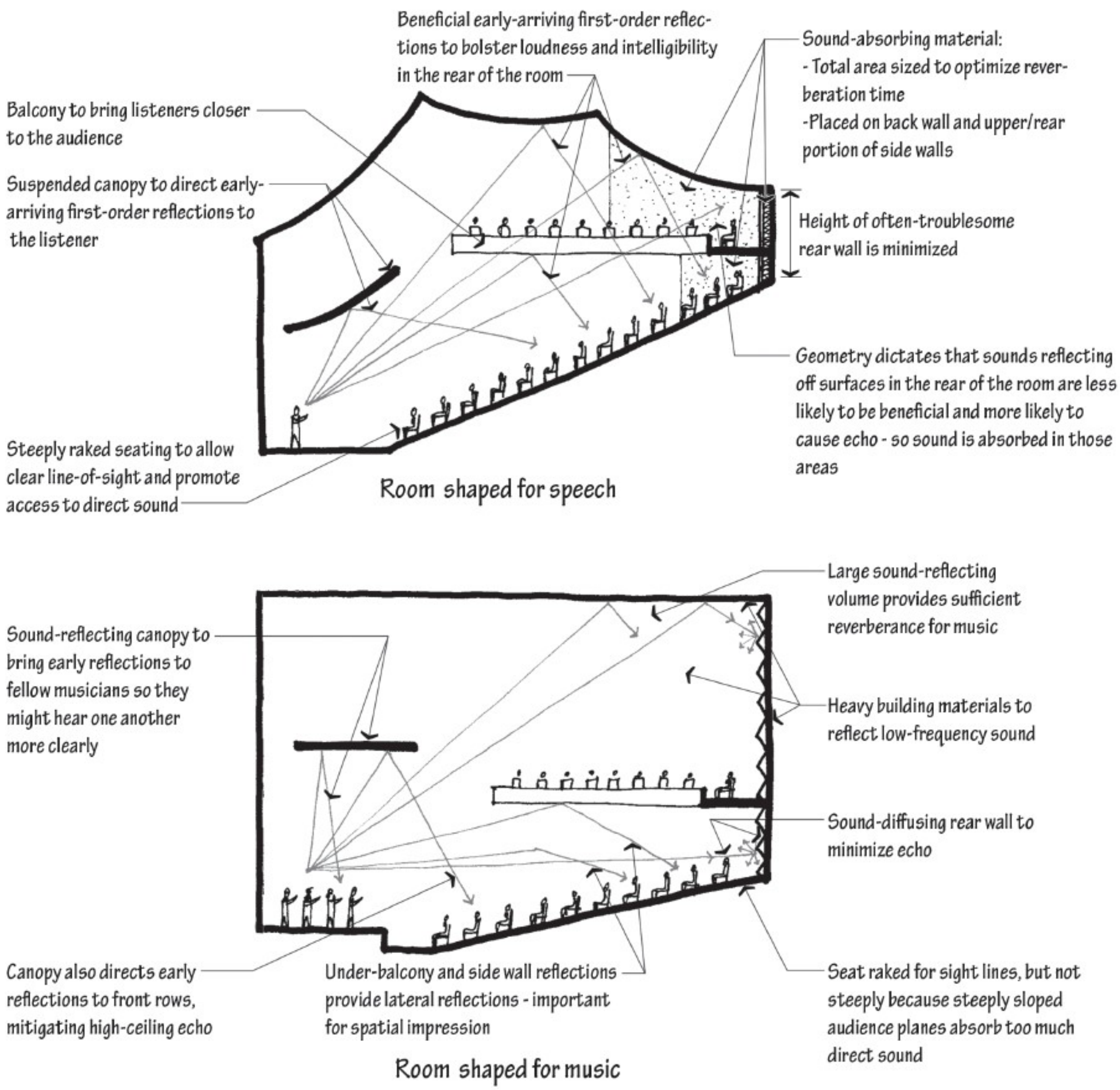

Figure 26. Page 75 from Architectural Acoustics Illustrated. (Source: Derek Phillips, Daylighting: Natural Light in Architecture, (Oxford: Architectural Press, 2004), 75)

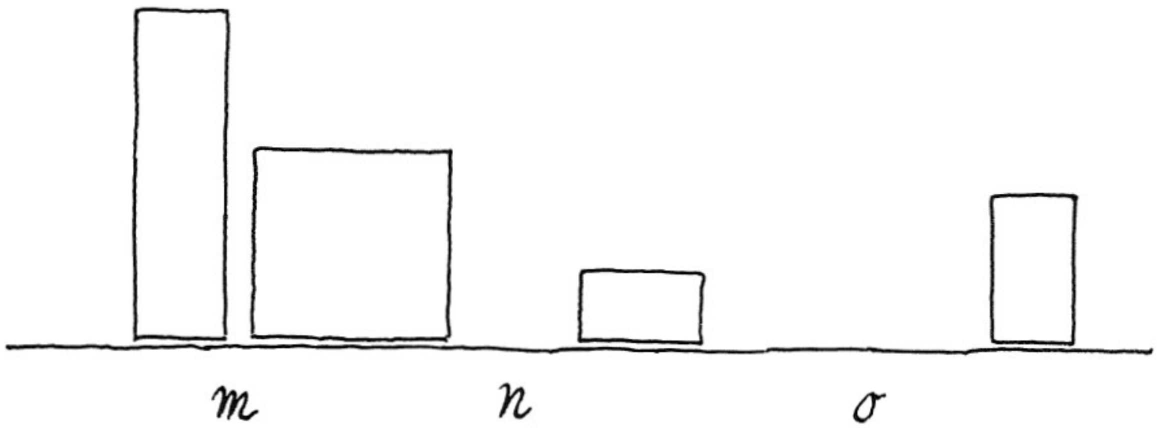

Figure 27. Diagram illustrating interspace where 'n' is the ideal configuration. (Source: Rudolf Arnheim, The Dynamics of Architectural Form, (Berkeley: University of California Press, 1977), 19)

Psychology of space talks about how architectural forms can be used to establish spatial perception. This is seen in *The Dynamics of Architectural Form* by Rudolph Arnheim. One analysis in the book demonstrates the concept of interspace which investigates the perception of an observer depending on the distance between buildings as well as their sizes.[40] Looking at the above diagram, the first interspace is too close together, the second is just right, and the last is too far apart. This is dependent on the way the human mind perceives the tensions and stresses present in the graphic. The same neurological process is present when we arrange anything from placement of furniture in a room to the arrangement of buildings in a plaza.[41]

[40] Rudolf Arnheim, *The Dynamics of Architectural Form* (Berkeley: University of California Press, 1977).
[41] Arnheim.

Figure 28. Ground floor daily activity observations from office space. (Source: Stamatina Th. Rassia, Workplace Environmental Design in Architecture for Public Health, (Cham: Springer International Publishing, 2017), 51)

Occupant space use outlines how end-users will generally use space. *Workplace Environmental Design in Architecture for Public Health* does this through illustrations of pathways where people walked. The data collected in the illustrations also indicate whether journeys are 'voluntary' or 'imperative'. They also use this analysis to determine what elements of the design worked well such as an open-concept floor plan that allowed staff to initiate socialization in the communal area.[42]

[42] Stamatina Th. Rassia, *Workplace Environmental Design in Architecture for Public Health: Impacts on Occupant Space Use and Physical Activity*, SpringerBriefs in Public Health (Cham: Springer International Publishing, 2017), https://doi.org/10.1007/978-3-319-53444-2.

2.2.3 Design Review Panel

We can consult with other designers to find out what they've done in similar design situations.

Figure 29. Design Review Panel of the City of Toronto review a project. (Source: City of Toronto / Downloaded from https://www.toronto.ca/city-government/planning-development/outreach-engagement/design-review-panel/ on January 2021)

The purpose of a Design Review Panel (DRP) is to aid in a city's planning review process to determine whether certain proposals get approved. For example, in the City of Toronto, the DRP is made of individuals which are external to city staff which volunteer to provide design advice to the city.[43] The members of the panel are composed of professionals in various fields such as architecture, sustainability, and urban design. The DRP may not be a direct communication line to the end-user but can provide helpful responses to the architect regarding design concerns which are specific to the city and its people. Some of the things they may comment on include

[43] "Design Review Panel," City of Toronto (City of Toronto, September 7, 2017), Toronto, Ontario, Canada, https://www.toronto.ca/city-government/planning-development/outreach-engagement/design-review-panel/.

how friendly the design is for pedestrians, building layouts on the site, as well as how the building relates to the public realm.[44]

2.2.4 Attitude Surveys

We can reach out to potential end-users and ask them what they think through attitude surveys. This helps us learn about the user a little bit more, but takes a lot of time, and feedback is typically on something simple like a static image.

One of the easiest ways to find out what a user likes and dislikes about a building proposal is to send them an attitude survey. An attitude survey involves showing an end-user an image or document, and then proceeding to ask them a series of questions to reflect on what they saw. The questions involved can be about how an end-user felt after seeing a certain image, or about how much they would agree or disagree to certain statements pertaining to the image.

2.2.5 Post-Occupancy Evaluation (POE)

To find out more about what the end-user thinks about an already existing project, we can conduct Post-Occupancy Evaluation. Unfortunately, most architects do not conduct POE on any completed projects.

Upon the completion of a building, it can be critically assessed to determine the efficacy of design and construction strategies. This

[44] Urban Toronto, "DRP 101: What Exactly Is the Toronto Design Review Panel? | UrbanToronto," accessed November 11, 2020, https://urbantoronto.ca/news/2019/12/drp-101-what-exactly-toronto-design-review-panel.

is called Post-Occupancy Evaluation (POE). This method can help uncover aspects of the building that occupants liked or disliked while using the space. The value of a POE can be seen when making design decisions for a proposed building with similar requirements. Problems and effective solutions proven though POE can be resolved and employed for the new project.[45]

In 2013, the Evidence Based Design Journal conducted a global survey of 420 designers to determine how people gather information for designing buildings. Of the respondents, 73% identified as primarily architects, and 80% of respondents thought that there was a requirement for evidence in the design process. Out of all the respondents, only 32% ever reviewed research literature, and only 29% ever conducted any form of post-occupancy analysis for completed projects. Most of the designers which recognized the need for evidence-based design but did not use it cited the issues of time and money. Clearly, evidence-based design did not have enough perceived value for the client to justify increasing the duration and cost of a project to be completed.

Architects can conduct POE after a project is completed, but what if we could perform Pre-Occupancy Evaluation?

[45] Silvio Plescia and Dunsky Energy Consulting, “Research Insight: Post-Occupancy Evaluation — A Guide for Multi-Unit Residential Buildings” (Canada: Canada Mortgage and Housing Corporation, April 2017), https://assets.cmhc-schl.gc.ca/sf/project/cmhc/pubsandreports/pdf/69087.pdf?rev=13ae6ae4-f555-4ad4-a5c8-3e55f377bc40.

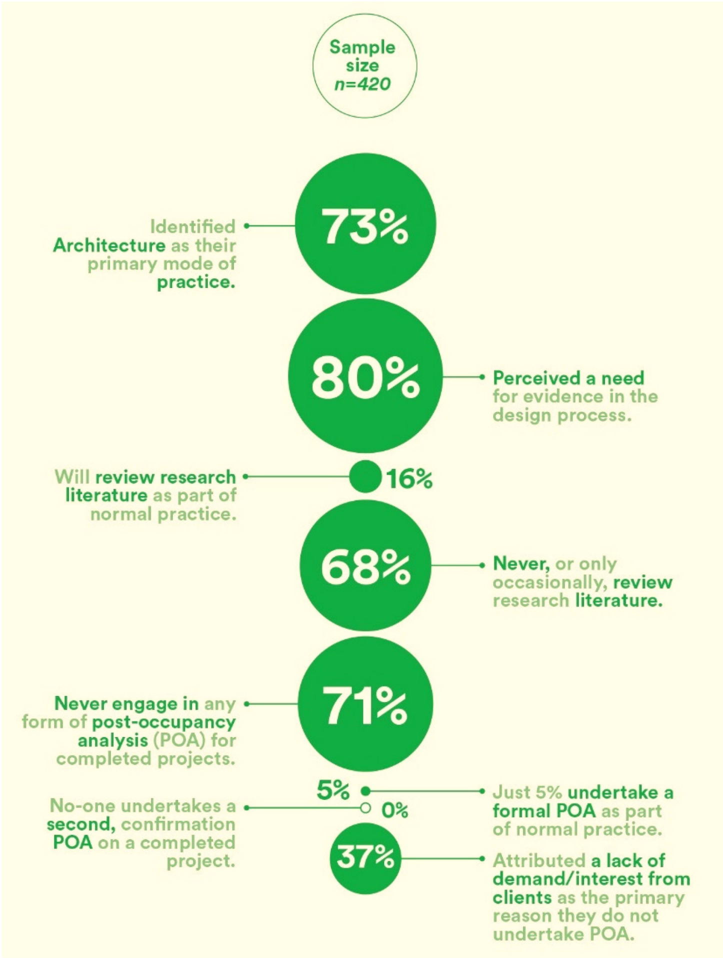

Figure 30. Main results of global survey into knowledge practices of design studios conducted by Evidence Based Design Journal. (Source: EBD Journal / Downloaded from http://ebdjournal.com/blog/general-design/the-knowledge-problem on January 2021)

The Evidence Based Design Journal argues that the case for this is through two main reasons. The first reason is our training as designers in the field of architecture to be the universal model for all end-users. Design studios in general do not require students to gather enough evidence regarding the impact of their ideas. They state that, "We make design decisions about anthropospatial[46] consequences on the basis of personal experience alone, and the potential truth of our

[46] EBD Journal defines 'anthropospatial' as the transaction between people and the built spaces that they occupy. Since the term 'Proxemics' refers to person-to-person crowd behavior, they define the new term to account for the impact of the built environment.

assumptions is almost never tested." The second reason that they give is that architectural space is traditionally viewed as something that is static in time and does not adapt to its surroundings in time.[47]

While POE does serve as a critical stepping point in understanding the end-user for architectural design, where it falls behind is adapting for active projects. The information that is collected from existing buildings can only serve so well for newer projects since there will inevitably be differences that cannot be accounted for in POE. An example of this may be that the new building is not for the exact same demographic as the previous, or it may be that the city planning requirements for the building alter the programmatic content of the building slightly resulting in a different project layout. End-users are people, and we need to identify that these are people with different behaviors, needs, and attributes that vary from person to person. Speeding up the design process just to finish a building does not provide extra value to users. Often, it is more productive to work smarter with design intelligence rather than rapid reactionary design.[48] We cannot assume the needs of the end-user; therefore, validation throughout the design process is needed for a successful product.

[47] "Evidence Based Design Journal | The Knowledge Problem," accessed November 10, 2020, http://ebdjournal.com/blog/general-design/the-knowledge-problem.
[48] Michael Hinnant August 14, 2018 July 22nd, and 2019, "The Risks of Reactionary Design: Part One," *Filter* (blog), August 14, 2018, https://filterdigital.com/blog/risks-of-reactionary-design-part-one/.

2.3 Designer and End-User Co-operation

2.3.1 The Designer Still Matters

This isn't all to say that we should rely on the end-user to design projects for us. We need to find the balance between the designer and the end-user to supply both experience and expertise in making design decisions.

The responsibility of making design decisions should still reside with the designer since they are the expert for a reason. Architects know how to create spaces well through construction methods, programming, and sustainable design strategies, and provide expertise needed for projects which users lack. The importance finding the balance of power is what matters here. Since architects are creating buildings for people, it only makes sense that those same end-users be the ones to fill in the gaps of knowledge for the architect.

2.3.2 Shifting Design Power for The Right Reasons

The end-user should get more say in the design process, but the illusion of participation is something that should be avoided. The value gained from participation should not purely profit those in positions of power.

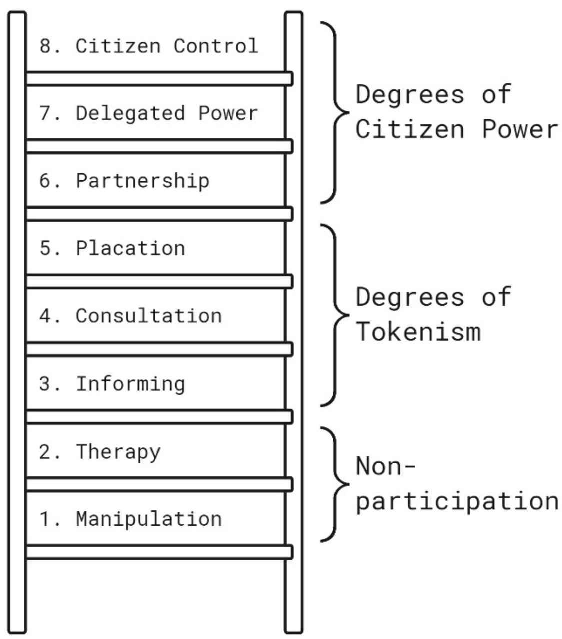

Figure 31. The Eight Rungs of Citizen Participation as defined by Arnstein. (Source: Sherry R. Arnstein, A Ladder of Citizen Participation, (Chicago: Journal of the American Institute of Planners, 1969), 35:4, 217 / Redrawn by Author)

In the article *A Ladder of Citizen Participation*, Sherry Arnstein defines the levels of “citizen participation” in the form of rungs on a ladder. The lower rungs of the ladder denote little to no citizen participation, whereas the higher rungs of the ladder define high degrees of citizen power. Fundamentally, everyone wants high citizen participation, but the implementation of this in real-world applications proves to be difficult. Participation can easily become a meaningless process that does nothing but provide the illusion of including the citizen. As Arnstein states, “There is a critical difference between going through the empty ritual of participation and having the real power needed to affect the outcome of the process. This difference is brilliantly capsulized in a poster painted last spring by the French students to explain the student-worker rebellion.”[49]

Figure 32. Poster painted by French students to illustrate student-worker rebellion. (Source: Sherry R. Arnstein, A Ladder of Citizen Participation, (Chicago: Journal of the American Institute of Planners, 1969), 35:4, 216)

Understanding the combination of avoiding the illusion of participation as well as the steps needed to climb the rungs of the ladder are critical in finding the balance in design decision power between the designer and the end-user.

[49] Sherry R. Arnstein, “A Ladder Of Citizen Participation,” *Journal of the American Institute of Planners* 35, no. 4 (July 1969): 216–24, https://doi.org/10.1080/01944366908977225.

3 [Context] Processes in Parallel

3.1 Design Processes in Use

The field of video game design is like the design process of architecture. The difference is that there is a great focus on testing, specifically with end-user usage.

In architecture, there are many things about a building that we can test during its design. We can test the viability of its structure using computer software to simulate the forces acting on the building. We can also test what the building will look like by creating a digital model and rendering certain viewpoints to analyze. What we cannot test very well is how a building will be used with end-users. The field of video game design may provide some insight as to how this can be achieved.

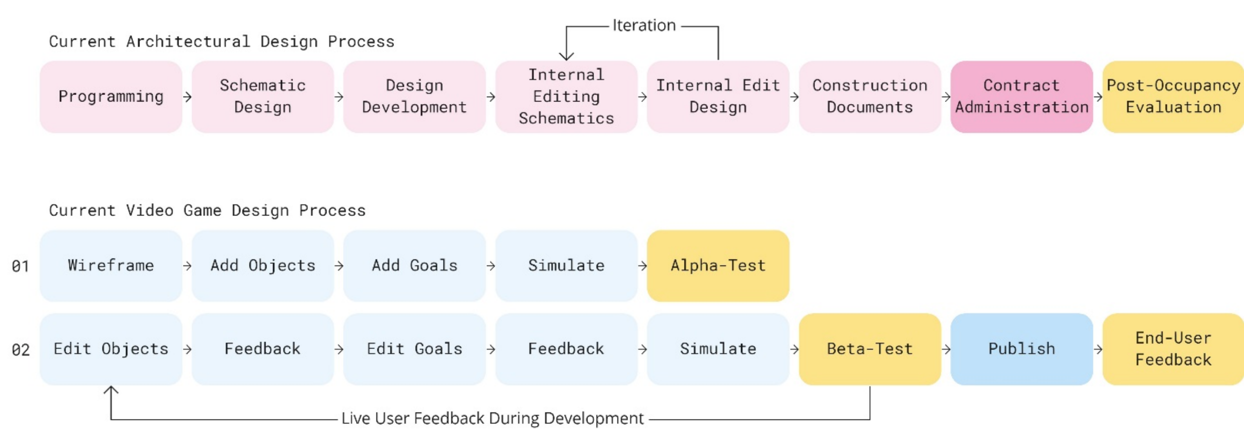

Figure 33. Diagram illustrating the current design processes found in architectural design and video game design. (Source: By Author)

3.2 Player Testing in Video Games

3.2.1 Playtesting

Playtesting is used in game design to understand the player experience while playing the game.

A typical method to improve game design is by using player testing to understand how players will experience the game. The information that can be gathered through this process is vital for the development of the game. The main issue with this process is how effectively the data about the end-user can be analyzed and visualized allowing for actionable points to aid in the game's design.[50]

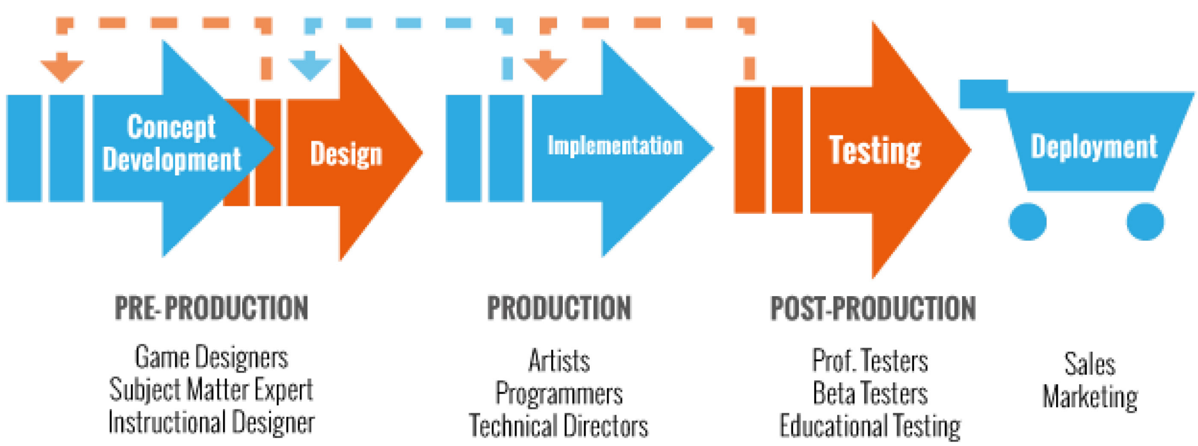

Figure 34. Video game design production process. (Source: BitBar / Downloaded from https://bitbar.com/blog/the-agile-process-for-mobile-game-development-and-testing/ on January 2021)

[50] Pejman Mirza-Babaei, Naeem Moosajee, and Brandon Drenikow, "Playtesting for Indie Studios," in *Proceedings of the 20th International Academic Mindtrek Conference on - AcademicMindtrek '16* (the 20th International Academic Mindtrek Conference, Tampere, Finland: ACM Press, 2016), 366–74, https://doi.org/10.1145/2994310.2994364.

3.2.2 Alpha-Testing

In game design, alpha-testing is the process of in-house playtesting. Knowledge generated from this is limited to the user-base within the design team.

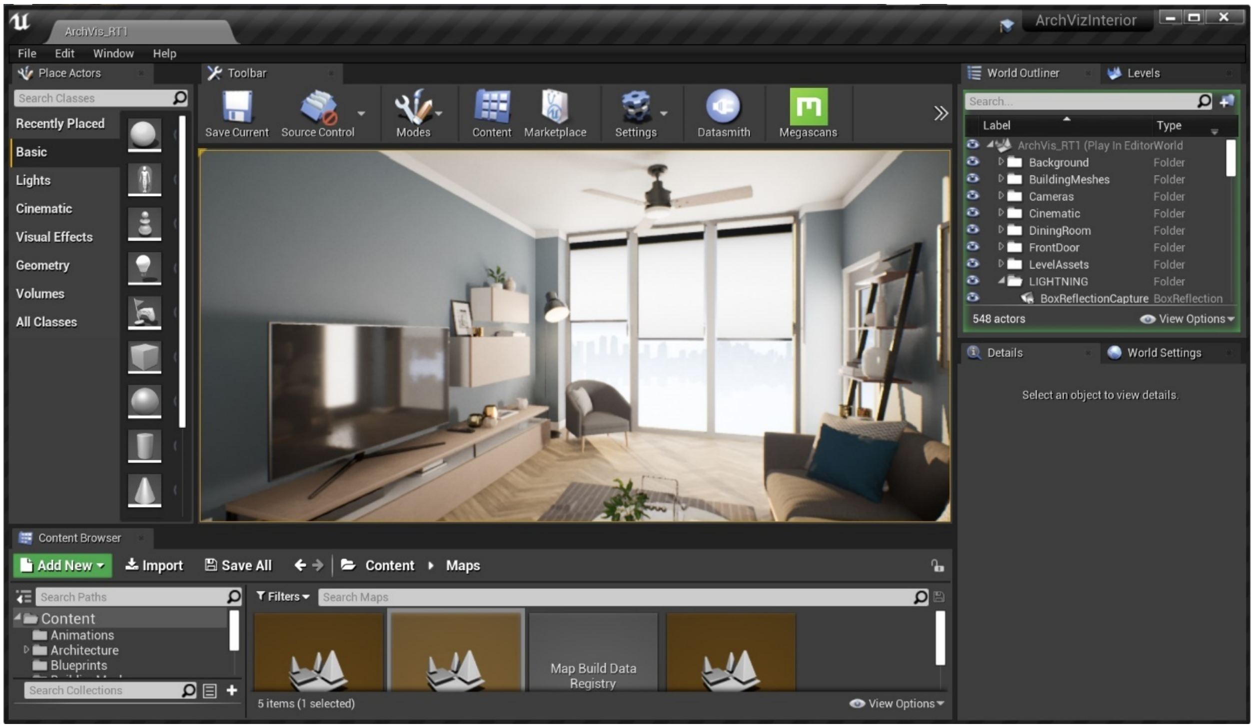

Figure 35. Screenshot of Unreal Engine 4 Editor "playing" the level. (Source: By Author)

The development process of a video game is like the architectural design process in that the first two phases involve a conceptual phase which leads into the design phase. The conceptual phase involves the creation of a core idea of the game along with a proposal document drafted up to outline topics such as market analysis, technical issues, budget projections, and game-feel. The design phase involves the development of a design document that encompasses more specific technical requirements of the project such as game engine selection, software development needs, and game mechanics. It is at this point where the game developer starts production using the information provided by the design document and the core concept of the game.

This first version of the game is called the alpha version. The alpha version of the game is a minimum playable version of the game which is used to test functionality of the game. Alpha-Testing is the phase of game development where the developers themselves play the game to determine issues around how easy the piece of software is to use, as well as if it is reasonably challenging and fun to play. Through this internal testing, problems are revealed which are resolved before progressing to the development of the beta release. [51]

In architecture, the process to get to this point of development is almost identical. The main difference is that the act of alpha-testing involves the architect speculating on how a space may be used. Spaces are laid out according to requirements, and the architect envisions how users might interact with those spaces. Any issues which may arise from this envisioning process are edited before the next phase of production.

[51] Simon Egenfeldt-Nielsen, Susana Pajares Tosca, and Jonas Heide Smith, "Understanding Video Games," n.d., 387.

3.2.3 Beta-Testing

Beta-testing is when real-world end-users are involved in the process of playtesting. In this stage, users can experience spaces without the direction of the designer to find out problems in the scene.

Figure 36. What a beta-tester might see while play-testing the game. (Source: By Author)

In video game development, the beta version of a game is developed for the purpose of real-world testing. This version of the game further developed with the intention of inviting beta testers to experience it. The goal here is to have beta-testers play through the game and offer suggestions on bug fixes and gameplay changes.[52] By introducing external viewers to play the game and offer feedback, insight about how to improve the game is now gained that the developer did not previously know. For example, if the player is presented with a fork in the road, how many of these players will go left, and how

[52] Egenfeldt-Nielsen, Smith, and Tosca, *Understanding Video Games*.

many will go right? It is up to the developer to observe how the tester interacts with the digital space and learn from the experience. The important part is that the beta-tester is not given explicit instruction to go either way by the developer, rather the game must speak for itself.[53]

The most common way for a developer to collect information about an end-user's experience in-game is to have them submit a feedback form. The information that this form may include are a title, steps that the end-user took to get to the problem point (or bug), and screenshots of the part of the experience that they are referring to.

In architecture, we do not have the same methodologies in place, and we often have designer led presentations of our drawings, renderings, and virtual walkthroughs. End-users aren't typically able to explore space on their own; therefore, our building designs aren't necessarily able to speak for themselves.

[53] Bates, *Game Design*, 2004.

4 [State of the Art] Leading Methods and Tools

There are two main categories in describing leading methods and tools. These are methods of representation, and tools for learning about the end-user.

In terms of state of the art, there are two main categories that need to be addressed. The first category is the methodology that is currently being used in architecture to address how to test and or evaluate architecture for how well it performs in the real world. This will talk about the different types of software and hardware available right now for architects to use. The second category is the technology involved in digital architectural representation.

4.1 Use-Case and Scenario Programming

Use Cases and Scenarios is a design method that allows the analysis of different scenarios to guide design decisions. Instead of predicting the usage of buildings in 10 years, we should be strategically designing for flexibility of how a space can be used.

4.1.1 Requirements Engineering for a Synagogue Kitchen

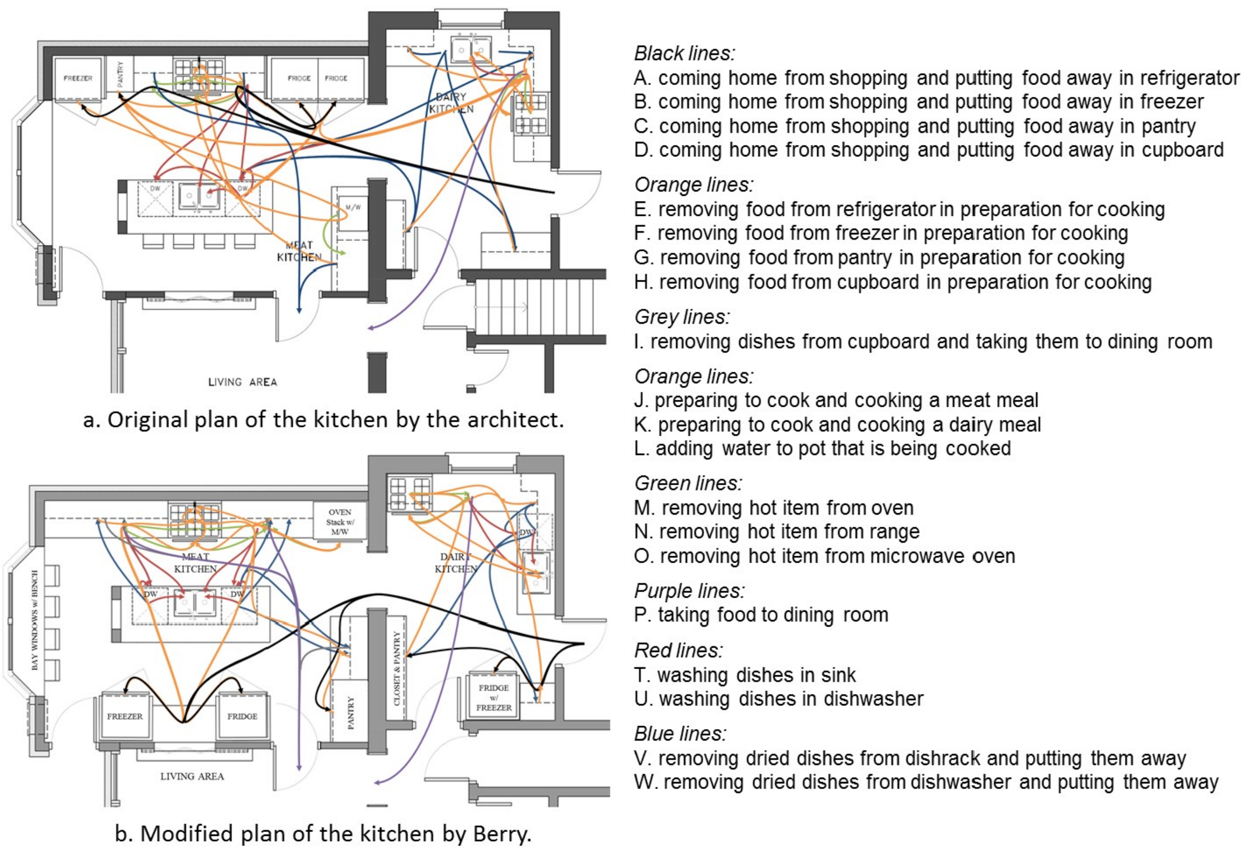

Figure 37. Daniel Berry lays out a synagogue kitchen based on different scenarios to minimize travel distance between stations. (Source: Daniel M. Berry Lessons Learned from and for Requirements Engineering and Building Construction, (Waterloo, Canada: IEEE, 2014), 52)

In 2014, Daniel Berry attempted to redesign a synagogue kitchen proposal since he felt that the original design did not address the functionality of the space enough. Being an expert in kitchen design, he found that the original architect of the design had inexperience in laying out a synagogue kitchen based on functionality. In his redesign of the kitchen, he used the concept of Use Cases and Scenarios (UCaSs) to determine the layout and adjacency of each element in the kitchen.[54] The principles which he followed were determined based on Kashrut (the property of being kosher) as well as basic kitchen usage laid out in the book *Household Engineering: Scientific Management in the Home written* by Christine Frederick in 1919. The book lists the UCaSs required in a kitchen which Berry used.[55]

[54] Cyril Mauger and Daniel M. Berry, "Lessons Learned from and for Requirements Engineering and Building Construction: A Case Study of Requirements Engineering for a Synagogue Kitchen with Use Cases and Scenarios," in *2014 IEEE International Conference on Software Science, Technology and Engineering* (2014 IEEE International Conference on Software Science, Technology and Engineering (SWSTE), Ramat Gan, Israel: IEEE, 2014), 67–76, https://doi.org/10.1109/SWSTE.2014.11.
[55] Christine Frederick and American School of Home Economics, *Household Engineering: Scientific Management in the Home* (Chicago: American School of Home Economics, 1921).

4.1.2 How Buildings Learn

Stewart Brand describes the idea of scenario planning. Where the traditional form of planning relies on predicting what users might need ten years into the future, scenario work acts as a strategy to address current concerns as well as future concerns with flexibility. Brand states this in the following quote:

> *"ALL BUILDINGS are predictions. All predictions are wrong. … I suggest that there is a tool ready to hand, not used by the design professions before, that could be as useful to a home-owner-builder as to a city planner. The tool, called scenario planning, has been evolving quietly for thirty years —first in a military context, later by corporations forced to think ten years ahead by a business environment which had become so turbulent that traditional forecasting was useless. The product of skilled scenario work is not a plan but a strategy. Where a plan is based on prediction, a strategy is designed to encompass unforeseeably changing conditions. A good strategy ensures that, no matter what happens, you always have maneuvering room. Many architects would insist, "We already do that. It's the whole point of programming. We talk to the people who will be the building's users in great detail to find out exactly what the range of their future needs might be, and then we build around that." Programming is indeed one of architecture's great achievements, a sophisticated planning technique that might be profitably employed by many another industry. But it has limitations built in that are worth examining, because they make explicit a systemic fault in modern architecture. The cure also, then, must be systemic."*[56]

Rather than using feedback to predict what buildings need, we should use feedback to "encompass unforeseeably changing conditions."

[56] Stewart Brand, *How Buildings Learn: What Happens after They're Built*, 1995.

4.2 Tools to Gather Information

State of the art methods that we gather information include simple conversation, electronic surveying, eye tracking, mapping paths of travel, and annotating virtual space.

The tools that we use to gather information from the user can range from low-tech to high-tech solutions. Some of the lower-tech solutions can include paper surveys or simply talking to people. Surveys can be critical tools to provide designers with information about end-user requirements. An even more direct connection with the end-user would be in-depth interviews with them. Even though this method would gather more direct information from the end-user, information that is implicit to their experience may not be easily communicated.

4.2.1 A Conversation

Gathering information from the potential end-user could be as simple as just talking to them. As seen in the exercise in redesigning the synagogue kitchen by Berry, one of the strategies he employs is simply walking the end-user through the kitchen layout with a print-out. He points to the elements of the design and simply requests the end-user use their imagination to run through the process of using the space.[57]

The method of just talking to people is helpful in finding out what people need and want but is also time consuming since a designer would have to talk to each person to collect this information. The

[57] Mauger and Berry, "Lessons Learned from and for Requirements Engineering and Building Construction."

usage of technology to get this feedback from people would be more beneficial since electronically processing this information would allow designers to collect more information.

4.2.2 Electronic Surveying

Figure 38. Results of One Shared House 2030 Survey. (Source: One Shared House 2030 / Downloaded from http://onesharedhouse2030.com/ on December 2020)

To decrease the amount of work required in a one on one interaction between the designer and end-user, we can use electronic surveys hosted on websites as our research tools to find out more about end-users. The One Shared House 2030 project run by Space 10 does exactly this by creating a playful online survey that asks about living space preferences of people. Through this tool, end-users were able to communicate what parts of living spaces they were comfortable sharing with other people. They were able to categorize this information about people of all ages, in any life situation, from all countries.[58]

4.2.3 Eye Tracking (Tobii Eye Tracker)

Figure 39. Woman wearing eye tracker glasses to identify what parts of Munich Airport she was looking at for wayfinding. (Source: Tobii Pro / Downloaded from https://www.tobiipro.com/applications/marketing-user-research/case-studies/munich-airport-study/ on January 2021)

Tobii Pro is a company that makes eye tracking hardware that aids in market research exercises.[59] One of the ways that they used that eye tracking software for providing insight for how people interact with space was with the Munich Airport wayfinding design. [60] They asked volunteer travellers to wear Tobii Glasses 2 devices as they navigated the airport to gather information about what they experienced in their

[58] "How Will We Live in the Year 2030?," ONE SHARED HOUSE 2030, accessed December 7, 2020, http://onesharedhouse2030.com/.
[59] Tobii Pro, "Eye Trackers and Software for Research | View Our Products," Offer, May 21, 2015, https://www.tobiipro.com/product-listing/.
[60] "Munich Airport Wayfinding Study Using Eye Tracking," CustomerCase, November 1, 2019, https://www.tobiipro.com/applications/marketing-user-research/case-studies/munich-airport-study/.

journey. The information collected involved ideas of visibility of signage, attention that the sign drew, and the understandability of the signage. The eye tracking devices allowed designers to see which pieces of information were necessary for the traveller, and what design elements to emphasize for future travellers' ease of use. This information collected can then be used to produce heat maps that indicate what elements were looked at the most.

4.2.4 Annotation in Virtual Space

Software like IrisVR is already taking advantage of using VR to help people annotate projects in virtual space. What this allows people to do is to preview architectural spaces and give live feedback that could be in the form of text bubbles tied to specific points in space or line drawings that can be created in virtual space.

4.3 Efforts of Digital Immersion in Architecture

IrisVR, Enscape3D, and Twinmotion are all examples of software used in the field of architecture to help achieve greater immersive experiences for designers. They are all generally focused on visual representation and markups.

4.3.1 IrisVR

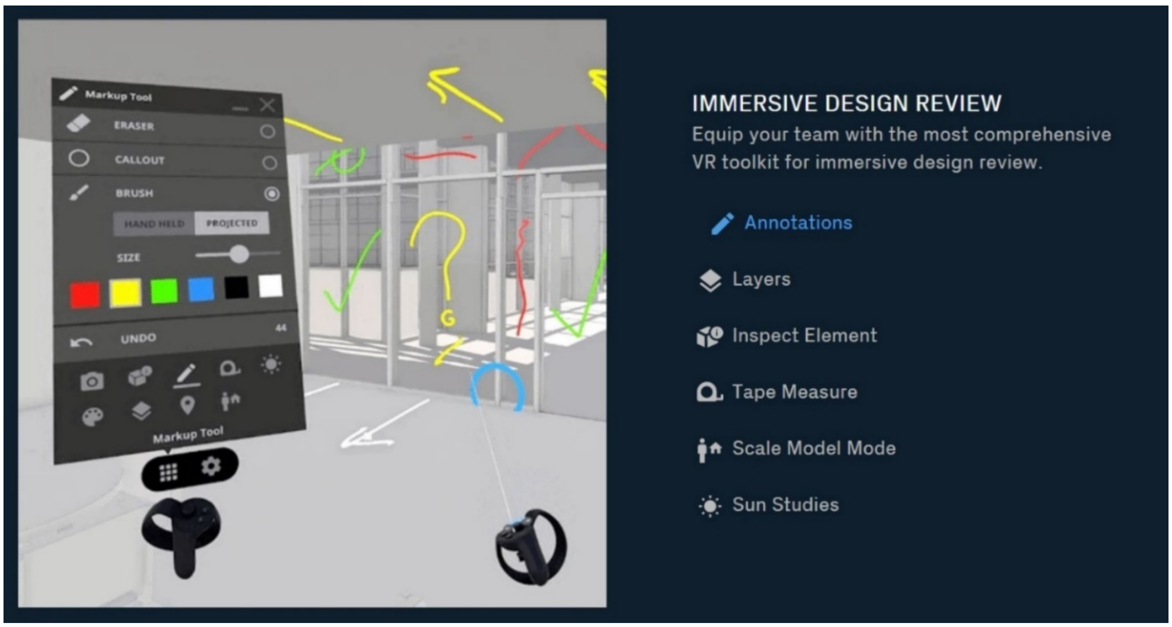

Figure 40. IrisVR allows users to markup 3D models using in-software annotation tools. (Source: IrisVR / Downloaded from https://irisvr.com/prospect on January 2021)

IrisVR is a virtual reality application that turns a computer model of a building into an interactive multi-user experience.[61] The model must be exported from a modelling software of choice, and then viewed in the program. The visual fidelity is low for its virtual reality experience, but the ability to mark up the model in real-time

[61] “VR for Architecture, Engineering, and Construction,” accessed December 10, 2020, https://irisvr.com.

with other users is a strength of the software. There is no ability to test the function of a space or even edit the space in real-time.

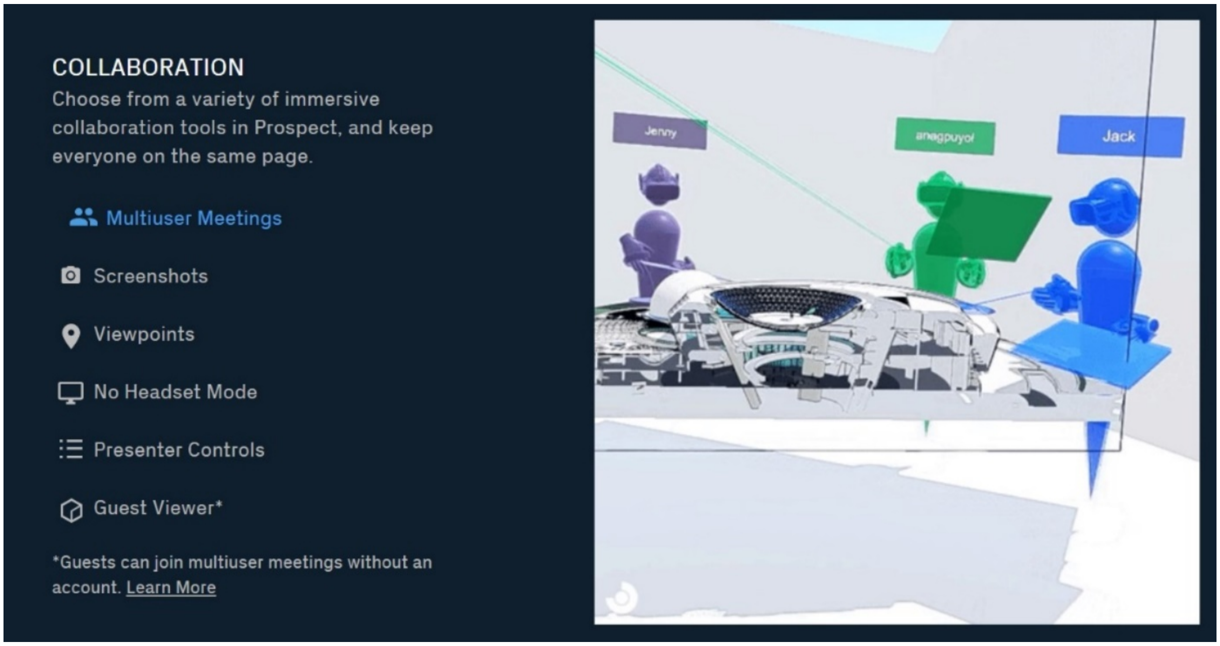

Figure 41. IrisVR allows multiple users to view a 3D model at the same time for better collaboration. (Source: IrisVR / Downloaded from https://irisvr.com/prospect on January 2021)

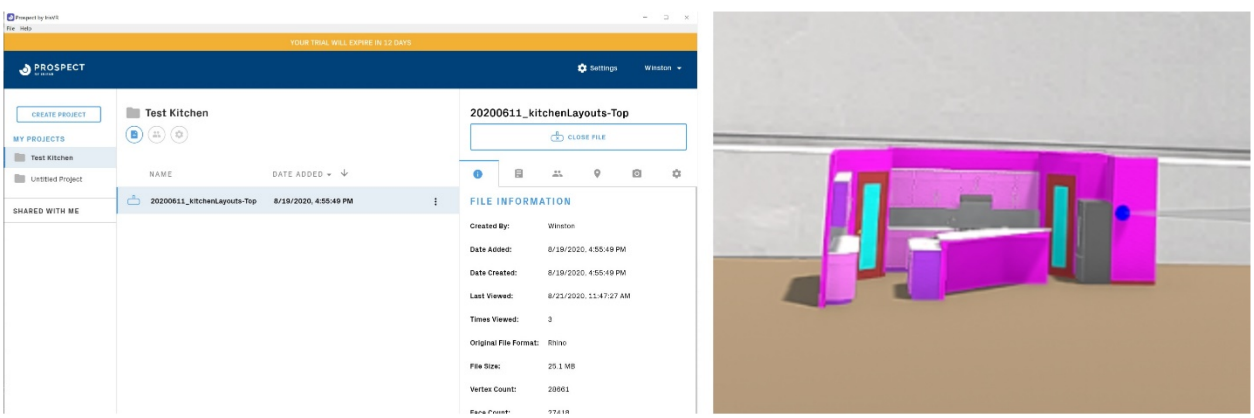

Figure 42. Screenshot of IrisVR user interface and model preview. (Source: IrisVR / Screenshot by Author)

4.3.2 Enscape3D

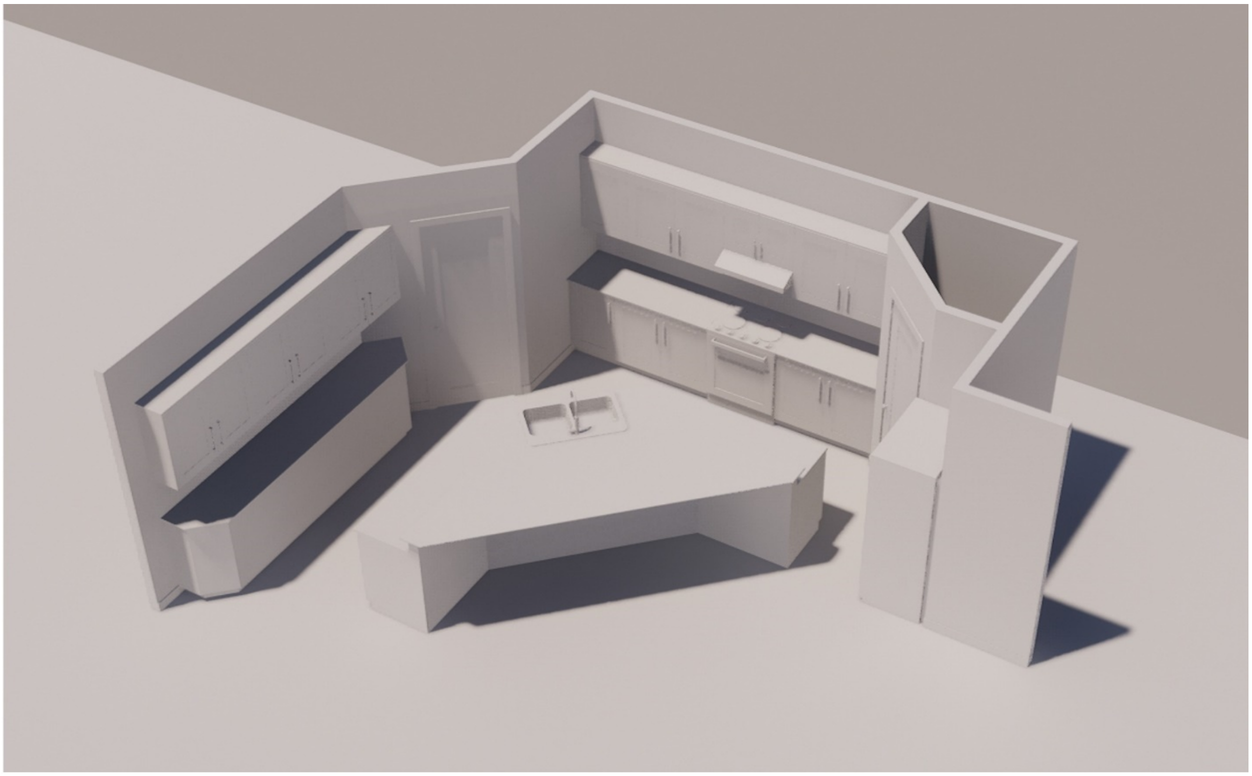

Figure 43. Screenshot of Enscape3D previewing a digital model. (Source: Enscape3D / Screenshot by Author)

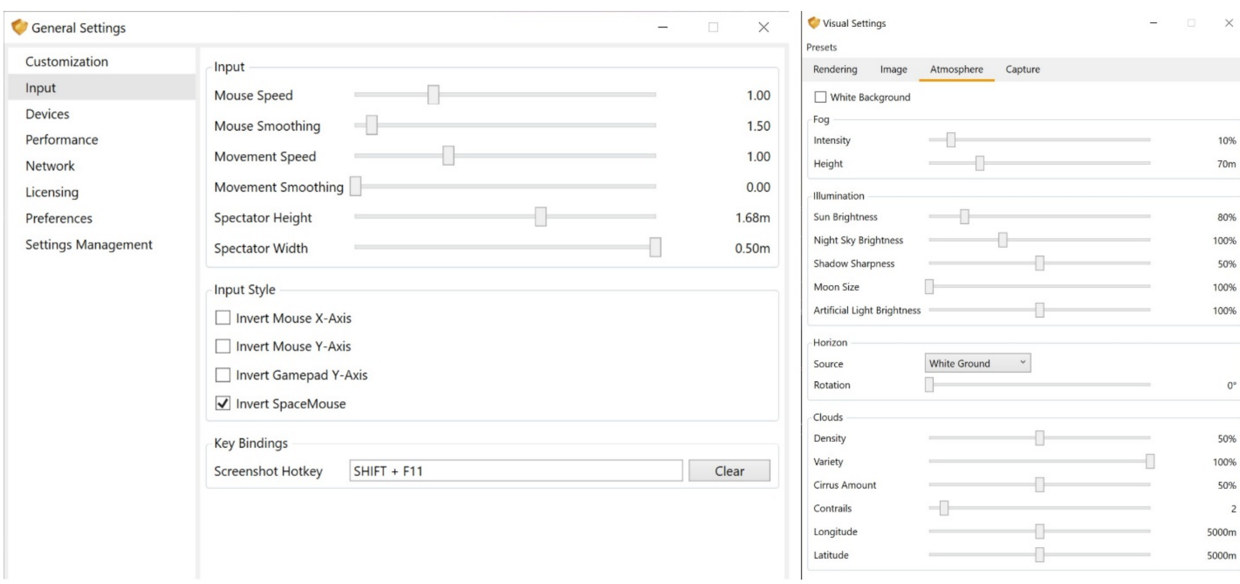

Figure 44. Screenshot of Enscape3D user interface and settings. (Source: Enscape3D / Screenshot by Author)

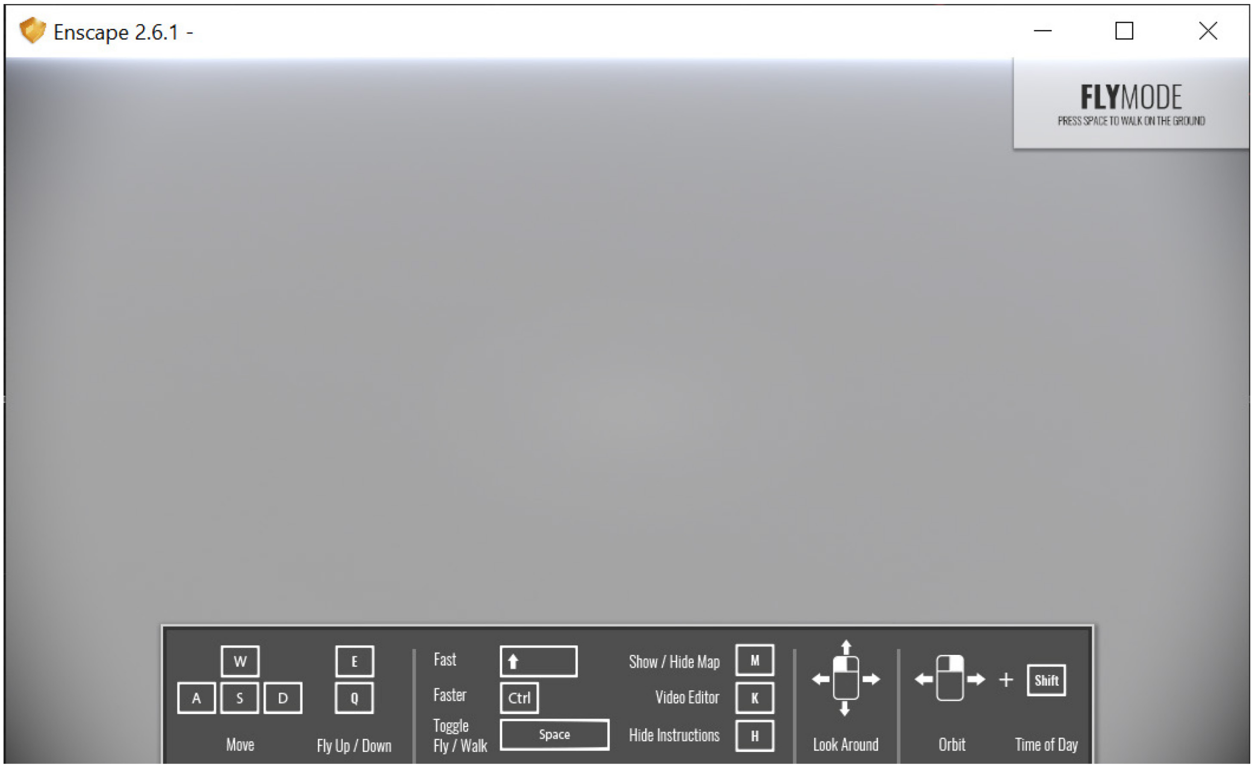

Figure 45. Enscape user interface and controls. (Source: Enscape / Screenshot by Author)

Enscape3D is a real-time rendering application that allows for still renderings, video animations, and virtual reality walkthroughs. This program does not allow for a multi-user experience but is a relatively simple out-of-the-box program which allows a designer or user to jump into virtual reality.[62] It does not have any annotation features like IrisVR, but its simplicity makes up for it. One downside that I did notice about it was the latency of the headset's display while running the program. This latency resulted in an unpleasant experience for extended sessions of virtual reality. Varying visual latency in head-mounted displays is known to cause motion sickness in users.[63]

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[62] "Enscape™ - Real-Time Rendering and Virtual Reality," accessed December 10, 2020, https://enscape3d.com/.

[63] Michael Lee Wilson, "The Effect of Varying Latency in a Head-Mounted Display on Task Performance and Motion Sickness" (Clemson University, 2016).

4.3.3 Twinmotion

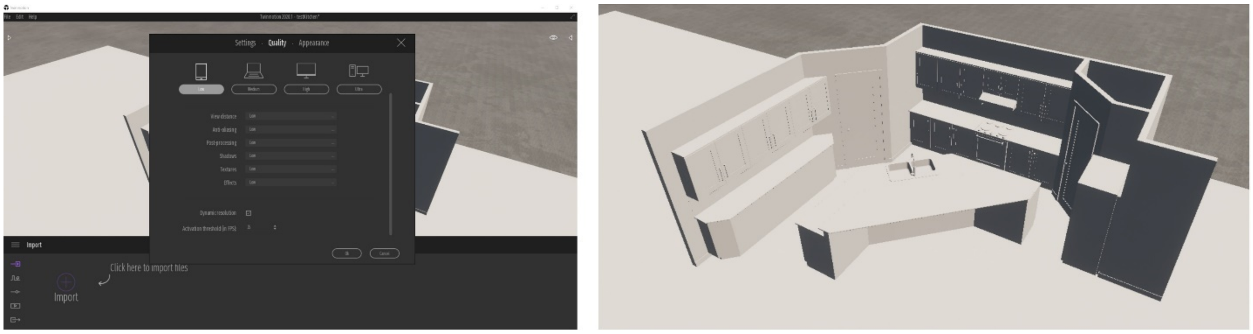

Figure 46. Screenshot of Twinmotion user interface and model preview. (Source: Twinmotion / Screenshot by Author)

Twinmotion is a similar solution to Enscape3D but has less visual latency and more advanced animation capabilities. This software allowed designers to create simulations which could be exported to standalone applications which could be shipped out to clients or end-users depending on what they wanted to achieve with it.[64] A big advantage of Twinmotion over the other two software would be that it is free to use as part of the Epic Games software suite as well as looking good.

[64] "Unreal Engine | Twinmotion," Unreal Engine, accessed December 10, 2020, http://www.unrealengine.com/twinmotion.

4.4 Efforts of Digital Immersion in Video Games

Some examples of video games with excellent immersive environments are Job Simulator (intuitive interaction), Tilt Brush (VR creation), and Boneworks (advanced physics).

The videogame industry has focused on mainly making virtual reality immersive for all players. From the early days of Job Simulator, the focus of its design was to provide players with as many knobs and switches to interact within virtual reality to give them the feeling that they were there in the virtual world before them. Tilt Brush was another piece of software released that same year to allow people to paint for the first time in three-dimensions. This opened the door for the possibilities for editing space in virtual reality. Beat Saber and Boneworks focused on making interactions in virtual reality believable experiences and made sure that the fidelity delivered to players was top-notch. All these games used methods of immersion to trick the player into thinking that they were in the space doing those activities.

4.4.1 Job Simulator (2016)

Figure 47. Player answers a phone in virtual space, and when they hold the phone up to their ear, they can hear the earpiece of the phone. (Source: Owlchemy Labs / Screenshot by Author)

In *Job Simulator* by Owlchemy Labs, players are given a task to complete via a ticket system. These tasks can then be accomplished through user interactions in space with simple physics-based objects and environments. All a user would have to do to play the game would be to use the VR controllers to reach out and press a button to grab objects.[65] Then they would move their hand through space, and it would be a seamless one-to-one room-scale[66] interaction. The immersion and intuitive flow in this case helps sell that you're really in the space.

[65] Owlchemy Labs, *Job Simulator*, 2016.

[66] Room-scale interactions take place at the same point in space in Virtual Reality as they do in real-life. For example, if you move your hand 30 cm in real life, your hand moves 30 cm in virtual space.

4.4.2 Tilt Brush (2016)

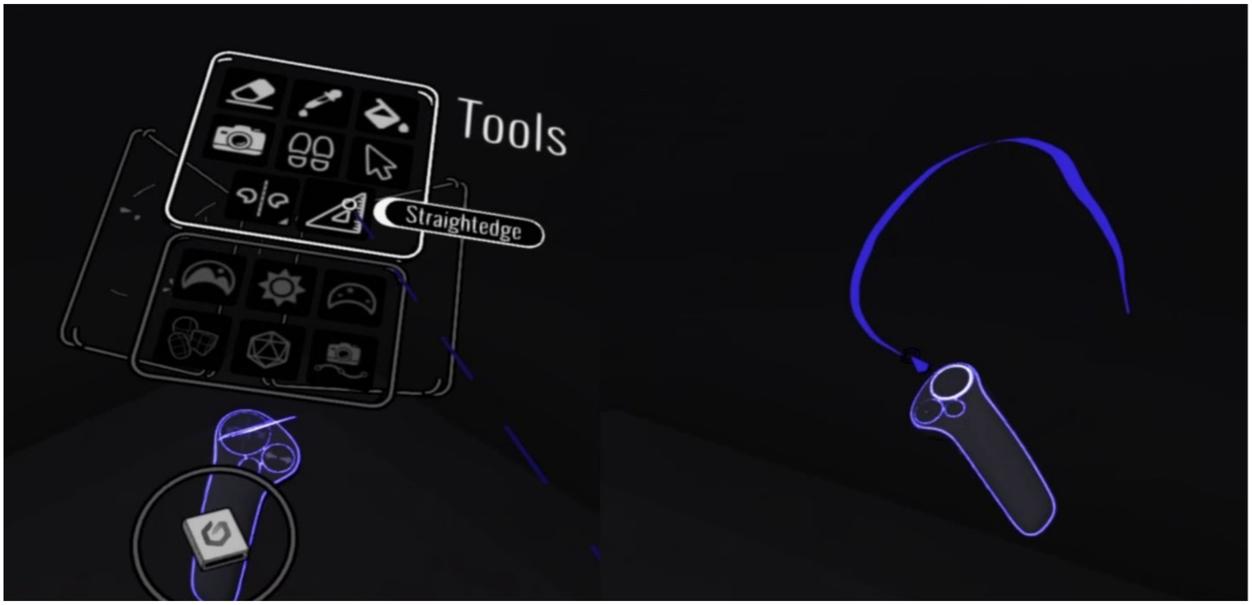

Figure 48. User in Tilt Brush paint a line in Room-Scale VR. (Source: Tilt Brush / Screenshot by Author)

Tilt Brush is a 3D painting application developed by Google and allowed players to paint in virtual space using a variety of different brushes and tools. This was one of the first mainstream attempts at developing a game which allowed users to make their own VR creations. The user could create their own volumetric pictures. The interaction involved selecting a tool on the left-hand palette and using the right-hand controller to paint. The player could also bring in their own objects by importing 3D models into the game.[67]

[67] Google, *Tilt Brush*, 2016.

4.4.3 Boneworks (2019)

Figure 49. Player in Boneworks grabs a crate to put other objects in. (Source: Stress Level Zero / Screenshot by Author)

Boneworks, developed by Stress Level Zero, is a more advanced VR experience. This allowed for all the previously added functionality of VR as well as per-finger interaction due to the release of the Valve Index VR headset. The interaction in game was more natural and allowed users to grab objects in VR space as they would in real life with their fingers.[68] An example of this was using the left hand to grab a crate, while they used the right hand to pick up objects to put in the crate.

[68] Stress Level Zero, *Boneworks*, 2019.

5 [Scope and Limitations] What Can Be Done?

5.1 Scope

How can we use immersive technologies to beta-test architecture? This is not strictly about VR, rather it is about how we can represent architecture to end-users to get feedback about using a space.

What this thesis looks at will be how immersive technologies can be used in architecture for a beta-test. In terms of methodology, I will look at how architecture is currently tested and evaluated. I will also analyze different immersive technologies and look at their strengths and weaknesses in beta-testing architecture with end-users. In addition to existing technologies, I will explore how to create my own digital immersive experiences using software such as Unreal Engine 4. The audience which this research would affect is the architect and the end-user. The architect would use this proposed method to interface with the user.

Originally, what I had planned to do for my simulation was create a set of virtual reality experiences to take people through and use that information as a part of my research. I wanted to see how end-users would react in a VR experience of a space. This would have been my ideal method of evaluating how immersive technologies could be used to beta-test architecture, but due to the 2020 COVID-19 pandemic, I was unable to safely carry out such experimentation.

The focus of this simulation is to find out how architects should be working in the future to support the end-user. The process I aim to develop is as a tool for the architect to use and implement into the current architectural design process. It is to act as another tool in the architect’s toolkit. The architect in this situation remains the author of the architectural project, and the end-user can be the editor. This is not meant as end-user design, as the architect should remain integral to the design of buildings. This is instead co-design where the designer and end-user work together to come up with a solution. The designer does not relinquish control of the project to the end user. The end-user instead participates in the design as a beta-tester to verify the architect’s work. The architect possesses the expert knowledge required for the construction of a project, and the end-user provides feedback to fill in the gaps in the architect’s knowledge about specific use-cases and scenarios.

The first simulations that I was working on in VR sought to outline the functionality possible in creating a custom software experience to showcase architecture. The simulation was not showcased to many people due to the 2020 COVID-19 pandemic but was mainly used to find out benefits and limitations of current immersive tools. The latter simulations were focused on trying to get potential end-users involved in giving feedback. These simulations were built in existing pieces of software to help find out what immersive beta-testing might look like as well as the workflow required to get there.

This thesis is not strictly about VR, rather it is about the gradual progression of architectural representation into immersion. VR as a topic is contained within the umbrella topic of immersion within architecture, but I will also outline different methods of using immersion to represent architecture for testing. In addition, I am not stating that other methods of architectural representation are obsolete with this research but am instead proposing this new method of working as a supplementary tool for our existing methods of representing architecture. In this way, the experience I am showing to peers does not act as a comparison between architectural representation methods, instead the analysis revolves around the feedback that the end-user is able to give back to the architect, and how this feedback can be used to fill in the gaps of knowledge for the architect.

5.2 Limitations

This thesis has some limitations in software and hardware, as well as limitations due to external factors. In terms of software to create the immersive experience, I was limited to either choosing a prebuilt application designed for architectural use, or a more general-purpose application for games development. An architecturally focused application would allow me to use a more streamlined workflow to develop a virtual walkthrough but would be limiting in the features I would be able to implement. A general-purpose application would allow for more open-ended development to add features but would require more work to get to the same level of visual quality the architecturally focused application would provide. The main external factor that ended up dictating how I designed the immersive experience would be the 2020 COVID-19 Pandemic. Initially I thought that this would not be a long-term issue, so I kept pushing the idea of using VR as the main technology to achieve immersion. This proved to not be possible in the end due to the prolonged period of quarantine everyone locally was subjected to, and I needed to pivot towards something that would be easily distributable to peers, without a hardware requirement. The immersive experience which I initially created in VR will be referred to as Immersion Version 1 (IV1), and the immersive experience which I show to my peers will be referred to as Immersion Version 2 (IV2).

5.2.1 Immersion Version 1 (IV1)

Immersion Version 1 was limited to the hardware available as well as my knowledge of the software. I was unable to show this version to more people due to the 2020 COVID-19 pandemic.

IV1 required the usage of powerful computer hardware, knowledge of software, as well as VR equipment requirements. Any computer hardware has limitations tied to processing power and image quality. This limitation affects the quality and the size of the immersive experience I was able to produce. The hardware requirement would also necessitate that any peer I showed the experience to would either possess an equivalent set of hardware to what I was using or use my hardware directly.

The availability of VR headsets proved to be a challenge since not everyone had one as well as the hardware available to run it. Most architectural offices will also encounter this limitation of hardware if they want to create immersive experiences for either client or end-user evaluation usage until there is mainstream adoption of the platform.[69]

Knowledge of Unreal Engine 4 was also required to develop the VR application. The limitation here was my ability to learn how to use the software within a short timeframe and try to develop a functional product from it. VR hardware is still relatively too expensive for

[69] "The Fall and Rise of VR: The Struggle to Make Virtual Reality Get Real," Fortune, accessed January 15, 2021, https://fortune.com/longform/virtual-reality-struggle-hope-vr/.

mass-market consumption.[70] The VR headset that I settled on was the Samsung Odyssey Plus Head Mounted Display (HMD). For a cost of 500 CAD, this headset was capable of room scale VR through inside-out tracking (no external cameras were needed to determine the position of the headset or controllers), and it was able to be connected to the computer to develop simulations for.

Figure 50. Samsung Odyssey Plus HMD (Source: Samsung / Downloaded from https://www.samsung.com/hk_en/news/product/reality-headset-hmd-odyssey-plus/ on January 2021)

The computer hardware that I used for creating the immersive simulations was:

- AMD Ryzen 9 3900X 12-Core Processor
- 32 GB, 3200 MHz Memory
- NVIDIA GeForce RTX 2070 SUPER

This hardware was necessary to build and run the simulation.

[70] Ben Kuchera, “The VR Revolution Has Been 5 Minutes Away for 8 Years,” Polygon, October 20, 2020, https://www.polygon.com/2020/10/20/21521608/vr-headsets-pricing-comfort-virtual-reality-future.

5.2.2 Immersion Version 2 (IV2)

The limitations with Immersion Version 2 are that the peers I chose to experience the simulation needed powerful computer hardware. It was also assumed they knew the control scheme of a first-person video game as this was how one would control the simulation.

IV2 makes use of computer software to create an immersive experience which was then presented to my peers. Because of the way that the simulation was designed, the peers I chose were required to have powerful computer hardware to run the simulation. This meant that the peers I choose to look at the experience were limited to people I knew which had hardware to meet these requirements. Since most of my peers did not have access to a VR headset, a decision was made to make this a desktop computer application that they would run and operate with a mouse and keyboard. The purpose of building the software experience was to immerse my peers in an architectural project which I had designed. I wanted them to pretend that they were end-users of the space and I presented them with scenarios in the space which could be used to spark discussion about the building’s design.

In IV2, there are two main assumptions being made. The first assumption is that orthographic drawings and renderings presented in virtual space have the functional and experiential equivalent of viewing drawings in real-life (either pinned up on a wall or on a tabletop).

Figure 51. This assumes that viewing a drawing in real-life has the same effect as viewing it in the virtual space that I have created. (Source: By Author)

The second assumption is that my peers are familiar with the First-Person video game control scheme most found on desktop computer games. This limitation was a result of the software being chosen to develop IV2.

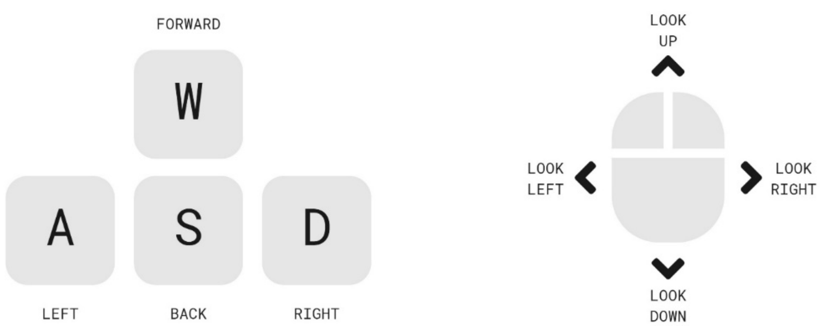

Figure 52. Keyboard and mouse control scheme found in most First-Person video games.

6 [Method] Building a Beta-Test

Beta-testing a building will allow an architect to learn about how users will interact with their buildings in ways that other evaluations methods don’t. For good testing to occur, the tester must experience the game of their own accord, and the task of the designer is to merely observe the experience of the player.

How can we player test architectural designs before they're built? In video game development, developers work on a project until it is in a playable state and then invite participants to test out the game to find out what things they like and don't like about it. Player testing must be designed well to be effective. Poor player testing design is when a game does not reflect the final product accurately, or it does not allow for the player to truly choose how to test the game. In other words, a prescribed experience is not ideal for testing since it imposes the biases of the designer onto the tester and skews the feedback produced. For good testing to occur, the tester must experience the game of their own accord, and the task of the designer is to merely observe the experience of the player.[71]

[71] Bob Bates, *Game Design*, 2nd ed (Boston, Mass: Premier Press, 2004).

6.1 Why Immersive Testing?

Immersive testing allows us to tackle the element of human scale, give the end-user a sense of presence in the environment, and create a common ground for discussion between the designer and the end-user.

Why wouldn't we use other tools for testing, and why is immersive testing the best way to conduct beta-testing in architecture?

6.1.1 Element of Human Scale

This method of testing would allow a person to view architecture on a human scale. Being able to look around a space frees the viewer from the restriction of a prescribed view present in still renderings. In addition, allowing the viewer to walk around on the ground plane would be reflective of how an end-user would experience the space in real-life, and not from a bird's eye view. Viewing the image at the eye level of a person allows for the sense of being in the space as an occupant.[72]

Figure 53. The camera should not be set above the heads of people, rather it should be at eye level. (Source: Alex Hogrefe, Visualizing Architecture / Downloaded from https://visualizingarchitecture.com/composing-your-perspectives/ on January 2021)

[72] Alex Hogrefe, "Composing Your Perspectives | Visualizing Architecture," accessed January 15, 2021, https://visualizingarchitecture.com/composing-your-perspectives/.

Isometric renderings of projects can serve well for developers to quickly understand the scope of a project, but it does not allow an end-user to see how one would experience that space.

6.1.2 Sense of Presence

Allowing a person to interact with a space in real-time can facilitate functional testing of that space. In addition, the introduction of other senses to the experience can help craft a sense of presence.

In 1999, a group of researchers gathered 322 test subjects to see what the effects of touch, smell, sound, and sight had on the participants' sense of presence and ability to remember things about their environments and its objects. The study found that in a virtual reality experience with the inclusion of non-visual sensory cues, participants felt a greater sense of presence in the virtual environment.[73] The increased feeling of presence should then help generate more realistic feedback from end-users during an immersive simulation.

6.1.3 Creating a Common Ground

While looking at flat orthographic drawings can help people understand spaces with greater dimensional accuracy, putting people in immersive experiences can help unify their collective perception of space. Ronald Tang, an alumnus from the University of Waterloo, conducted an experiment where he tested how well people could guess the sizes of spaces based on orthographic drawings and VR. He found that people looking at flat drawings were better at guessing the exact

[73] H.Q. Dinh et al., "Evaluating the Importance of Multi-Sensory Input on Memory and the Sense of Presence in Virtual Environments," in *Proceedings IEEE Virtual Reality (Cat. No. 99CB36316)* (Virtual Reality, Houston, TX, USA: IEEE Comput. Soc, 1999), 222–28, https://doi.org/10.1109/VR.1999.756955.

dimensions of the room but were more varied in their responses from person to person. In virtual reality however, people had less accurate responses regarding the room size, but this inaccuracy was more consistent between participants when looking at all the responses. In an immersive experience, people were able to share the same understanding of space even though it was inaccurate to a certain degree when compared to flat drawings.[74]

6.2 Hypothesis

The use of immersive methods of digital architectural representation along with scenario led experiences will help beta-test architecture because it gives end-users something closer to reality to give more feedback on. Borrowing strategies from the field of video game development, beta-testing will allow an architect to learn about how users will interact with their buildings in ways that other evaluation methodologies do not. The feedback generated by the end-user will help improve an architectural project because it fills in the gaps of knowledge for the architect.

[74] Ronald Tang, “A Study of Spatial Perception in Virtual Reality” (2019).

6.3 Immersion Version One

The first versions of the simulation I was making involved running through kitchen scenarios in VR. The simulation involved a kitchen space with interactable objects. It was difficult to uncover architectural problems at this scale of interaction.

6.3.1 IV1 Setup

The question that I wanted to try and answer in this version of the simulation was how we could start testing out conceptual architectural spaces at a human scale by playing through routines that an end-user might encounter in such a space in real life. I wanted to play into the idea that we could use tasks in everyday life to find out what pain points exist in a space not yet built in real life.

IV1 involved building an immersive experience in VR. Initial iterations of this simulation played with the idea of interacting with furniture items in ways such as changing the type (one-seater, or two-seater), the colour, and the placement. The idea with this simulation was to create an environment where the user was altering their own space to find problems with it. Building upon this idea, I wanted to increase the interactivity between the user and the space and create testable routines that would allow a user to experience the space by completing tasks.

Figure 54. Player can highlight the sofa to pick colour options. (Source: By Author)

Figure 55. Player can select variants of furniture to place in the room (Source: By Author)

Figure 56. The player has changed the colour of the couch to be a dark blue (Source: By Author)

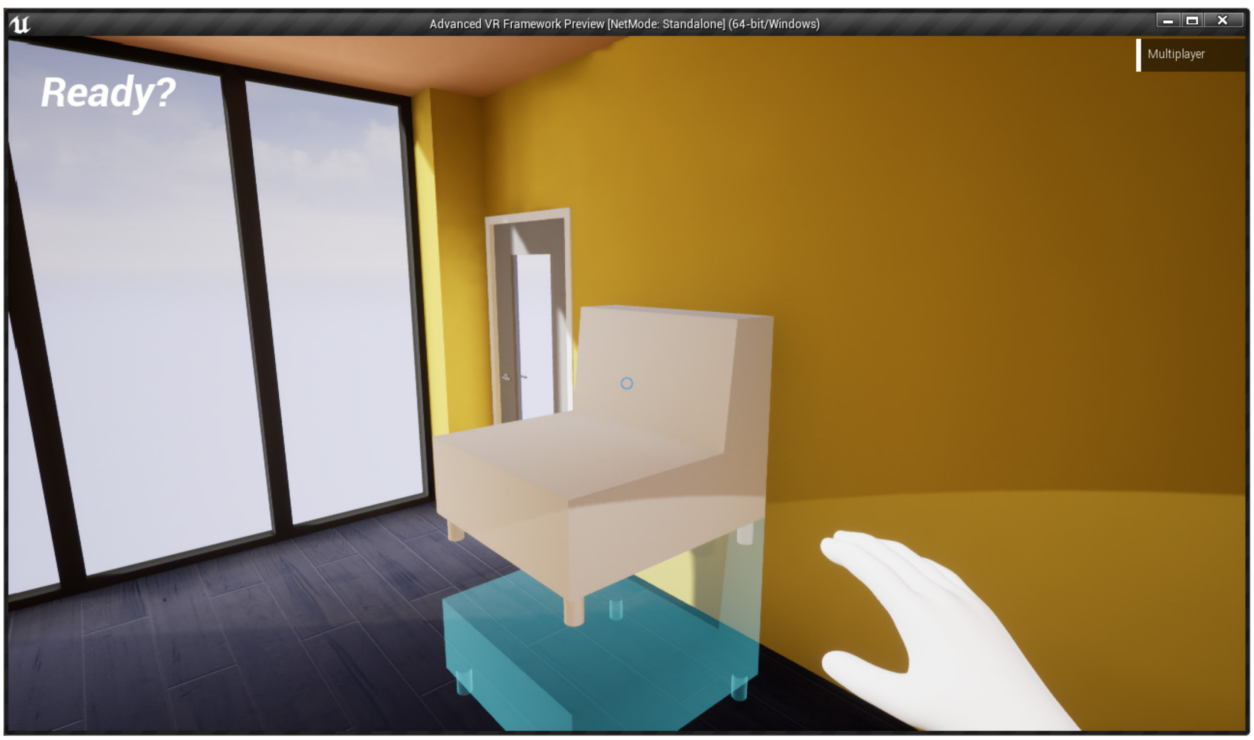

Figure 57. The player can pick up the couch and move it around the room if desired. (Source: By Author)

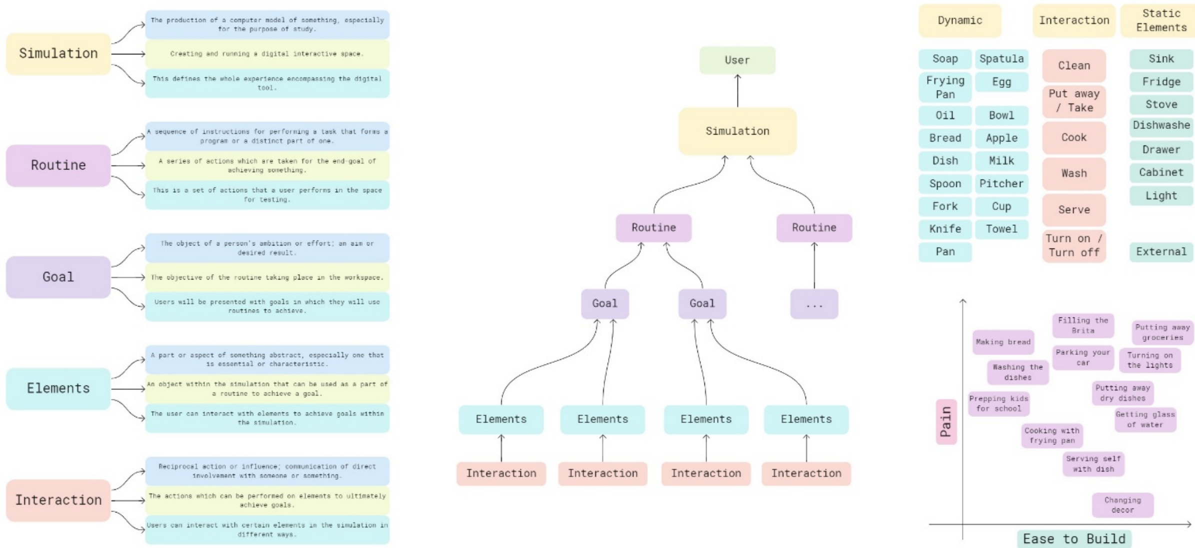

Figure 58. Diagram illustrating the different components which I needed to build in the VR experience. (Source: By Author)

The experience I created was a high-fidelity kitchen experience used to test scenarios for end-users in a VR setting. The simulation was made in Unreal Engine 4 using the Advanced Virtual Reality Framework (AVR) to help guide the development of VR functionality. The idea with this experience was that end-users were given tasks to complete in the kitchen such as cooking an egg or cleaning up, and this method was to be compared with traditional methods of architectural representation. To choose what scenario to test in this situation, I mapped several possible scenarios comparing the ease of implementation in software to the level of involvement I thought the design would have in the end-user's ability to use a space. Through this process, I determined that the easiest things would be to simulate a series of four scenarios in the simulation: putting away the groceries, making a meal, plating the meal, and cleaning up after the meal.

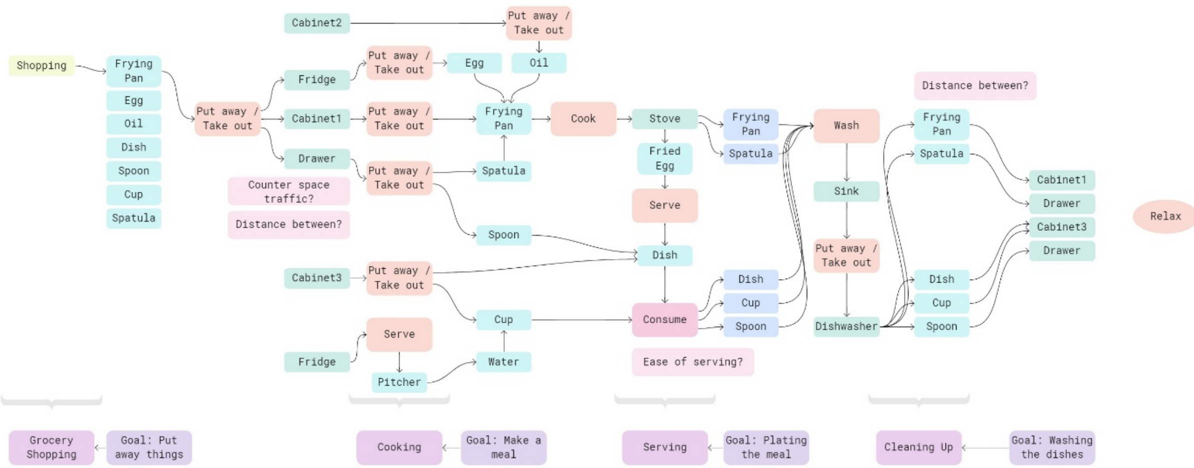

Figure 59. Diagram showing the workflow of different scenarios that end-users could do in VR. (Source: By Author)

Figure 60. Showcase of earlier versions of the kitchen simulations. (Source: By Author)

Figure 61. Overview of initial kitchen simulation I was trying to develop. (Source: By Author)

Figure 62. User can interact with hinged objects such as the fridge door to complete tasks (Source: By Author)

Figure 63. User can turn on the stove to cook an egg. (Source: By Author)

Figure 64. User finds that the doors to the oven and dishwasher clash during use. (Source: By Author)

6.3.2 IV1 Conclusions

This simulation did not appear fruitful though since it was too fine grain for the medium it was being presented in. I found that in laying out the potential outcomes the findings would not be significant enough for meaningful feedback. In addition, because of the 2020 COVID-19 Pandemic, I needed to come up with a different method of simulation which didn’t involve the usage of a single VR headset. The insights that I was able to gather were reliant solely on people within my quarantine social circle, but even then I was able to learn a lot.

In IV1, I found out about “what not to test” in VR, and its limitations. The kitchen experience which I used turned out to be minimally beneficial as a method to beta-test architecture. This is because the number of scenarios which I could test at a small scale were limited in how the feedback given would affect the architecture around it. The use cases for this then leaned towards it being used as a marketing tool, or an interior design tool rather than architectural.

From this experience, I learned that the largest draw back in VR was being able to navigate space. While VR was great for room-scale navigation (e.g. walking around, looking under something), the disadvantage was that it was all limited to how much physical space you had in your room. In addition, the length of the cable was a limiting factor as well to how far you were able to walk. This meant that the experience was locked into testing a space where you could only move as much as your physical constraints allowed you to.

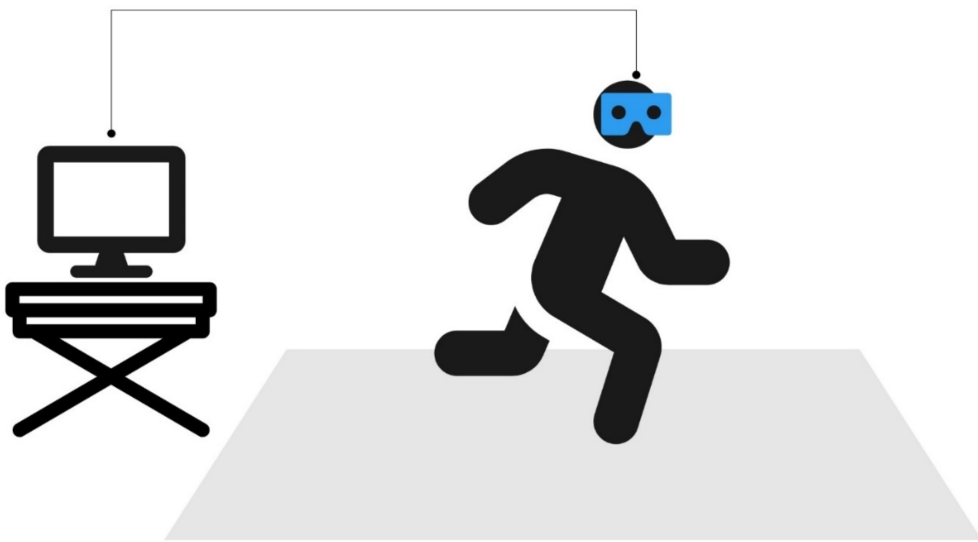

Figure 65. VR headset usage is limited by room dimensions and wire length. (Source: By Author)

A workaround to this problem would be to use the hand-controllers included with the HMD to allow the player to walk around in the virtual space without walking in real-life. The issue with this is that the disconnect between the physical act of walking and the visual aid provided of walking forward would cause the user to become motion sick. The acceleration experienced visually in the experience would not be experienced by the rest of the body's senses causing disorientation.[75] To counter act this, the user would then have to be limited to a popular method of navigating in VR known as teleporting. Teleportation in VR allows the user to navigate the VR environment with little disorientation. The user would then use the hand controllers to point at the place which they would like to be, and they are instantaneously transported there.[76]

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[75] "Motion Sickness in VR: Why It Happens and How to Minimise It," accessed January 15, 2021, https://virtualspeech.com/blog/motion-sickness-vr.
[76] "Teleportation Demo | Google VR," Google Developers, accessed November 13, 2020, https://developers.google.com/vr/elements/teleportation.

If the problems with navigating the space could be worked out, there would also the issue of what to test. I think that testing such small-scale items in VR resulted in it being harder to comment on the architecture. Managing the scenarios of using the kitchen would distract from the architecture itself and serve as a poor beta-test. The scenarios seemed to work well because it gave users something to invest their efforts on in the space. I think the change that this needed would be to expand the idea of scenarios and look further on expanding them to embrace a whole building rather than a single room. The theory here is that a scenario that forces a user to stay in a room during the entire experience results in the room being tested really well, but there are only so many issues to be uncovered in a single room at the level of detail in the experience I was creating.

Learning from this simulation, I needed to choose a method of representation that would allow more people to see it. Being unable to invite others to use my own VR headset meant that I couldn't expect all viewers of this experience to have their own VR headset. This meant that ideally, the next version would be an experience which a user could run on their own desktop computer.

What I ended up using was a first-person walkthrough experience. Instead of the user using specific objects to complete tasks as scenarios, the scenarios were built from the requirement that the user had to progress from point A to point B in the space by moving on their own. I chose a library project that I had previously worked on as the space being evaluated, since I could imagine the scenarios being set up as the process of finding a book and checking it out of the library. In this way, I could take people through the space with that scenario in mind as a beta-test.

6.4 Immersion Version Two

This version of the simulation involved allowing users to walk around virtual spaces on their own accomplishing tasks. The experiences of running through tasks would be used as talking points to find out what things could be changed about the spaces.

6.4.1 IV2 Setup

For IV2, I wanted to create an immersive prototype which allowed the user to be central to the design process. I first wanted to showcase a minimum working prototype to subject matter experts (SMEs) to see what they would say about my simulation. Then I wanted to discuss the idea of immersive beta-testing in architecture with them to gather insights. I would then make changes to those comments and redevelop an experience for resonance testing with non-experts. In this simulation I would be looking at the feasibility of using a process like this to interface with the user. I would then have them comment on the architecture, as well as the process.

The idea of what scenarios to use was since I wanted the user to be able to experience more architecture than just a single room like in the previous version.

Figure 66. User approaches the library (Source: By Author)

Figure 67. User enters the library and sees the interior. (Source: By Author)

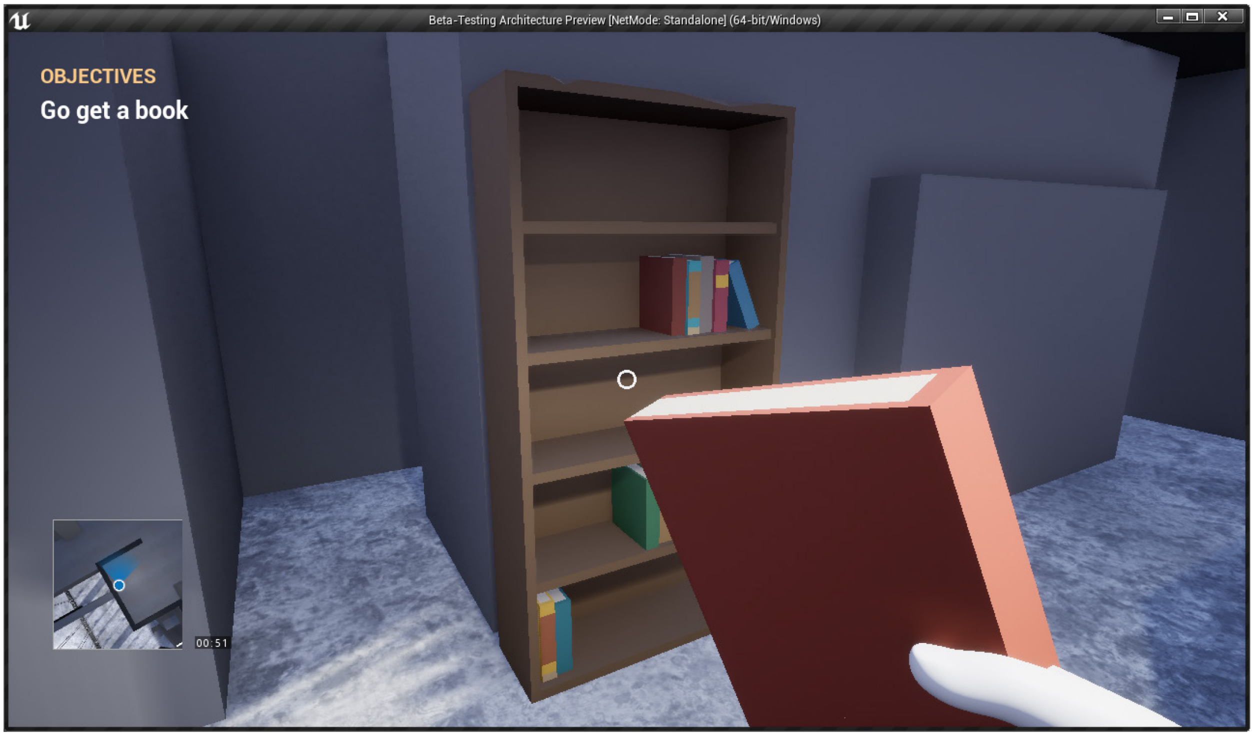


Figure 68. User is asked to get a book from the shelf. (Source: By Author)

Figure 69. User must then leave the library. (Source: By Author)

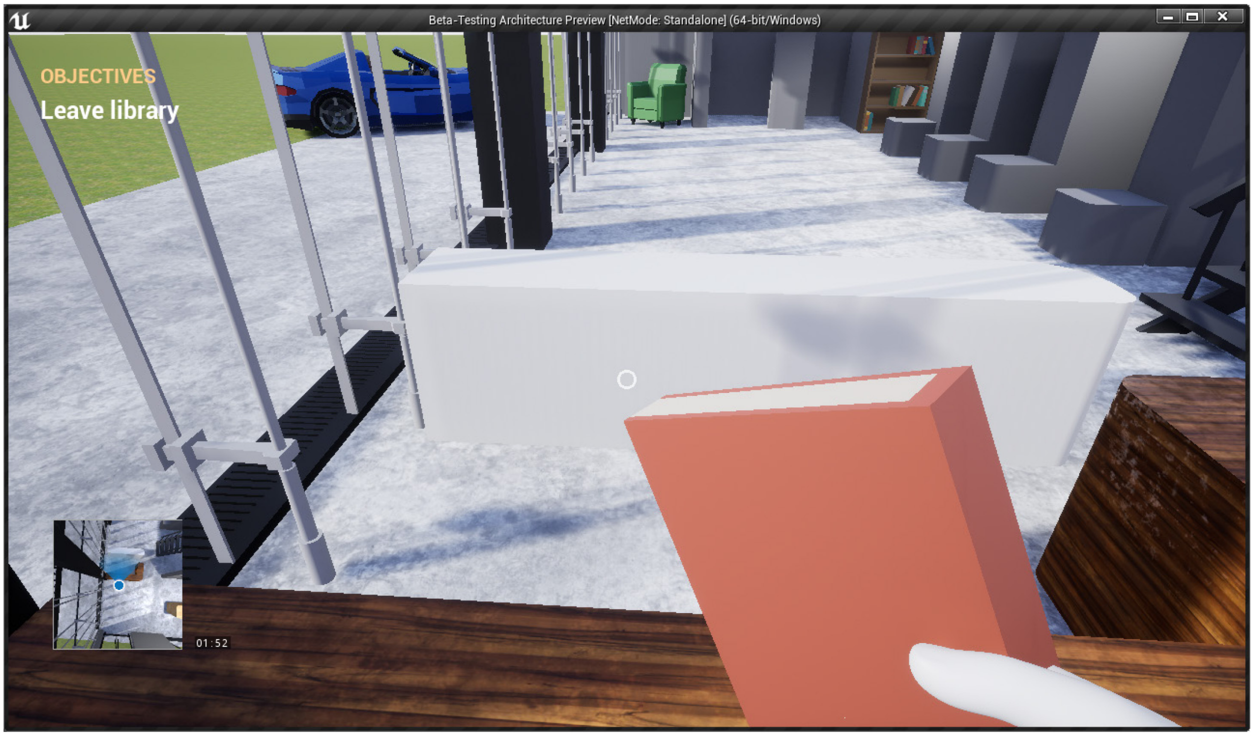


Figure 70. User approaches the circulation desk. (Source: By Author)

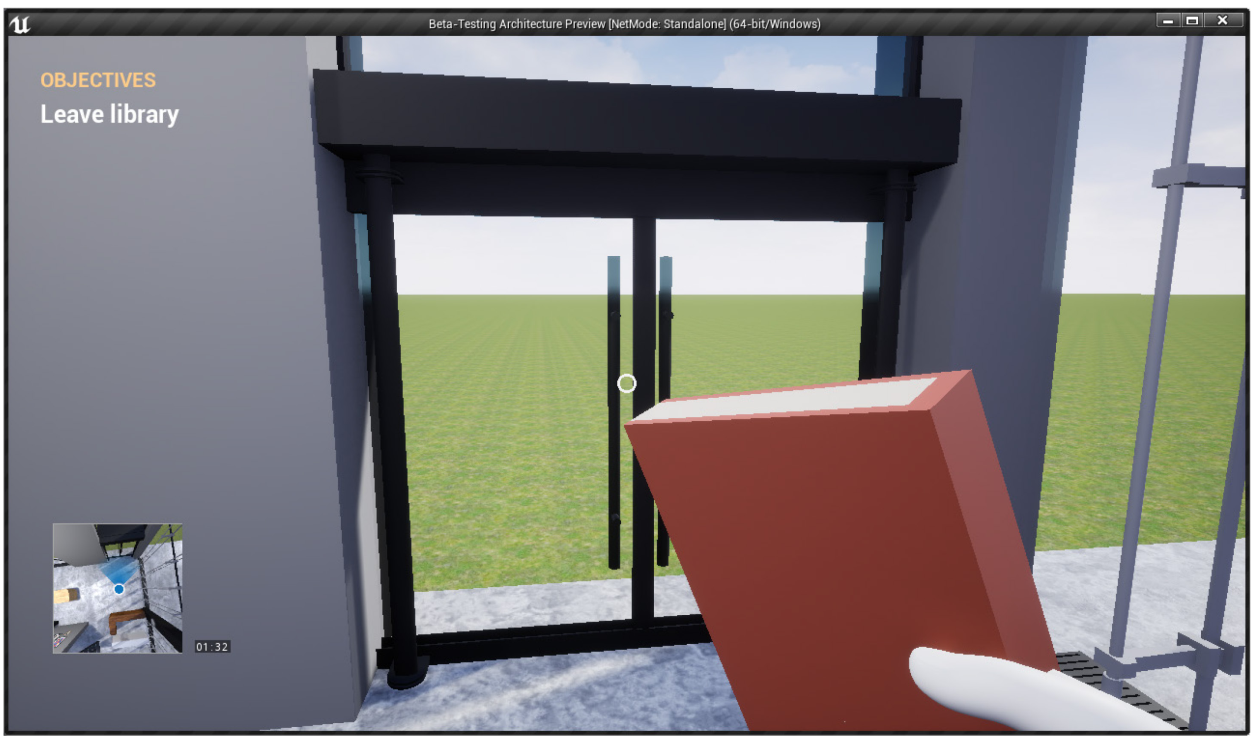


Figure 71. User checks out and leaves the library. (Source: By Author)

To talk to SMEs, I tried to create a basic beta-test in Unreal Engine involving a library. The library project which I used was a design project from my time as an undergraduate. The scenario which I set up in this environment was the act of borrowing a library book. The experience that I was able to create in Unreal Engine did not have the level of visual fidelity that I was aiming for. Things like materials, lighting, and reflections did not look realistic enough. Even though the functionality of crafting a detailed interactive scenario like checking out a library book was possible in Unreal Engine, the advantage of visual fidelity creating a more believable experience was a stronger reason to pick one method over another.

In addition, it would be more difficult to package a compact piece of software to ship out to my peers to look at. In my experience, exporting the small scene of the library ended up being around 6 GB whereas Enscape would easily be under 1 GB.

Ultimately, due to the requirements of fine tuning the software to meet my needs of creating the immersive scenario I chose to use Enscape.

Figure 72. Various screenshots from Enscape3D showcasing the quality of rendering in the simulation. (Source: By Author)

It was here that I chose to instead use Enscape to create a simulation with. The advantage with Enscape was that visual fidelity was high without too much intervention, so I could focus on the scenarios and simulation. In addition, the piece of architecture being tested was switched from a library to a community pool because there were more testable scenarios in the latter. The community pool design came from a project that I worked on in my time as an undergraduate. The Enscape simulation was modeled in Rhinoceros 3D, and then brought into Enscape with the added detail of figures, furniture, and foliage. I then used Enscape to export an executable file to send to my peers. This was important since the beta-testing method outlined in video game development required the users to operate and navigate the experience themselves rather than be led through it by the designer.

6.4.2 IV2 Scenarios

I was able to use photo-realistic real-time rendering to help run my peers through different scenarios in a virtual building. This helped spark discussion that brought up strengths and weaknesses of the design. The main finding using this method was about the wayfinding experience through these journeys.

The three scenarios which I used to lead the experience were as follows:

1. It’s 9:45 PM. You’re attending an evening event to listen to some guest speakers. The talk starts at 10:00 PM, so you should start making your way in.
2. It’s 9:00 AM on a Saturday. You're taking your child to the pool. They want to go swimming, but you have some work to do. That's okay, you can go to the café to supervise them while you work.
3. It’s 5:45 AM on a Monday. You’re going to the beach at the pool to relax before work.

The journey map will have four colour-coded components to illustrate different aspects of documentation:

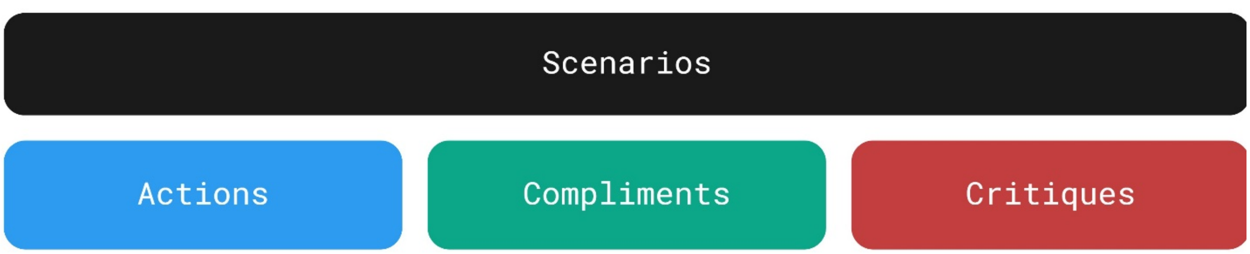
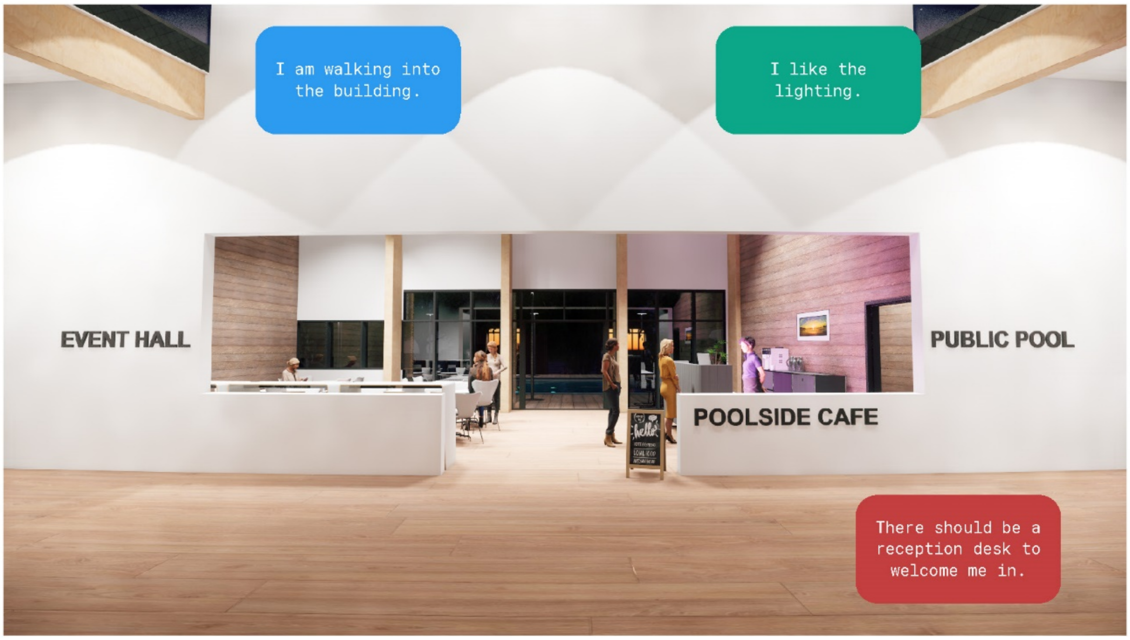


Figure 73. Colour coding of text boxes for journey map. (Source: By Author)

The actions indicated on the following illustrations are my labels based on what the user would be doing at each point in time. Compliments and critiques are my summary based on what I heard from my peers in running through each scenario.

6.4.3 Scenario 1 Journey Map

Figure 74. Scenario 1, Panel 1. (Source: By Author)



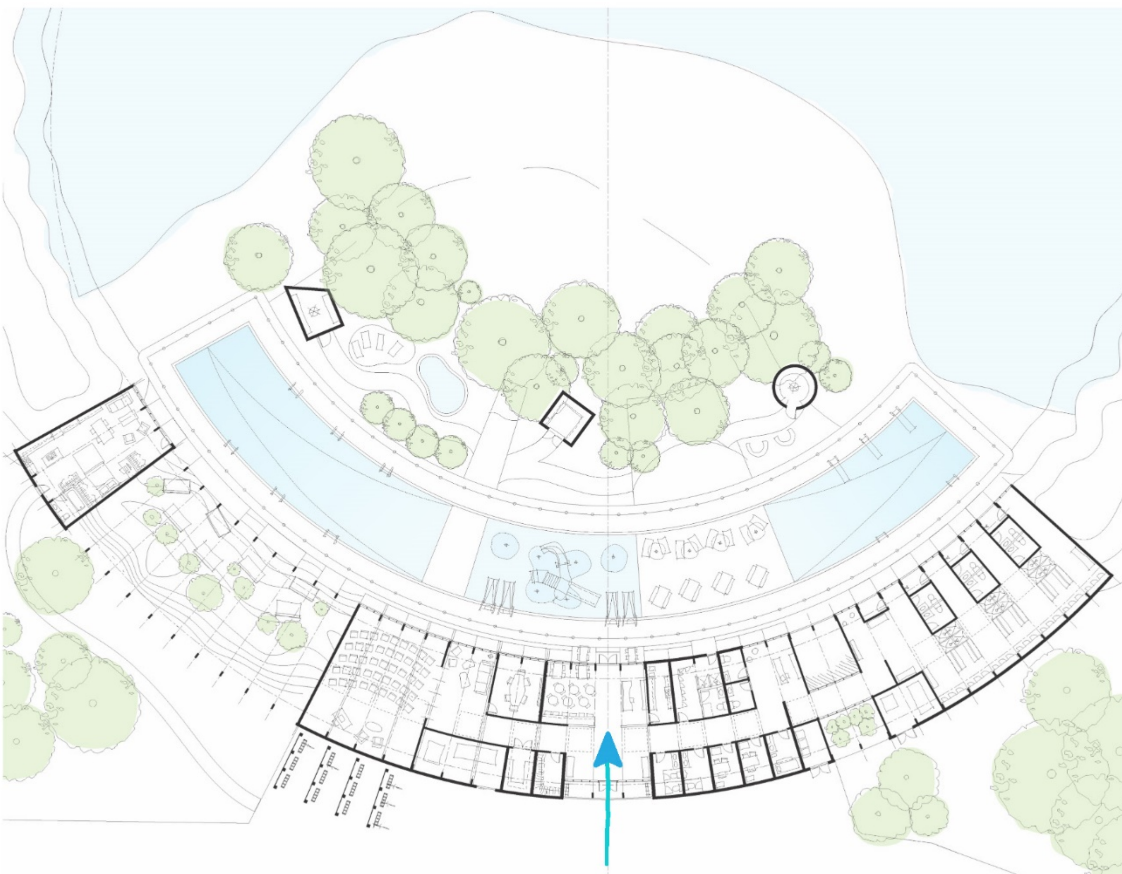


Figure 75. Scenario 1, Panel 2. (Source: By Author)

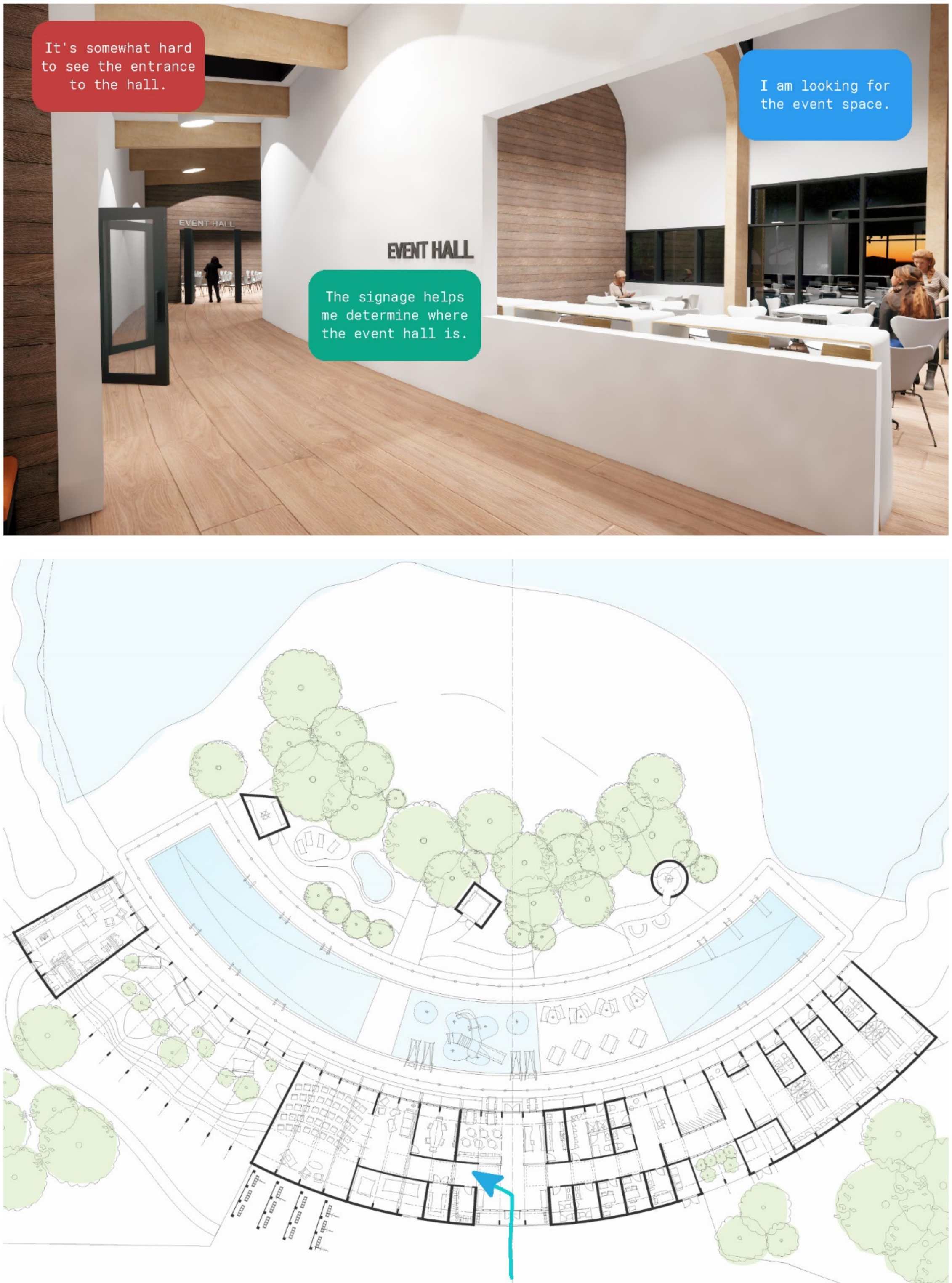


Figure 76. Scenario 1, Panel 3. (Source: By Author)

Figure 77. Scenario 1, Panel 4. (Source: By Author)

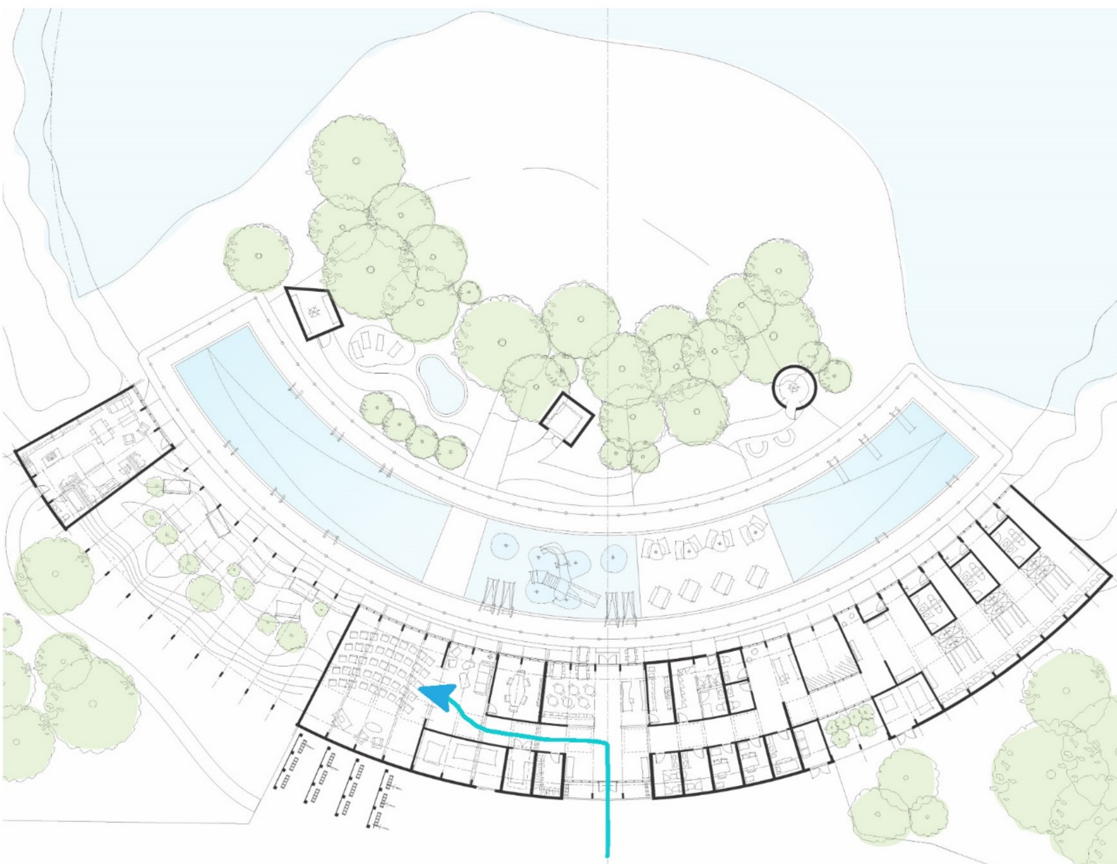


Figure 78. Scenario 1, Panel 5. (Source: By Author)

Figure 79. Scenario 1, Panel 6. (Source: By Author)

Figure 80. Scenario 1, Panel 7. (Source: By Author)

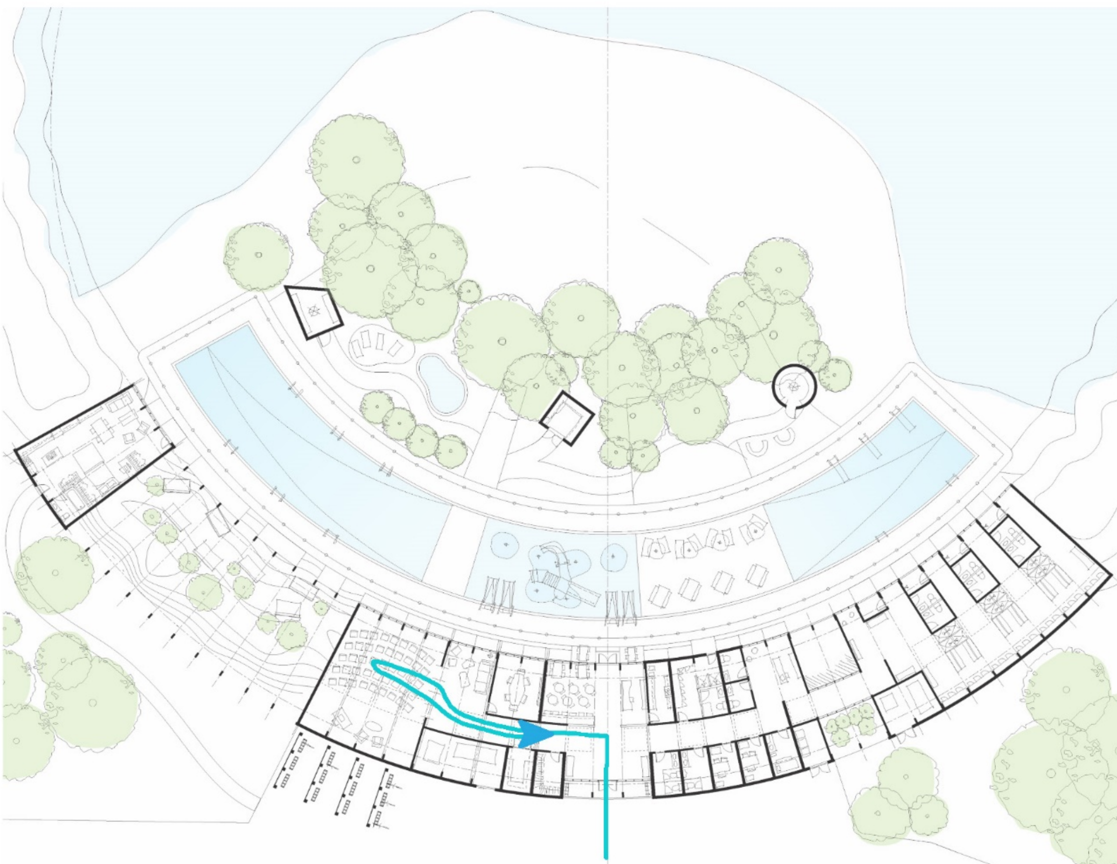


Figure 81. Scenario 1, Panel 8. (Source: By Author)

Figure 82. Scenario 1, Panel 9. (Source: By Author)

6.4.4 Scenario 2 Journey Map

Figure 83. Scenario 2, Panel 1. (Source: By Author)

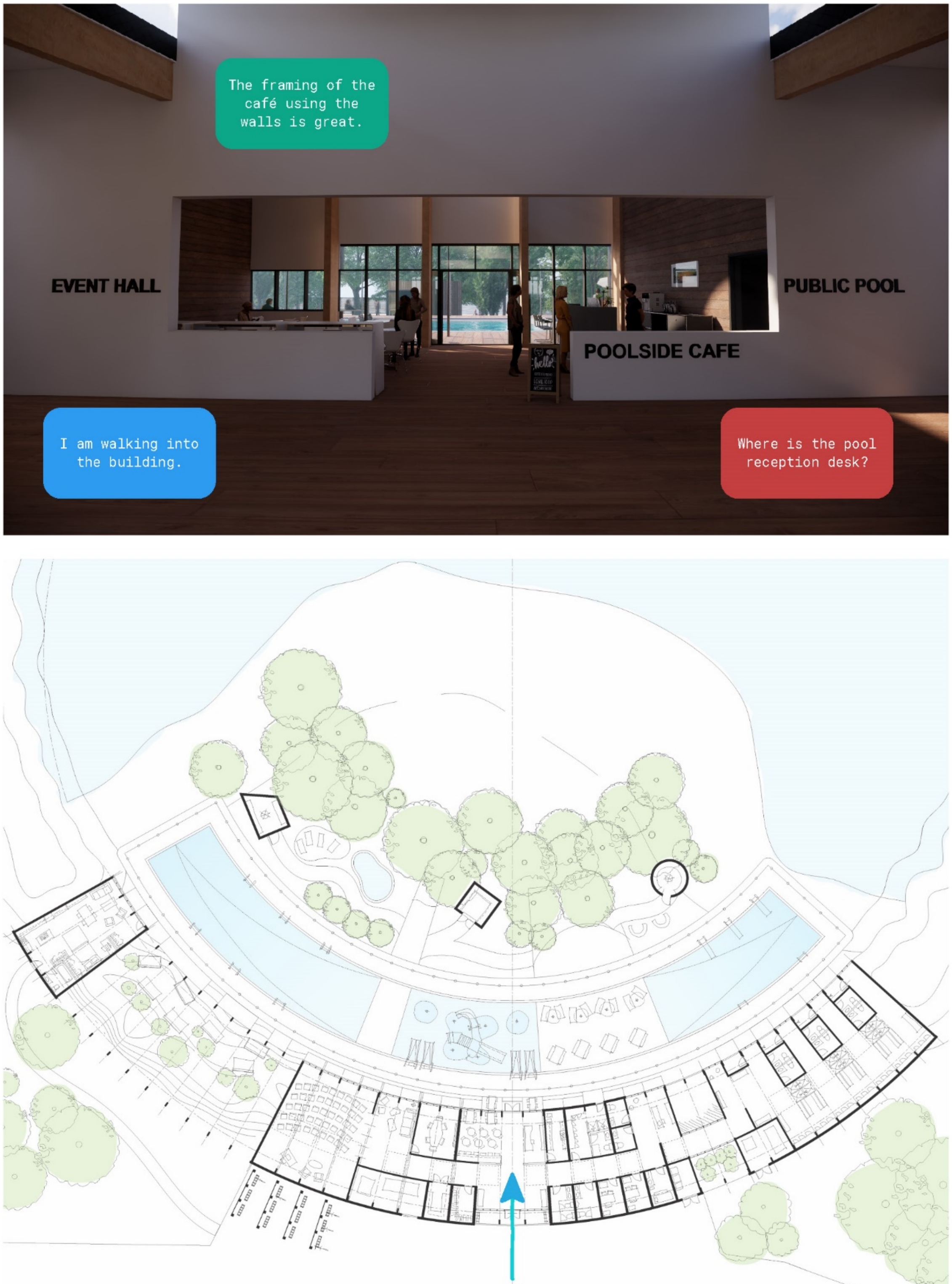


Figure 84. Scenario 2, Panel 2. (Source: By Author)

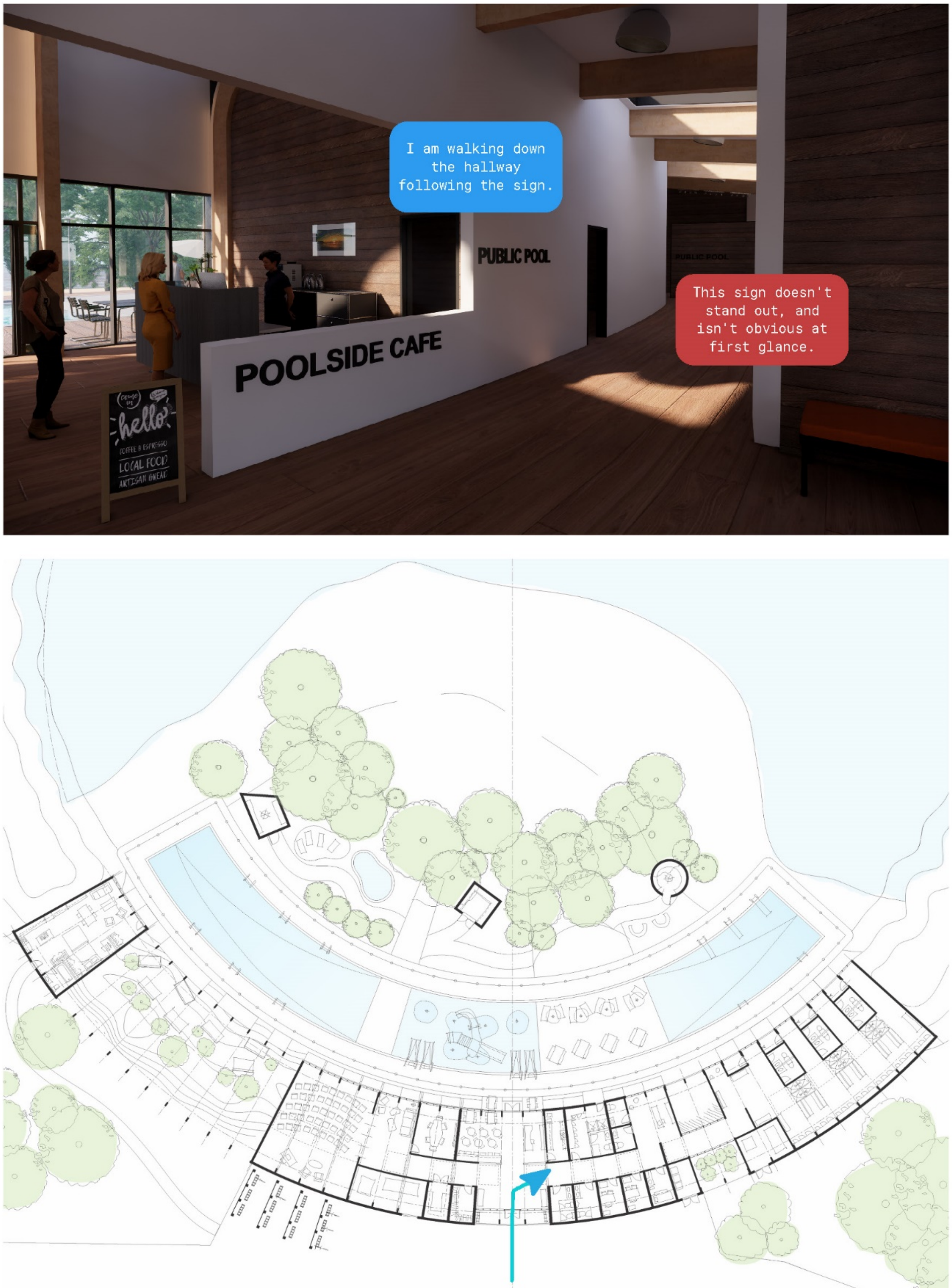
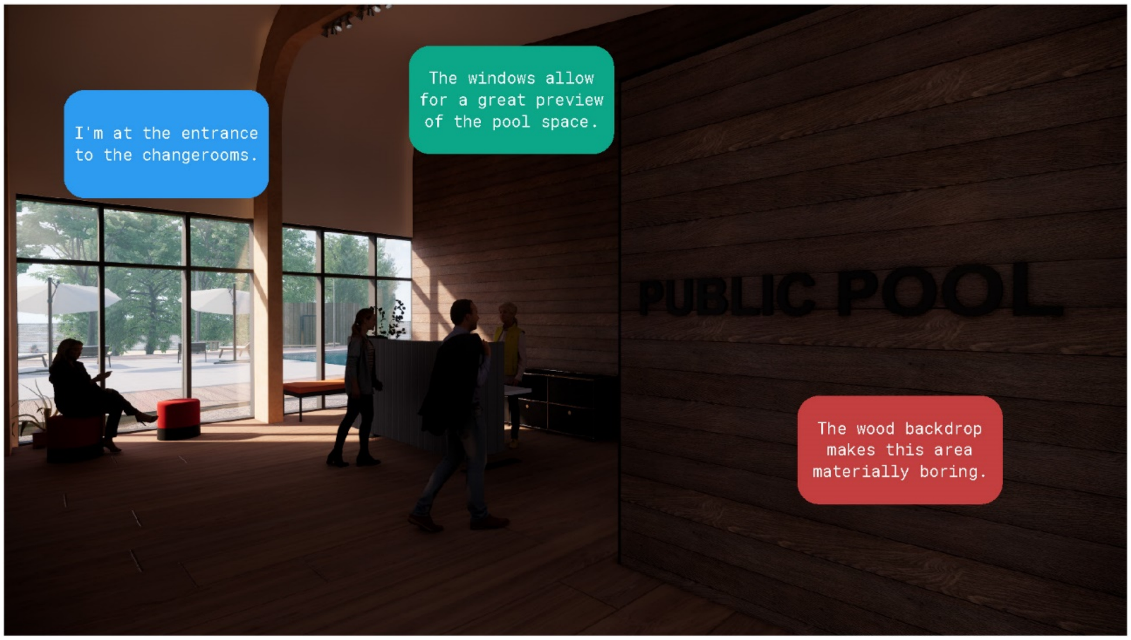


Figure 85. Scenario 2, Panel 3. (Source: By Author)



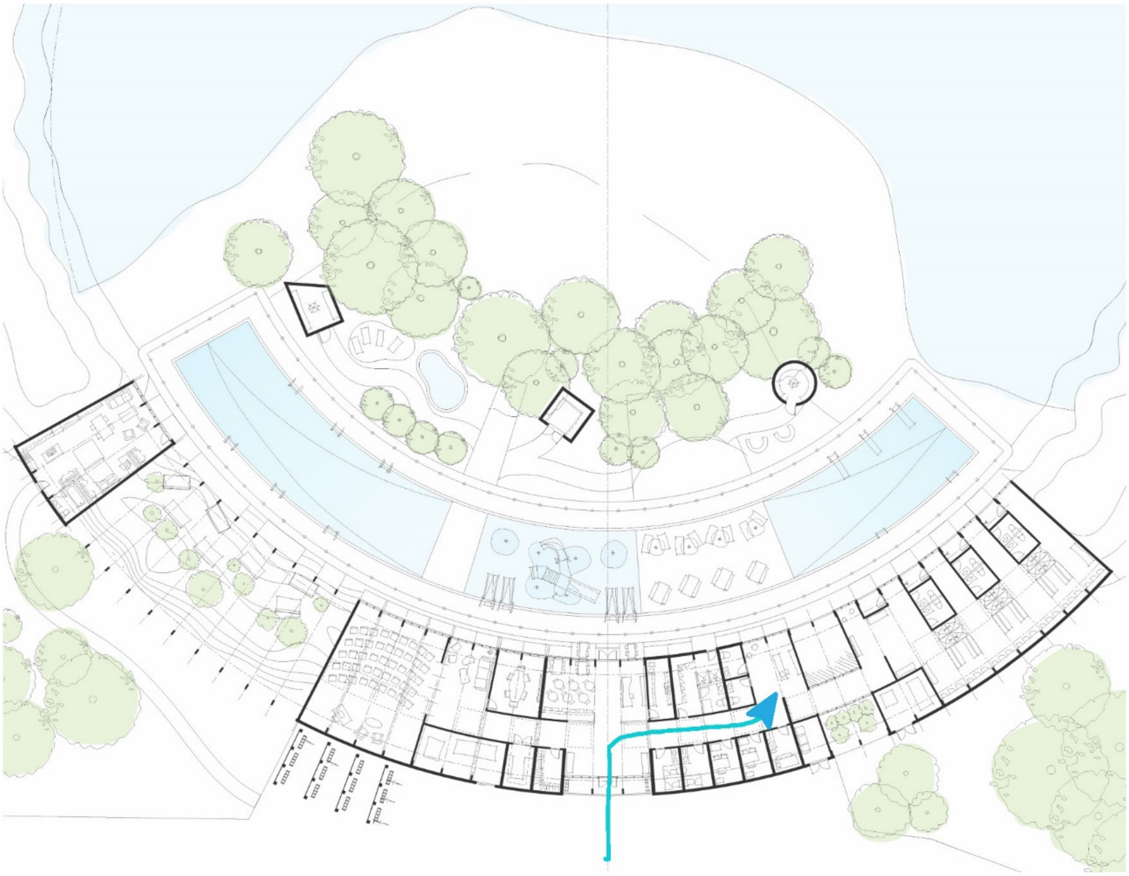


Figure 86. Scenario 2, Panel 4. (Source: By Author)

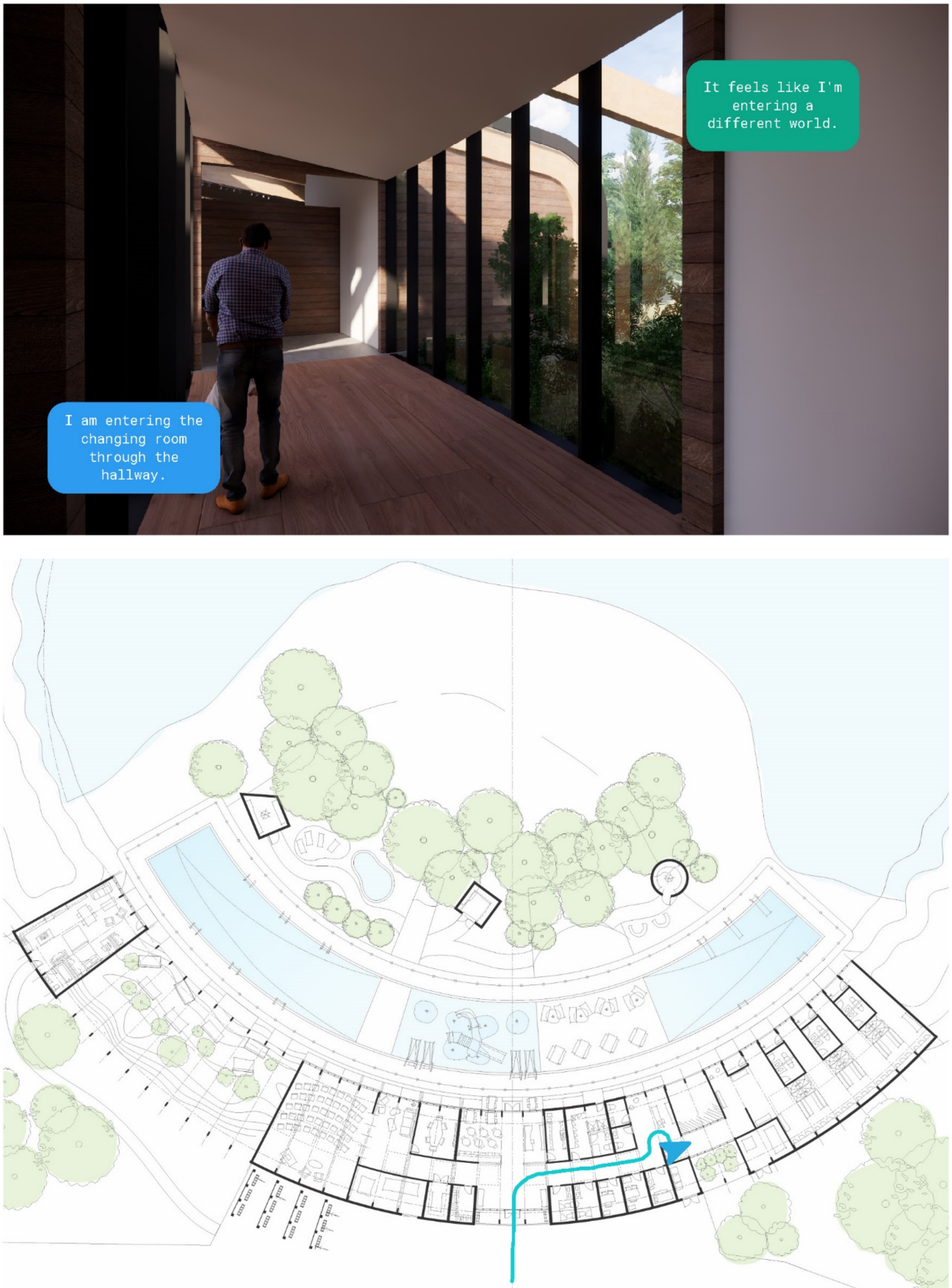


Figure 87. Scenario 2, Panel 5. (Source: By Author)

Figure 88. Scenario 2, Panel 6. (Source: By Author)

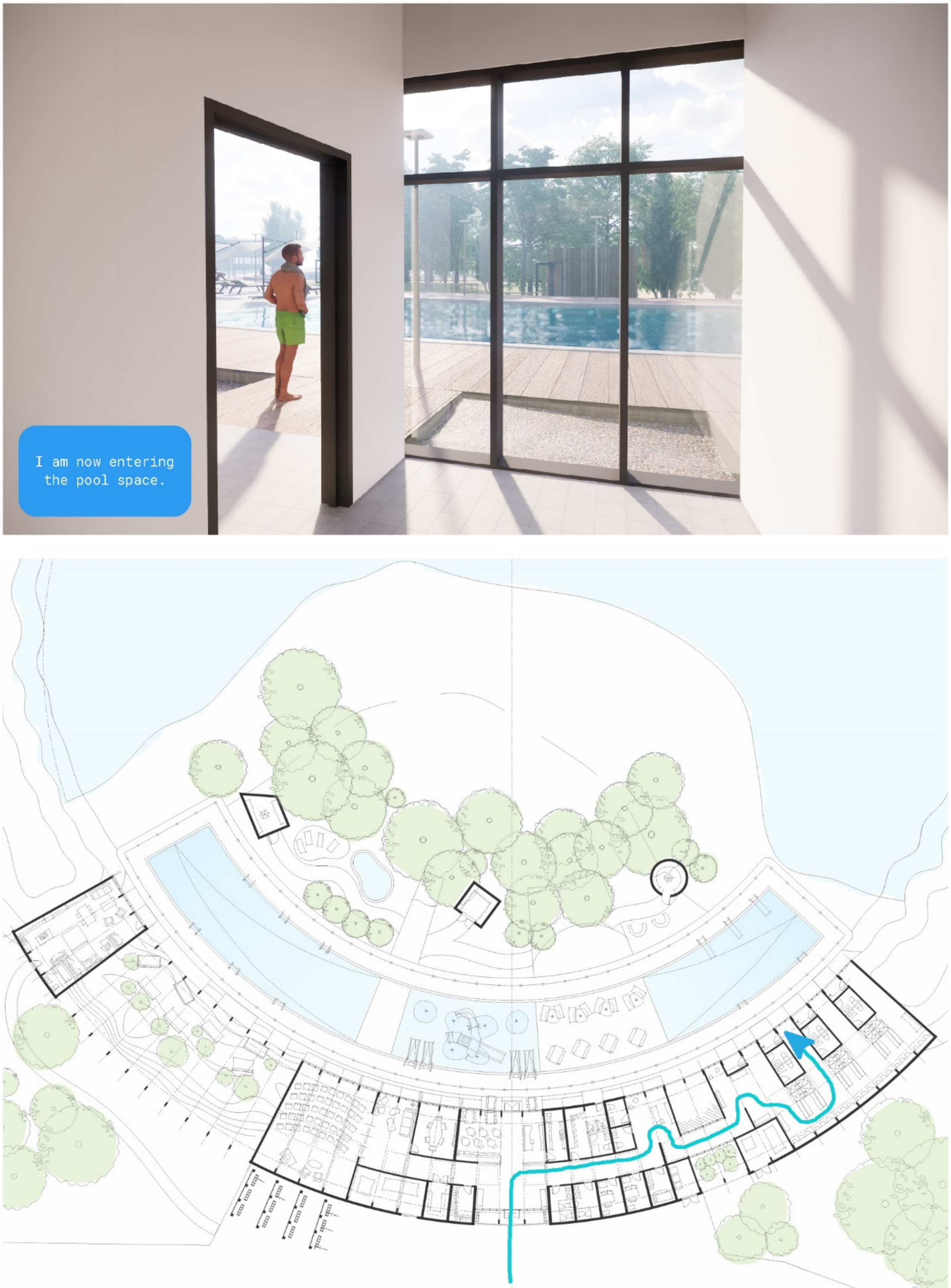


Figure 89. Scenario 2, Panel 7. (Source: By Author)

Figure 90. Scenario 2, Panel 8. (Source: By Author)

Figure 91. Scenario 2, Panel 9. (Source: By Author)

6.4.5 Scenario 3 Journey Map

Figure 92. Scenario 3, Panel 1. (Source: By Author)

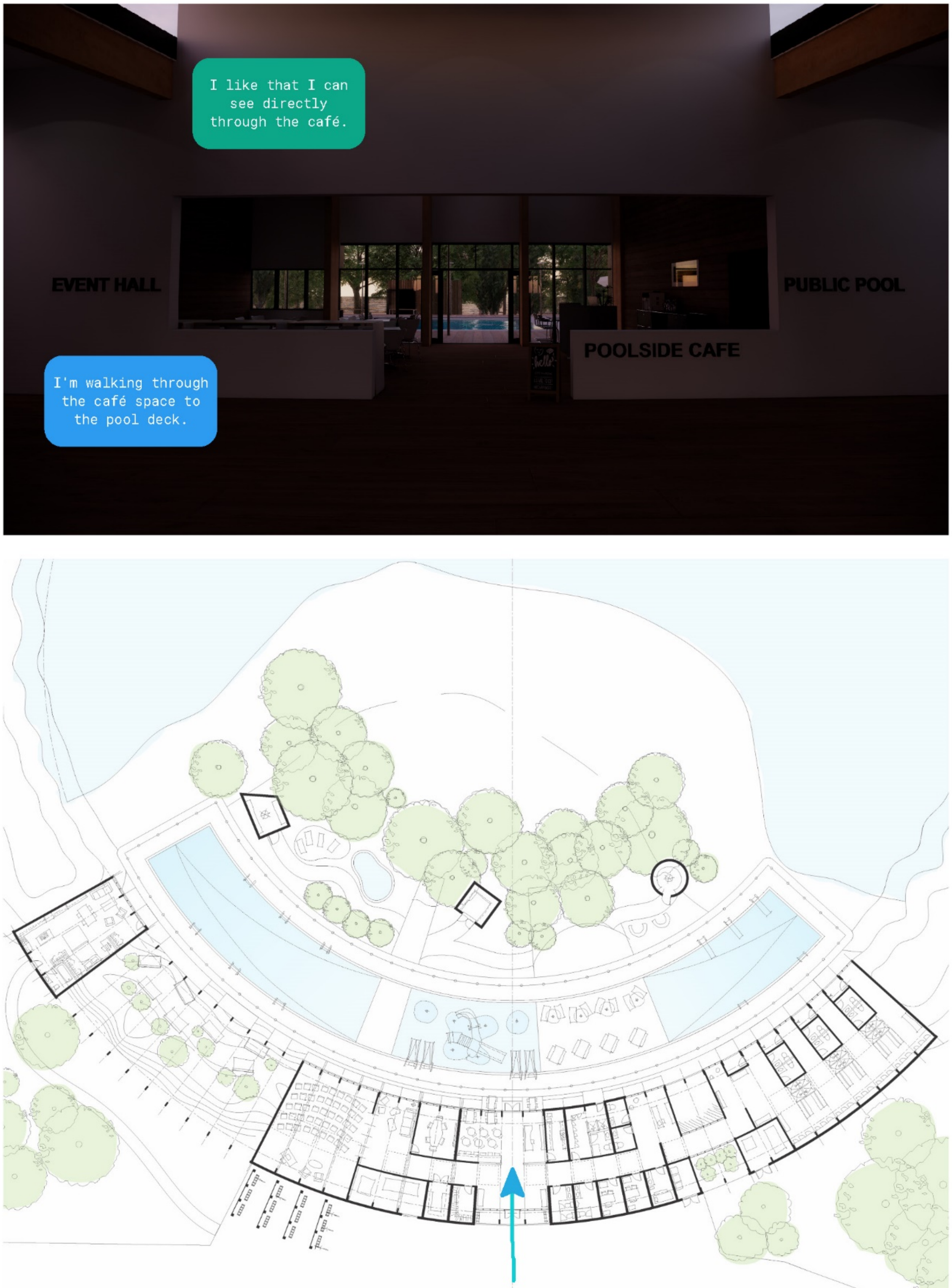


Figure 93. Scenario 3, Panel 2. (Source: By Author)

Figure 94. Scenario 3, Panel 3. (Source: By Author)

Figure 95. Scenario 3, Panel 4. (Source: By Author)

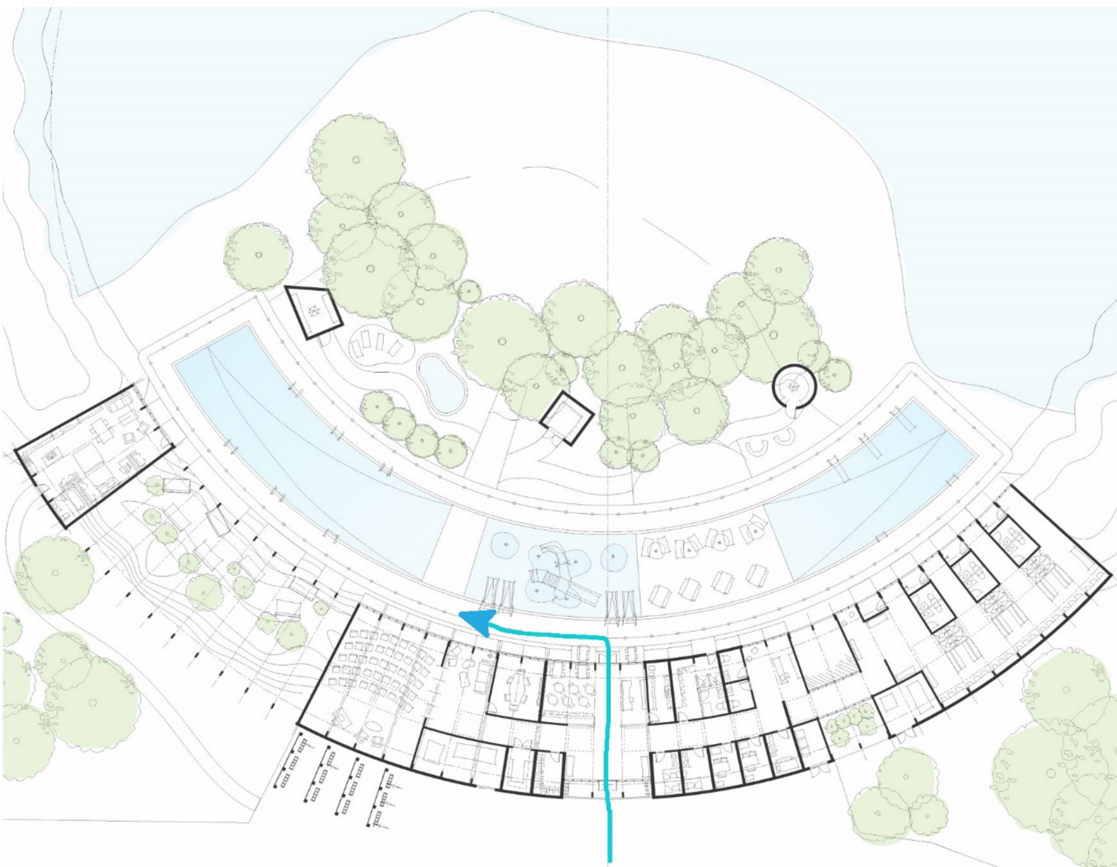


Figure 96. Scenario 3, Panel 5. (Source: By Author)

Figure 97. Scenario 3, Panel 6. (Source: By Author)

Figure 98. Scenario 3, Panel 7. (Source: By Author)

Figure 99. Scenario 3, Panel 8. (Source: By Author)

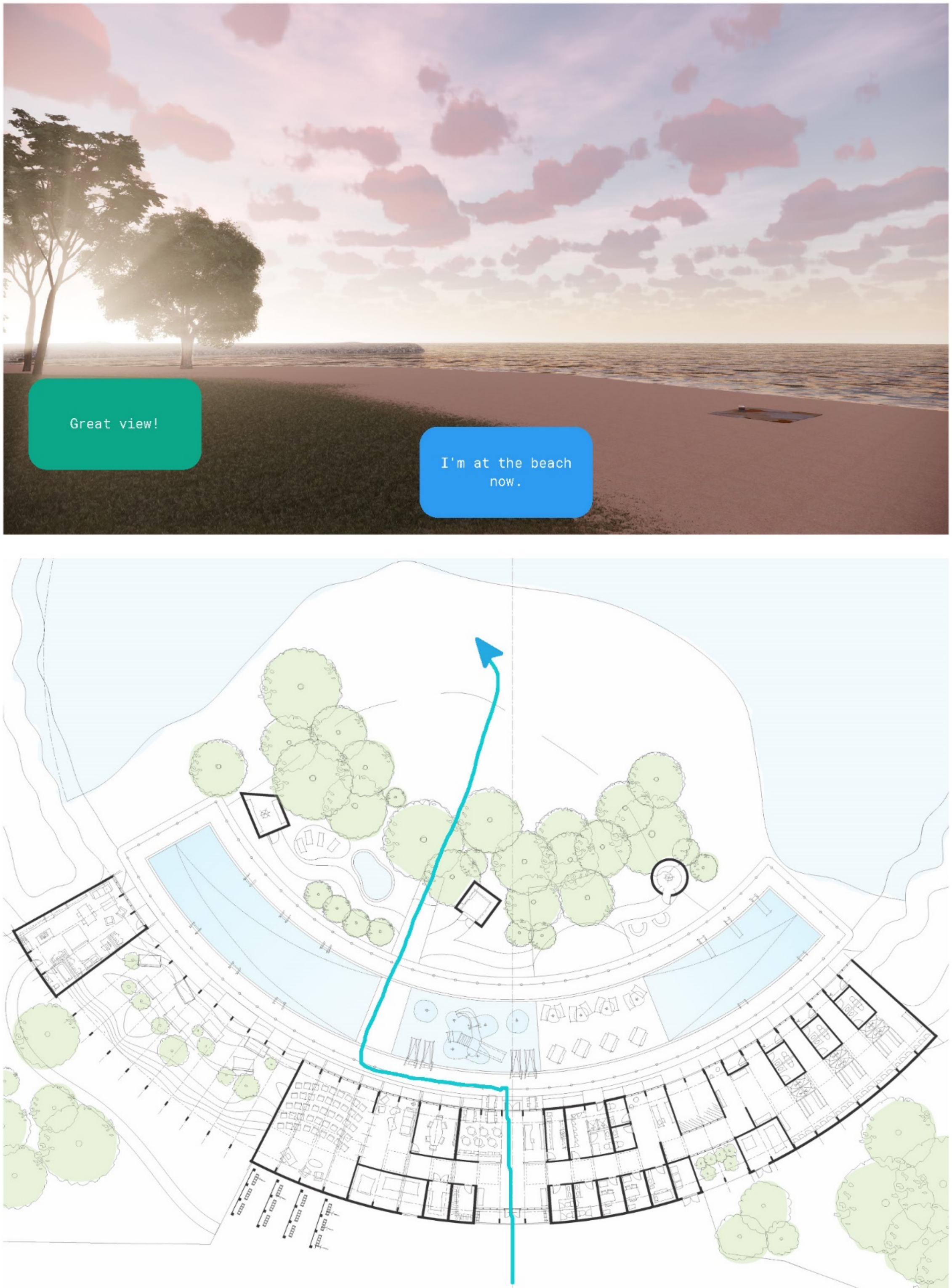


Figure 100. Scenario 3, Panel 9. (Source: By Author)

6.4.6 IV2 Conclusions

I was able to use photo-realistic real time rendering to help run my peers through different scenarios in a virtual building. This helped spark discussion that brought up strengths and weaknesses of the design.

I was able to walk seven of my peers through the scenarios and talk to them about the experience. My insights following discussion with my peers is that they had a lot more to say about the project from a usage standpoint. In showing them 2D drawings and renderings, I noticed the discussion revolved around the composition of the design being proposed rather than its use. In the immersive experience, the comments were concentrated on how the space was to be traversed and used. To understand the true nature of the insights present in showing potential end-users these immersive scenarios, a more robust immersive experience and participant pool would be required in future work.

The idea of scenario led testing in this simulation was enticing to all my peers in the experience and helped guide the discussion of the project. It was easier to picture the usage of the space when pointed towards potential scenarios in which one would use the space. Not only was the experience more enticing, but it also helped outline the journey of a potential future end-user in the space. The feedback generated from these scenarios allowed for more actionable changes to edit the space than the previous VR study.

It was interesting that in showing this experience to my peers, all of them were more interested in walking through the space than looking at the drawings. They all wanted to jump in and experience the space rather than look at an orthographic drawing. I mean, this might seem very intuitive that something colourful and fun is more enticing to a user than something that isn't as interactive, but I think this shows that the user values that interactivity, and isn't inclined to stay and plainly receive information about architecture. Pointing back to a previous quote by Fillwalk, "You remember a trip, but you don't remember a lecture." The investment and user interest came from the telling of stories in the illusion of real spaces. Because the user was able to explore at their own pace, they were able to take in an experience of architecture and reflect upon that.

The kick-off scenario provided allows my peers to think about spaces in the sense that decisions are made based on what they would do in the same situation in real-life. Testing with different scenarios would also allow an end-user to experience all parts of the building while being self-led. Decisions to move in a certain direction or look at certain things can be more easily uncovered with scenarios. During each step of the journey presented in the scenarios, I was able to uncover new strengths and weaknesses to my design brought to my attention by my peers. For example, in the entrance area the different types of program available in the building were not immediately made clear even though I thought that the signage would be enough. Instead, more architectural elements were required to make the different programs and their locations more obvious. A few of my peers pointed out that the front desk to the pool was too far away from the entrance and should instead be immediately visible upon walking into the building.

7 [Products] Beta-Testing Architecture Guide

7.1 How Designers Should Show Their Work

During my experience with my peers, I found that these were the most important points in representing architecture to the layperson for beta-testing.

In order to get good feedback regarding design decisions, we must first craft an experience that an end-user can be immersed in. During my experience with my peers, these are my recommendations for beta-testing with end-users:

1. It must be a common-ground experience.
2. It must be navigable by the end-user.
3. It must have scenarios for an end-user to test.

7.1.1 Establishing a Common-Ground Experience

Initially, I thought that the experience had to be strictly photorealistic to be of any use to the designer and end-user, and I had originally titled this section, “High-Fidelity Experience.” In my presentations to my peers, the experience was focused on being photorealistic, but it is possible that the experience does not have to be photorealistic to function as a beta-test. The experience must instead present the elements that a designer wants feedback from the end-user on. This is a matter of strategic fidelity.

Earlier on in a project’s design process, the idea that the design is open to changing must be conveyed to the end-user. This means that the elements of design which are open to changes can be represented more abstractly in the form of basic geometry and volumes.

An example of this is if a designer wants to test out building massing for a plaza condition in a public space, the buildings do not have to be photorealistic, but the space that they take up should be blocked out as volumes. This helps a designer communicate that the elements being evaluated are the volumes that the buildings occupy, and not the facades.

In the case of the pool experience, I wanted to evaluate the experience of using the space, so I chose to implement a photorealistic representation to show to my peers.

Different levels of fidelity can help communicate ideas from different phases of a project. Abstraction can be good if the feedback the designer requires is about earlier, coarser, design decisions about the project. Higher fidelity can be good when feedback is about more fine-grained functionality of the spaces. The most important part is choosing the level of fidelity that accurately communicates the designer's intent on the direction of the project.

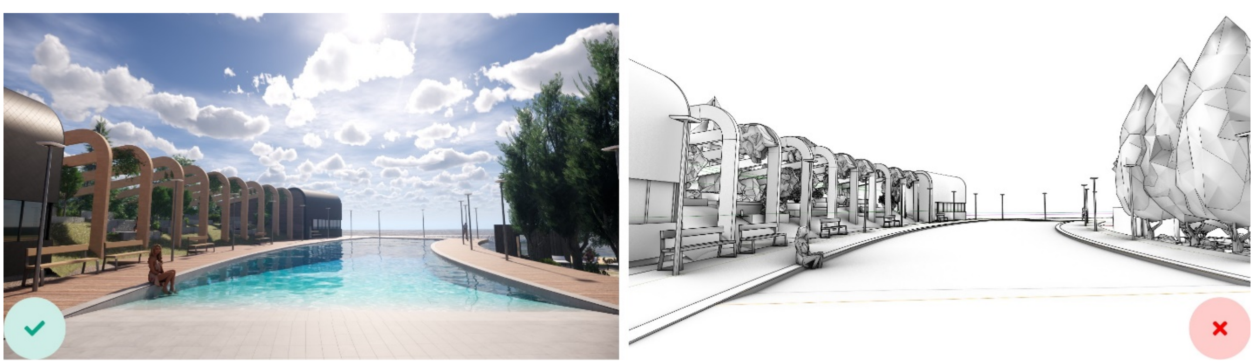


Figure 101. Left: High-fidelity simulation, Right: Line drawing with no colours. (Source: By Author)

- Do give your experience materials and realistic lighting
- Don't use a clay model without colours
- Give something for people to get invested in

7.1.2 Navigable by the End User

The experience must be navigable by the end-user during the beta-test. This is because it allows the user to have free-will during the simulation. This is like the beta-testing which occurs in video game development in that end-users are free to navigate the game at their own pace without the designer interfering or leading the end-user. The end-user should be able to interact with the space at a human-scale. The feedback provided in this way will be reflective of how the end-user may interact with the space in a real-world scenario. An example of a high-fidelity experience without navigability would be architectural animations. The end-user’s experience of this method of presentation would be a high-fidelity version of the project since the animation could be rendered with accurate lighting and materials. The disadvantage here is that the end-user is then subject to the bias in framing that the designer imposes on the animation. The end-user is not free to roam around the project and explore, rather they are reliant on the camera rails set out by the designer showcasing only the best parts of the project.

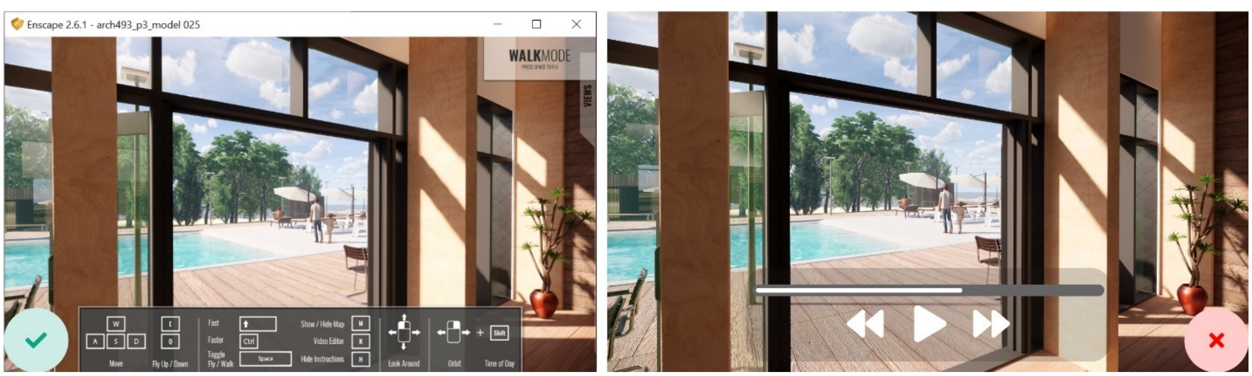


Figure 102. Comparing differences in letting the user navigate or look at a space. (Source: By Author)

- Do let your end-users take control of the experience
- Don’t show them a pre-recorded animation of the experience

- Let people walk around and explore your project. See how they use the space at their own pace.

7.1.3 Scenario-Based Testing

Lastly, scenario-based testing is critical for beta-testing because it sets up an objective for the user to accomplish within the navigable high-fidelity experience. If there is no scenario, there is nothing for the user to beta-test. A high-fidelity experience which an end-user can walk around aimlessly will not test the usability of the space. The end-user testing the space, must have something to test it with.

Figure 103. Comparing differences in scenario-based testing. (Source: By Author)

- Do give your end-users something to work towards
- Don't just tell them to look around plainly
- Don't direct their experience entirely and try to observe how they naturally respond to the experience.

End-users need something to work towards in the experience to be led through the building as they would use it in real life. From my experience with my peers, I found that if they didn't have a scenario to work within, the discussion focused mainly on the composition of the building and the aesthetics of the space. When telling them to run through real-world scenarios, they instead were able to experience flaws of the building through the usage of space. The feedback generated from telling them to look around plainly resulted in aesthetic comments, whereas the scenario-based experiences uncovered usability issues.

According to the guidelines for beta-testing set out in the design process for video game design, the designer must act simply as the observer and minimal interference with the end-user will provide insight to their real-world decision-making processes. This is especially apparent when there is a “fork in the road” during the scenario. Watching where an end-user will choose to go given the situation before them rather than the designer telling them deliberately to “go left” will provide this real-world insight.[77]

In conclusion, these three pieces of establishing a common ground, navigability, and scenario-based testing are the main building blocks for crafting a beta-test for architecture. This way an end-user will be able to provide knowledge to a designer which they did not have previously. A high-fidelity experience gives the end-user an accurate representation of an architectural proposal to provide feedback on. The navigability of the digital space would allow an end-user to explore and gather information about the project without the biased framing laid out by the designer. Finally, the scenario-based testing would give the end-user a wireframe for feedback. The user would be able to explore the space with an explicit objective without the prescribed experience of the designer.

[77] Bates, *Game Design*, 2004.

7.2 How We Should Learn About the End-User

The way that I used to gather feedback with my peers was simply to use the experience to spark discussion. In an idealized environment, we could also implement spatialized comments, as well as tracking movement in space.

In talking with my peers, the feedback which I was able to gather was in the form of comments fixated on specific moments in time during the scenarios that they were led through. What was great about this is that it helped uncover some problems that couldn't be easily identified by static renderings. Through my own bias as a designer, I was unable to frame renderings that would help an end-user respond with problems about how they would use the space. Ideally, what could also be done is a series of spatial comments laid out by each user to help illustrate to the designer where problems exist in an architectural proposal.

7.2.1 Spark Discussion

The number one most important thing is that this experience allows the end-user to have something to talk about. It's hard for a user to comment on a still image because they're not a part of it. The experience of looking at a corner view rendering of a building from a street intersection lacks the end-user feeling presence in the space. To give them something to talk about, we can show them an immersive scenario to start discussions about how spaces can be used.

7.2.2 Spatially Fixed Comments

Figure 104. Spatially tagged comments by the end-user along the way of the journey help identify problems in layout and paths of travel. (Source: By Author)

The benefit of letting the user walk around in the space themselves is that they can comment about anything within the space. Having walked around the space themselves and made decisions of moving around the space based on their experiences within it, the feedback from this can be tagged to certain points of their experience. They can be tags in sequence depending on where they walked.

7.2.3 Tracking Movement in Space

Feedback from the end-user does not always have to be restricted to what the end-user explicitly comments for the designer. Another way that we can start to record this information is to see where the end-user walks in the space, as well as what they look at. This type of information is implicit to the experience and can sometimes reveal information about the experience that the end-user themselves did not realize. For example, if there is a fork in the road, we can find out how long an end-user spent at the fork deciding which direction to go, as well as what they looked at.

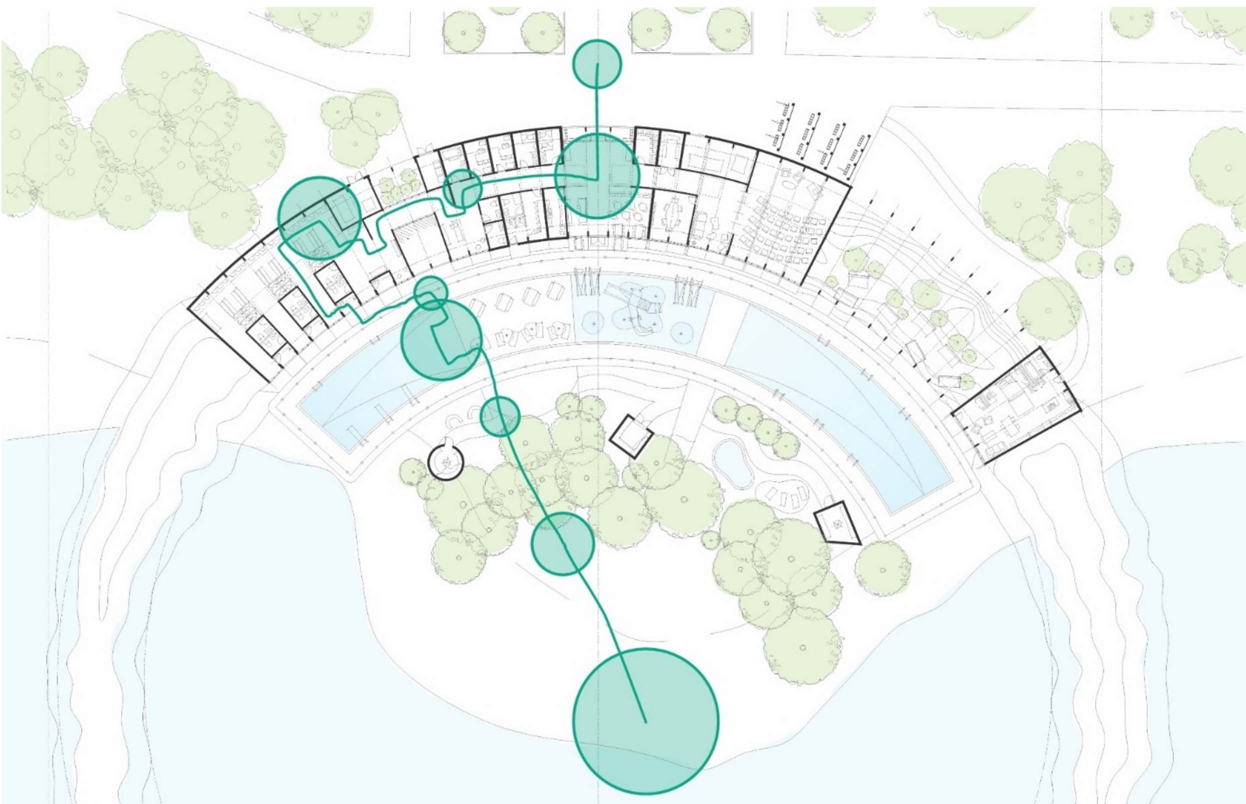


Figure 105. Paths of travel and moments of pause indicated on floor plan of pool. (Source: By Author)

One of the ways that this could be recorded could be in a floor plan with paths of travel indicated by a line, and circles for where the end-user spent time looking around.

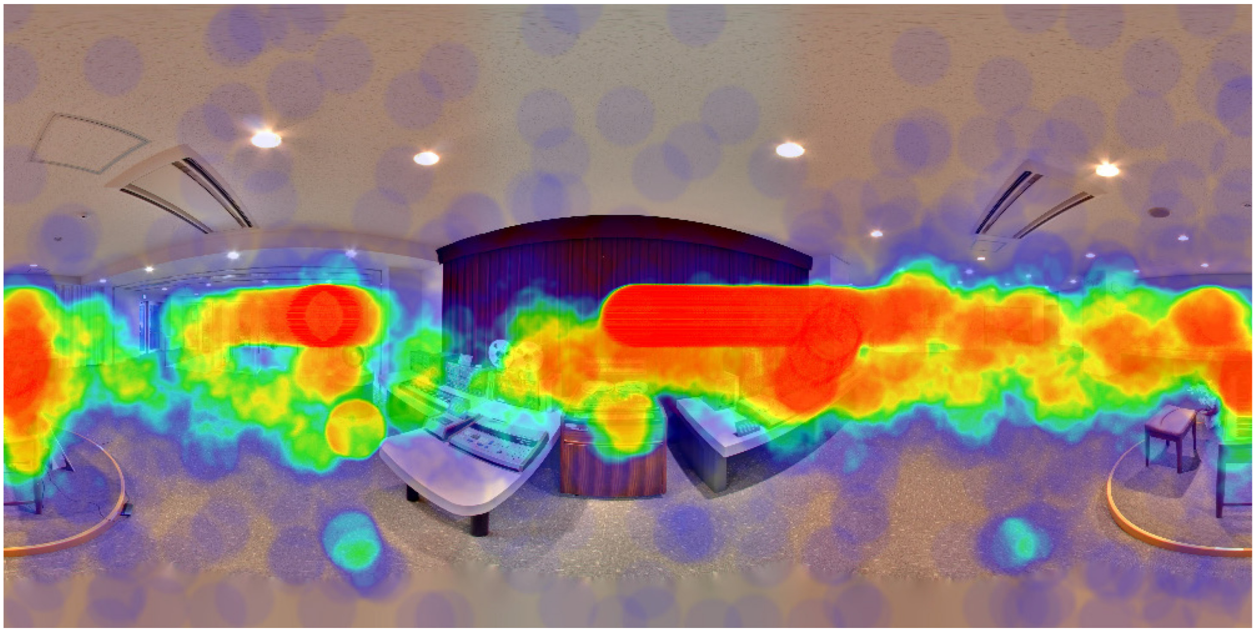


Figure 106. SeekBeak generates a heatmap from a 360-degree photograph. (Source: SeekBeak / Downloaded from https://seekbeak.com/2017/10/04/heatmap-analytics-for-all-360-photo-snaps/ on January 2021)

To record and find out what users looked at, we as designers could look at a heat map of where the user looked in the virtual experience. The hardware and software of the beta-test could track head position as well as eye position. This information can then be mapped onto the experience for the designer to review. In the case of the above image, the heatmap is overlaid on top of the original static 360 panorama that was presented to end-users.[78] This could help us uncover which design elements in our environments that users looked at the longest, and which design elements users did not really pay attention to.

[78] SeekBeak, "Heatmap Analytics for All 360 Photo Snaps," *Easily Create 360 Experiences & Virtual Tours* (blog), October 4, 2017, https://seekbeak.com/2017/10/04/heatmap-analytics-for-all-360-photo-snaps/.

7.3 Benefits of Beta-Testing with End-Users

The benefits of beta-testing with end-users include addressing some real-world issues, inclusive-design, and large user base testing.

7.3.1 Real-World Testing for Real-World Issues

The problems that we can beta-test with end-users will slowly get us closer to problems that they may encounter in the real-world. End-users can provide designers with critical information that allows for more informed design decisions to be made that address real-world usages.

7.3.2 Inclusive-Design

By communicating with the end-user more, the designer can account for more needs and wants of the end-user in the final product. Using this method means that less people will be left out in the design process, and a more accommodating architecture can be built.

7.3.3 Testing a Large User Base for Places with a Large User Base

Using a method like this can allow designers to showcase a project to a larger audience. This larger audience can help beta-test high traffic areas where a lot of people in the real world would walk through. Some of the places that can be tested are places that process people. These places include airports, transit terminals, community centres, pools, libraries, government buildings, public spaces, plaza designs, and shopping malls.

7.4 Guide Conclusions

Just using the immersive scenario-based simulations as a starting point to talk about the design of the pool was helpful. Not only did this provide me with insight on my own project’s design, but also insight on the whole process of using such a method to beta-test architecture.

Speaking from the point of design, some of the things that I realized through using the scenarios in the simulation were that the process that I had initially imagined for entering the pool needed editing. One instance of this that stood out was the need for the reception desk for the pool to be immediately visible from the entrance. Looking back on it now, it seems like an obvious feature to include, but it didn’t appear to me until I let my peers navigate the space on their own.

In the method of immersive scenario-based testing, it seems like the biggest takeaway is that giving an end-user a story to follow allows them to get invested in the space and feel like they are part of the space. This method of immersion gives them presence. The feeling of presence allows for more natural responses when exploring and using the space; therefore, can garner more feedback that reflects how we use spaces in real life.

8 [Impacts] Changing the Way We Think

We need to redirect focus of representation in architecture to functional experiences rather than key renderings. We need to learn the value of evidence-based design early on in our education to have them not exist as an afterthought often excluded in real-life projects.

The development of this methodology of beta-testing in architecture will lead to less biased architecture. The designers bias will be decreased, and the end-user will be able to influence real-world designs of architecture. This means that the field of architecture will hopefully be able to include end-users as an integral part of the design process in the future. We will be able to measure our own biases and see how end-users critique our designs. This way we can see how far off we were with our speculation when designing buildings for people.

8.1 Key Scenario, Not Key Rendering

In addition, the discussion in representing architecture will start to stray away from the idea of the poster rendering of a building. Buildings will no longer be evaluated based simply on how they look, but rather how they function. It won't matter if a building is nice to look at if it is dreadful to use.

8.2 Education

The education of designing spaces can also start to put more of a focus on people using space. We can start to learn about how we should rely on evidence to make design decisions rather than only using our personal experience and books. The knowledge that can be gained purely from reading books is explicit knowledge. During our time in school, we learn so much about these fantastic places that others have designed, but drawings and pictures can only go so far to convey the experience of being there. There is nothing quite like standing inside The Pantheon that can be conveyed through looking at static representations. Immersive tools can help us get closer to understanding experiences from the human scale.

8.3 Less Book, More People

In an ideal world where the design process can be accelerated through end-user feedback, designers will no longer have to rely only on slow-moving standards to design buildings. All buildings would be custom fit to their inhabitants, and all users' needs and wants would be accounted for.

9 [Outlook] Changing the Way We Work

We will reduce the onset cost of projects, as well as have a better combined design process that allows end-users to play a critical role in design decisions made by the architect.

The future usage of this methodology sees that the end-user is an integral part of the design process. End-users will act as an editor looking over the architect's work and verifying that this is how spaces will be used. Designers will then have a better method of communicating their architectural proposals with others. Ideally, what we also implement is a new piece of software that is the next step in building information modelling (BIM). Not only would we be able to include things like cost, material, and fit, but we would be able to include usage as a part of the building information.

We would then be able to send out a beta-test of an architectural proposal to a thousand people and have them comment spatially about what needs to be changed. For example, in the community pool project, we could have many people request that the reception desk for the pool area be moved further to the front since it is not visible from the front entrance. If a change like this is apparently needed in a beta-test, then the general public which would use the real-life building would be saved from the pain point identified in the beta-test.

9.1 Mixed Realities

Virtual Reality is one of the leading technologies that we use in architecture to help immerse users in virtual space. In an idealized world where VR headsets are commonplace in regular households, this would be the primary method of allowing end-users to beta-test architecture. There are still three main limitations that hold this technology back from being completely immersive. The three limitations are tactility, room-scale, and elevation.

9.1.1 On Tactility

There is no good mainstream solution for the implementation of touching objects in virtual space. The feeling of material cannot yet be conveyed in VR. With a future implementation of tactile objects in virtual space, we can start representing the real-world materials we would use in projects with a more fine-grain approach if needed.

9.1.2 On Room-Scale

The main advantage of modern mainstream VR devices like the Valve Index are that they have special tracking cameras that allow the user to move around a virtual space simply by walking forward in the real world. Cameras mounted on tracking towers and the headset calculate the translation of the headset in the real world and apply this to the headset’s position in the virtual world. The boundary of this experience is restricted how big the room is, as well as the length of the wire connecting the VR headset to the computer. An ideal implementation of this would either be by using a treadmill that runs infinitely in all directions[79], or a room which is larger than the virtual space being explored along with a wireless VR headset.[80] The

[79] “Virtuix | Invest in the Future of Gaming,” accessed January 13, 2021, https://invest.virtuix.com/.

[80] “Wireless VR,” accessed January 13, 2021, https://www.displaylink.com/vr.

latter option would require the VR headset to either be completely wireless, or the computer to be attached to the VR headset.

9.1.3 On Elevation

A feeling that is rarely conveyed in virtual reality is what it feels to walk up or down on stairs. One solution to this could be to build coarse stairs and floors into the real world for your end-user to step onto while in the virtual experience, but these would not be easily editable. Usually how this is tackled is a combination of changing the elevation of the person in virtual space paired with a physical gesture that they make, or a button press.[81] This combination of processes allows us to abstractly portray changes in elevation such as a staircase.

In the future with better immersive technologies that allow us to fully traverse virtual spaces, we can beta-test architecture using an all-encompassing experience to represent the spaces that we design.

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[81] Noorin Suhaila Asjad et al., "Perception of Height in Virtual Reality: A Study of Climbing Stairs," in *Proceedings of the 15th ACM Symposium on Applied Perception* (SAP '18: ACM Symposium on Applied Perception 2018, Vancouver British Columbia Canada: ACM, 2018), 1–8, https://doi.org/10.1145/3225153.3225171.

9.2 A New Take on The Universal Washroom

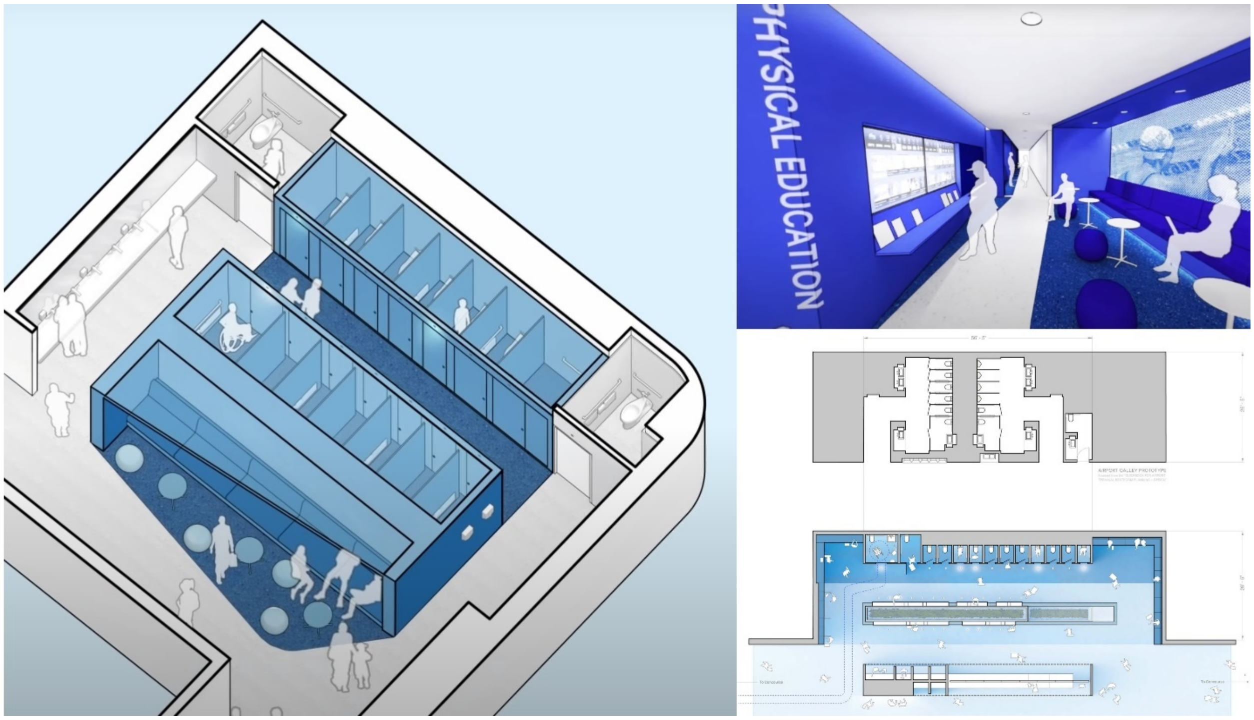

Figure 107. Drawings from the Stalled Project outlining a new take on the universal washroom. (Source: Susan Stryker, Stalled Project / Downloaded from https://www.stalled.online/ on November 2020)

A different project in which a method like this could be useful would be the Stalled Project by Susan Stryker. This is a project in which a design team is trying to redesign the idea of the universal washroom. They argue that the existing design of the universal washroom is outdated and does not fully address how the wide variety of different people regardless of age, gender, race, religion, and disability use washrooms.[82] Beta-testing in this case could be the form of having different people inputting their requirements as a player in the scenario, and then carrying out the beta-test to find out what changes need to be made. These requirements could be the same factors previously mentioned such as age, gender, race, religion, and

[82] “Stalled!,” Stalled!, accessed November 3, 2020, https://www.stalled.online.

disabilities. Testing prototype washroom designs with thousands of people in this way would help a designer with insights that they previously did not know of.

9.3 Airport Design

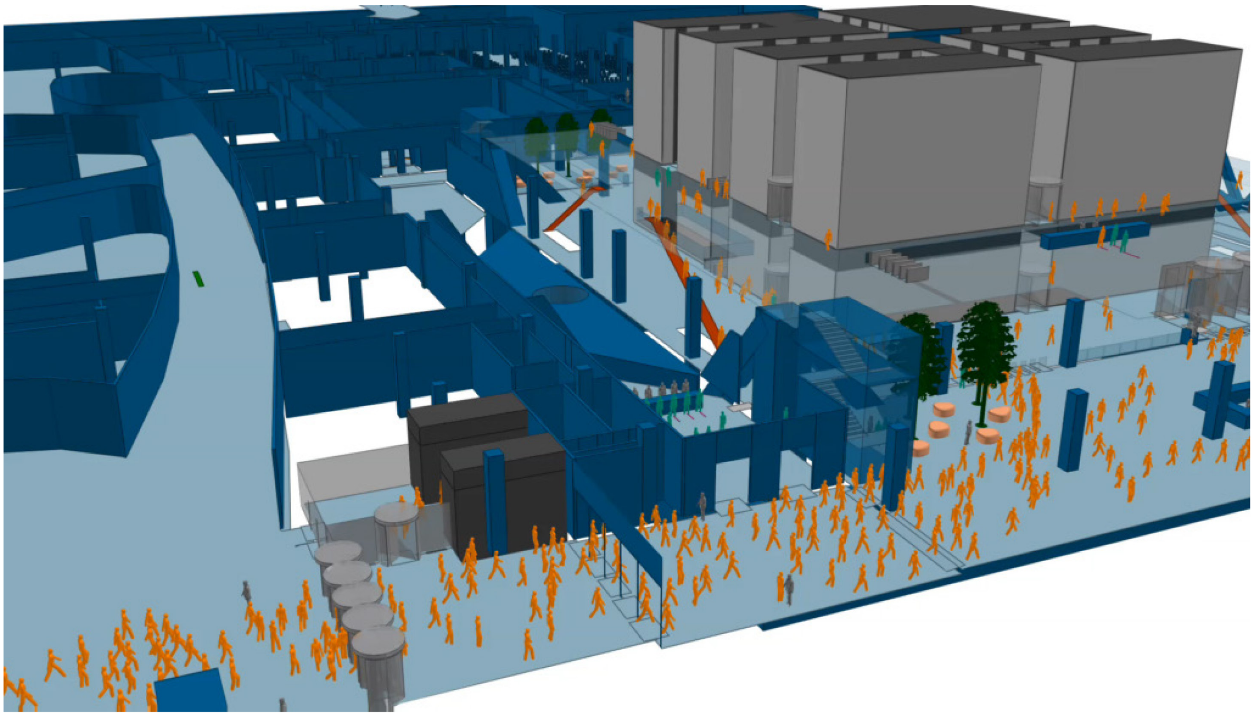

Figure 108. MassMotion crowd analysis of Commercial lobby, South Korea. (Source: Oasys / Downloaded from https://www.oasys-software.com/case-studies/commercial-lobby-south-korea/ on December 2020)

Currently in larger scale projects such as airports, we have tools to tell us how crowds would navigate a space. One such tool is MassMotion, a software program that allows designers to evaluate their designs with crowd simulations.[83] Expanding upon the idea that we can test spaces with crowd-based simulations, we can also utilize a critical mass of beta-testers to add a human touch of interaction to test spaces. By running through these sorts of tests with real people we can not only confirm how people navigate through space, but we can

[83] Mediaworks, "Commercial Lobby, South Korea," Oasys, accessed December 8, 2020, https://www.oasys-software.com/case-studies/commercial-lobby-south-korea/.

also potentially uncover new issues which only people are able to pinpoint.

9.4 Combining Design Processes

9.4.1 Proposed Architectural Design Process

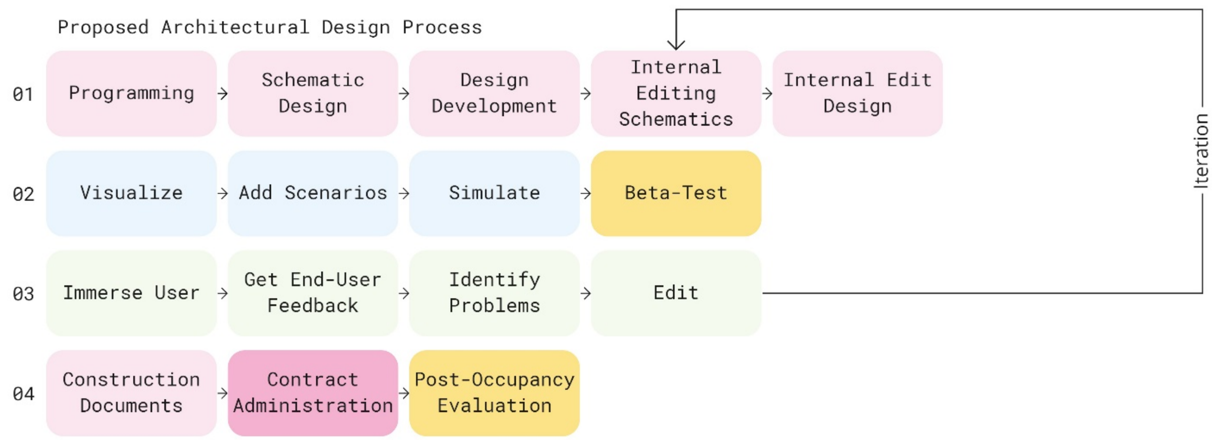

Figure 109. Diagram of architectural design process with elements found in video game development implemented. (Source: By Author)

Eventually, we can start to include the end-user in the design process. It's bizarre to think that the current process of end-user feedback is asking them what they think about the building after it's already built (POE). It's good that the feedback provided in that situation can help assist the design of future buildings of the same type, but it will never go towards those exact issues of that exact building. The unchangeable elements of the building will stay the way they are; therefore, the same problems will persist. Perhaps one day the idea of end-user co-design will not be something novel, rather it will be the norm of how we as designers acquire knowledge to make informed design decisions in our projects.

9.4.2 Workflow in Detail

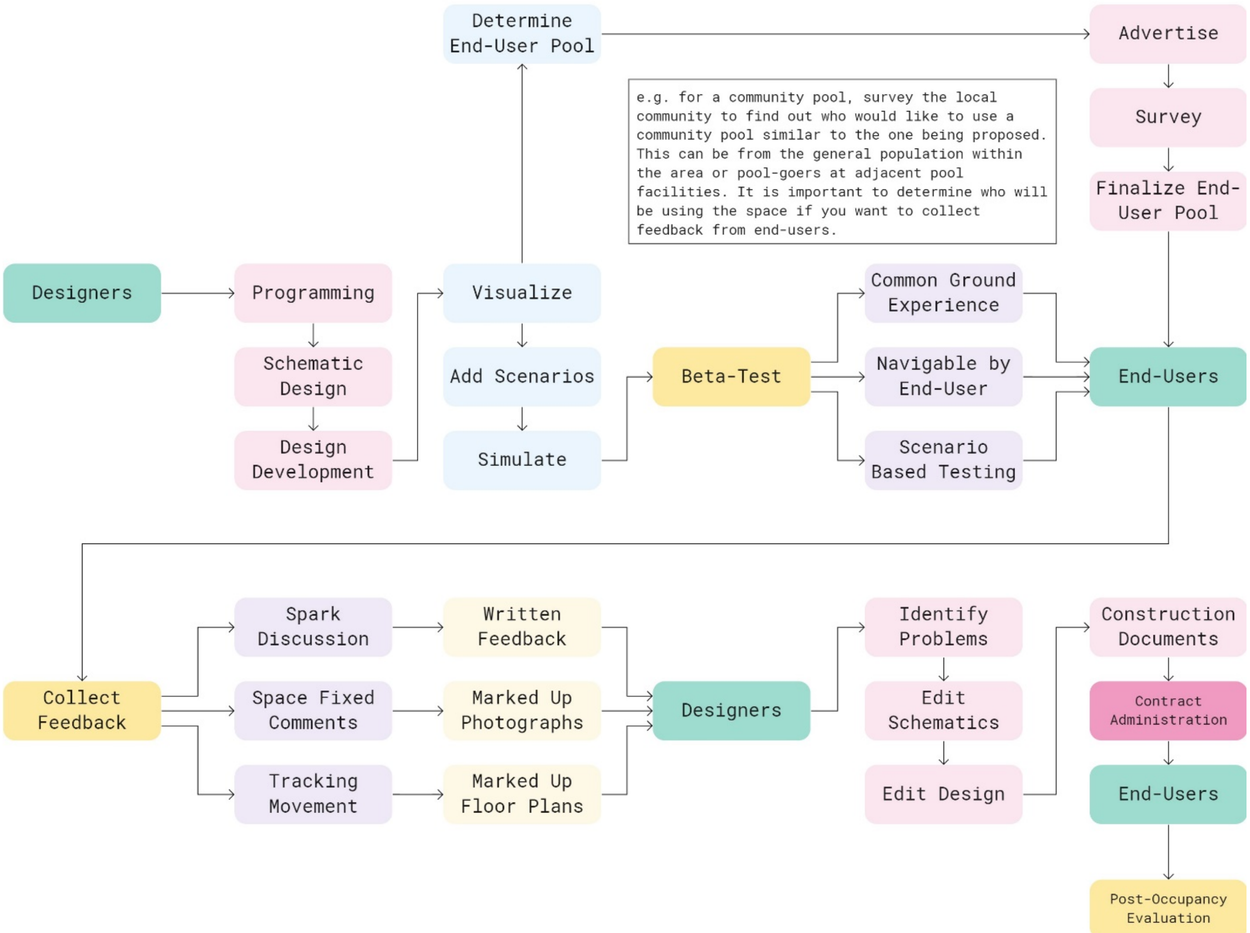

Figure 110. Workflow diagram outlining a detailed process for integrating beta-testing in architecture. (Source: By Author)

9.5 Concluding Remarks

The way that I ended up presenting my thesis during my review was through an immersive experience which I walked through with my panel. This presentation can be viewed through the following link:

Figure 111. QR Code for video of immersive thesis presentation linking to: https://youtu.be/kbYscpmHbYY (Source: By Author)

I chose to use immersion for this presentation instead of a slideshow presentation because it allowed for effective communication as well as establishing a common ground for understanding between the presenter and the audience. In the scenarios that I ran through with my peers, the focus seemed to be on wayfinding in the space, but just by talking to them during the immersive experience, I found out design flaws that I previously would not have known about.

The main issue is that we're not talking to people, and when we do, it's an afterthought. Just to reiterate, 68% of designers never reviewed reference literature to find out about the end-user, and 71% had never conducted POE on existing buildings. We're designing for people, aren't we? The designer still has the expertise, but people ultimately use the spaces we design.

The second issue is that the ways we currently represent architectural ideas with static renderings don't properly convey the user experience.

The proposed solution is incorporating beta-testing into architecture and involving the user earlier in the design process. Looking at the cost influence curve of projects, the first 30% of the project timeline significantly affects the project's outcome. This is where the designer has the most influence on the final cost of the project. Doing more research and gathering feedback at the start uncovers critical information that sets the project up for success. We can front-load the design process with end-user involvement. Beta-testing can help us uncover new qualitative insights, but more importantly introduce new quantitative data points about a project.

The current usage of immersive tools is mostly for marketing and showing a finished design to the end-user. I believe that they instead have the potential to shape the design from the start. To fully utilize immersive tools in our field, we should create experiences that: establish a common ground, are navigable, and are scenario based. If we can use this tool properly, then we can help architects make more informed design decisions and bridge the gap between abstract ideas and real-world experiences. Architects are the storytellers of buildings not yet built. We need to tell a complete story to end users, and we can start by beta-testing.

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Appendix

Drawing Set for Pool Building

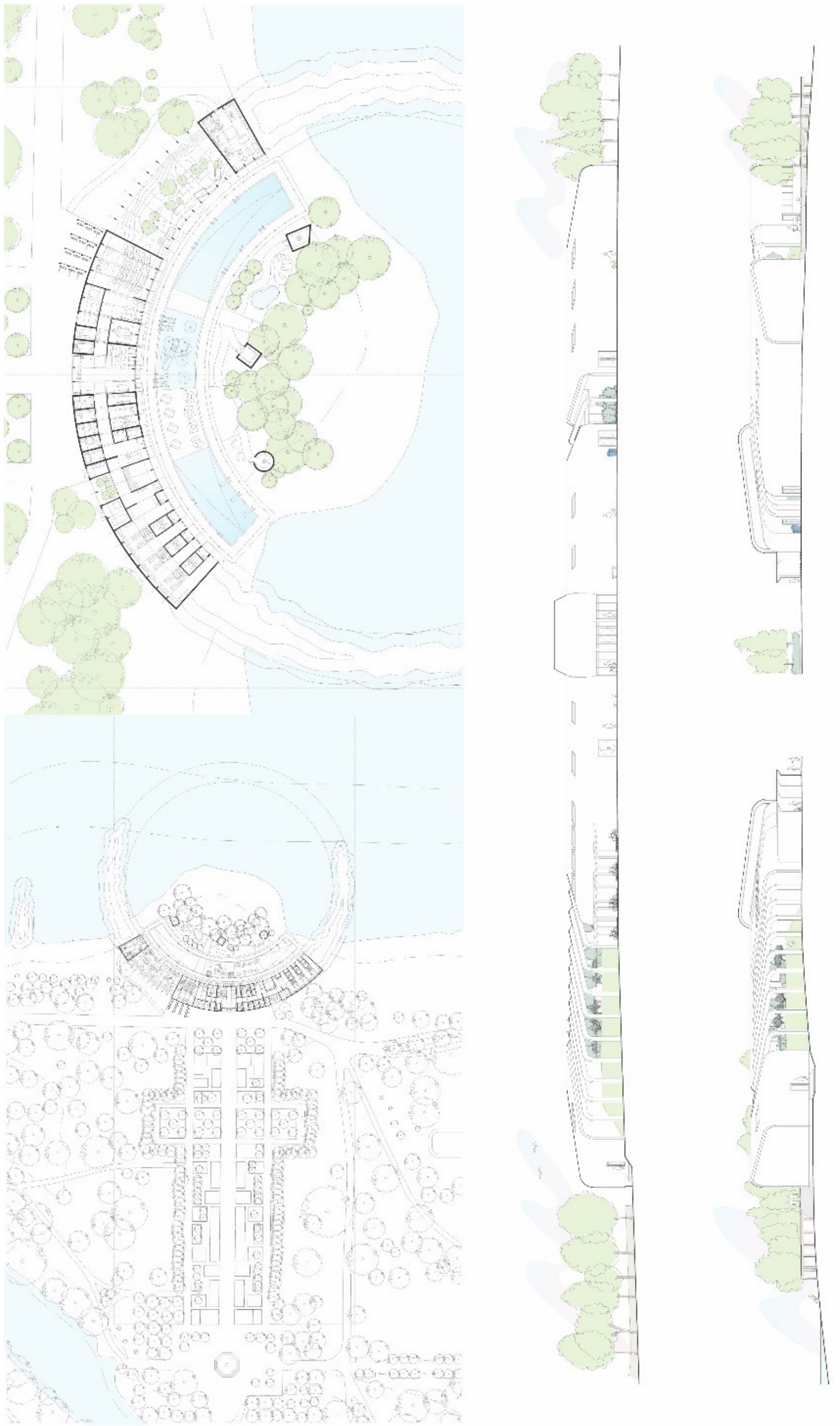

Figure 112. Top left: Site Plan, Top right: Floor Plan, Bottom: Elevations. (Source: By Author)

Figure 113. Various elevations and sections of pool building. (Source: By Author)

Screenshots from Presentation

Figure 114. Starting point for the immersive presentation. (Source: By Author)

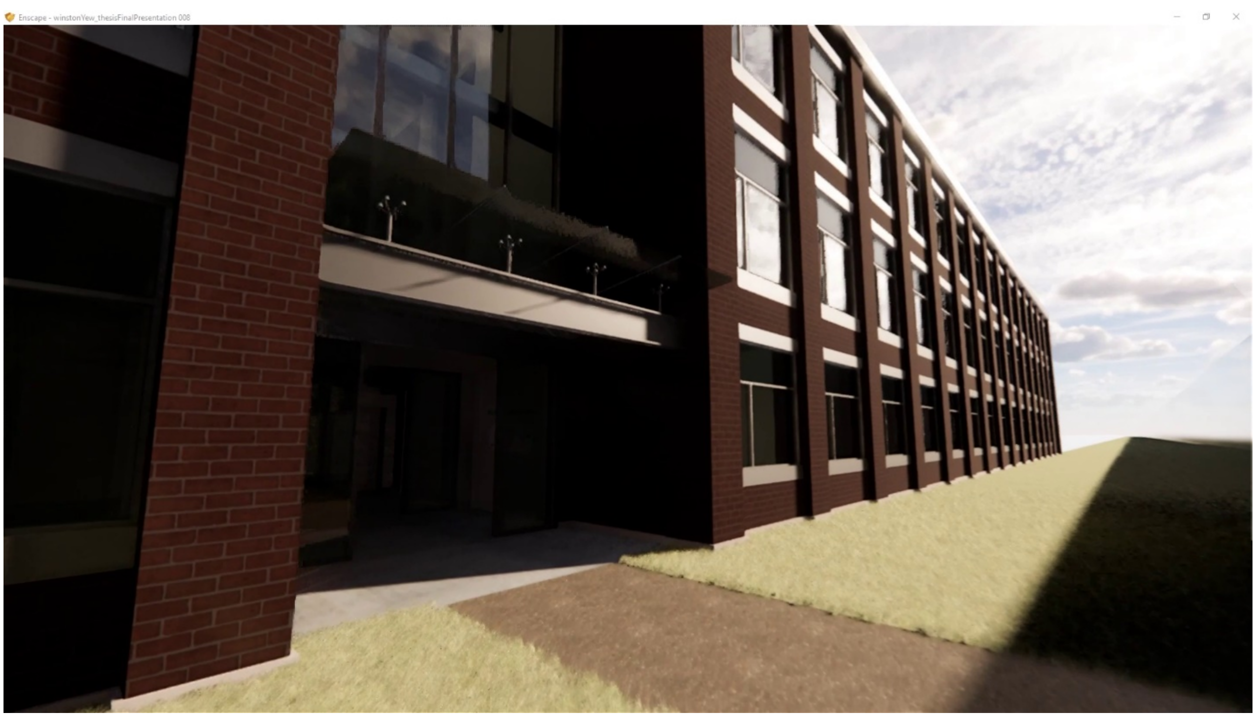

Figure 115. Entering the school. (Source: By Author)

Figure 116. Atrium of the school with example VR setup. (Source: By Author)

Figure 117. First room showcasing how designers represent architecture. (Source: By Author)

Figure 118. Entering the room in which we find out about the end-user. (Source: By Author)

Figure 119. Now Entering: Parallel Methods. (Source: By Author)

Figure 120. Room of cutting-edge technologies in immersion. (Source: By Author)

Figure 121. Scope and limitations room. (Source: By Author)

Figure 122. Immersion rationale room. (Source: By Author)

Figure 123. Room showcasing different versions of the immersive experience. (Source: By Author)

Figure 124. Snapshots of the library iteration. (Source: By Author)

Figure 125. Snapshot of drawings hung up on the wall. (Source: By Author)

Figure 126. Now Entering: Immersion Two Demo. (Source: By Author)

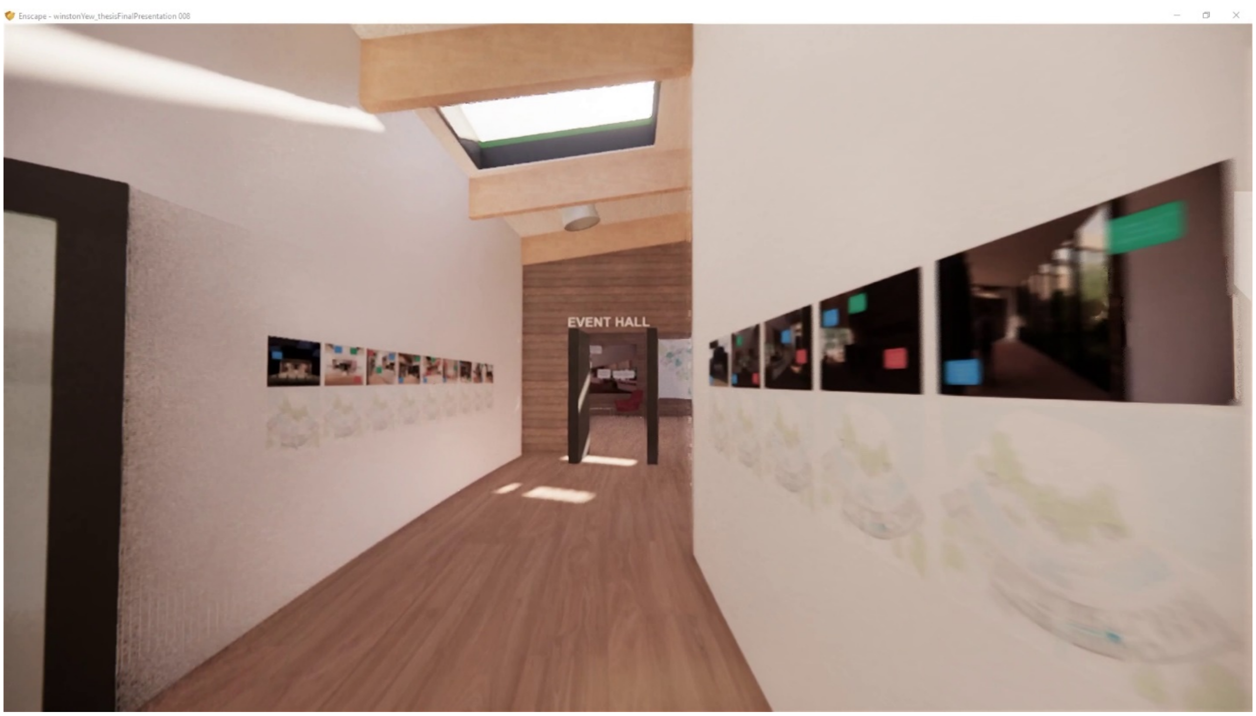

Figure 127. Walking down the hallway in the community pool. (Source: By Author)

Figure 128. The events space. (Source: By Author)

Figure 129. Final slide with closing statement. (Source: By Author)