ARCHITECTURAL ACCESSIBILITY AND PEDAGOGY VIA VIRTUAL REALITY INTEGRATION

HUI, VINCENT
ESTRINA, TATIANA
ZHOU, GLORIA
LEE, SARA
KINUTHIA, VIVIAN

DEPARTMENT OF ARCHITECTURAL SCIENCE
RYERSON UNIVERSITY
TORONTO, ONTARIO
CANADA
Architectural Accessibility and Pedagogy Via Virtual Reality Integration

Synopsis:

This presentation outlines the cost-benefits of integrating Virtual Reality (VR) in design curricula, specifically through implementation in the largest accredited architecture program in Canada. A framework on VR adoption and implementation is outlined to support pedagogical accessibility through pre-made as well as user-generated content.
ARCHITECTURAL ACCESSIBILITY AND PEDAGOGY VIA VIRTUAL REALITY INTEGRATION

ABSTRACT

Though Virtual Reality (VR) has quickly become a platform for entertainment, it has a great deal of potential as a pedagogical tool, specifically in architectural design. There are two paradigms of integrating VR pedagogy: a) the use of VR to experience pre-existing assets, and b) the use of VR to create content. Over the past decade, increased accessibility via advances in technology have been instrumental in promoting the transition from the former paradigm to the latter. Beyond the realistic, immersive experience afforded by VR, the medium also provides a far more robust set of features which facilitate the iterative design process so critical in architectural pedagogy. Among the litany of benefits of VR integration are the accessibility and experiential capacity of the outputs as well as the demand on resources within academic institutions.

Through a series of case studies within the largest accredited Architecture program in Canada that pioneered the use of VR in architecture pedagogy, this presentation outlines the merits of VR integration through a framework that may be adopted by other institutions. It is incumbent on design educators to understand the cost-benefits of VR and best practices of this emergent technology. VR is neither a panacea nor is it a fad in design pedagogy; like orthographic drawings or physical models, VR is another medium that inevitably is a component of future praxis.

INTRODUCTION

Virtual Reality (VR), the use of visual simulation in creating a simulation of an environment, is in principle not a new concept to entertainment and certainly not the case in architecture; from Alberti and Brunelleschi’s first outline of proper perspectival drawing through to stereographic visualization and computer graphics, methods of production of convincing, immersive imagery of ideas, both existent and conceptual, have been at the disposal of the arts and sciences for centuries (Hewitt, 1985);

Although immersive content is only at its early stages, mainstream media and general interest in VR technology has been growing at a rapid pace. Proceeding Facebook’s acquisition of Oculus, VR use and engagement within the mainstream had increased exponentially. Large investments from tech companies such as AOL and Facebook, combined with the accessibility of VR headsets and devices, ensured its demand in our modern-day market. Additionally, products such as Google Cardboard, Sony Playstation VR, the HTC Vive, and Oculus Rift encouraged the common use, creation, and exchange of 360-degree videos, ultimately influencing many tech manufacturers to produce products that are compatible with this medium. (Bucher, 2018)

Pop culture references to VR had become popularized in the early 1990s and later that decade, Sega and Nintendo introduced VR technologies into their gaming products, followed by Apple’s QuickTime VR. Although these systems were flawed and failed to garner much traction, it did pose many questions about the technology and its capacities.

Great advancements in technology has been made in the 21st century, ranging from computer graphics, technology, and hand-held devices. Ultimately, this has leveraged the
integration of VR in many different realms such as social media platforms, gaming programs, and the AEC industry, increasingly more common. In the early 2000s, HMD (Helmet Mounted Display) and VR technology had been developed by Kaiser and Canon; this began to pave the way for the devices in which would be used to view the VR products. (Bucher, 2018) It allows the user to move freely while the camera captures realistic and experiential footage, or in the case of Kaiser, the user is viewing the content completely hands free.

As we move closer to the present day, technology developed by Samsung, HTC, Sony, and Oculus has completely reimagined the capabilities of VR. Companies such as these have taken advantage of the large strides made in gaming graphics, computer software, and responsive technology. (Bucher, 2018) For example, the Oculus Rift S is a VR headset most commonly used for gaming although it can also be used to simulate experiences for entertainment purposes, and spatial visualizations, such as riding a rollercoaster, skydiving, and walk-throughs of buildings. In terms of performance, it ensures an extremely high graphic fidelity due to the use of an LCD display combined with high pixel density; additionally, it uses an Insight Tracking System which is comprised of five cameras to capture your movement. Ultimately, this creates an immersive experience that successfully simulates reality and superimposes the user into different contexts all the while retaining a human-scale. Although it’s extremely sophisticated in contrast to the products that preceded it, it’s to be expected that products with an even greater capacity of simulating real life will be released in the upcoming years. It can also be argued that responsivity in VR devices is not yet flawless and parallel to that of reality although it’s objectively an incredible visualization tool that allows us to understand contexts that’s not always readily accessible to everyone.

In the AEC Industry, VR has become an asset in visualization and spatial understanding at a 1:1 scale. In the case of conceptualizing spaces, static images and fly-throughs have been a standard vehicle of communicating ideas until the introduction of VR technology. Rendering software has been developed to adapt to the performance and technology available for 360-degree viewing as well as simulated walk-throughs. Software such as Enscape, Iris, Yulio, Lumion, Twinmotion and many more are all capable of producing visualizations that are compatible with popular devices in the market. At the very least, it’s recommended that a NVIDIA GeForce GTX1080 or Quadro P500 graphics card is used as the output resolution ranges up to 8192 x 8192 Pixels. The capacity to produce material with such graphic infidelity allows viewers to experience the smallest details of a design as opposed to viewing a still image that may not be as well rounded and effective in capturing certain conditions. (Stine, 2018)

The ubiquity of virtual reality as an entertainment medium has gained traction within architectural pedagogy. While initial forays into the medium examined the potential found in aspects of visualization including fidelity and immersion, recent investments in architectural applications of virtual reality have increased their scope to also facilitate exploration of design ideation. This paradigm shift is not uncommon within architectural praxis. When seminal Roman architect Vitruvius outlined the core architectural triumvirate of “durability, utility, and beauty”, as new methods of representation and construction emerged, visionary French architect, Étienne-Louis Boullée millennia argued that the Vitruvian ideal “mistakes the effect for the cause” and posited that such advances in technology reaffirmed that it is “first necessary to conceive... that
constitutes architecture and which can only be consequently be defined as the art of designing and bringing to perfection any building whatsoever.” (Rosenau, 1976)

Within Ryerson University’s Department of Architectural Science, virtual reality has become a component within the largest accredited architecture program in Canada. As the first in the country to have done so in 2016, the program has become one of the authoritative resources for its use in architectural pedagogy (LeBlanc, 2016). While the Department’s central location in the heart of the largest city in Canada, provides an excellent backdrop for architectural education, it draws from a significant commuter student population. Like their counterparts across Canada, Ryerson Architectural Science students are saturated with technology and quick to its adoption (Alson, 2016). However, unlike their contemporaries in Canada, Ryerson students are drawn from across the cultural and economic diversity of Toronto which includes high percentage of students simultaneously undertaking part-time employment or debt to facilitate their education (Ryerson University). As a result, technological adoption and innovation within the program must be tempered with accessible, cost-effective methods of providing experiential learning

DESIGN PEDAGOGY: EXPERIENCE OF THE PRE-EXISTING

Educators are currently witnessing a period of growing economic disparities, which ultimately has impacts upon the potential offerings an institution can provide (Alvaredo, 2017). Students sharing a classroom do not share the same financial comforts thus impacting educational opportunities, including fieldtrips and access to basic equipment such as computing and Internet connection. Fortunately, the latter issue is steadily improving as countries are asserting a need for their children to be digitally literate (Ribble, 2011). With the incredible volume and accessibility of information available online, greater demand has been placed upon virtualizing experiences on account of limited resources. As outlined earlier, VR provides users an engaging, immersive experience with reasonable fidelity to develop an understanding of environments both existent and conceptual.

Interactive virtual fieldtrips (iVFTs) have proven to be incredibly useful as an alternative to physically transporting, lodging, and sustaining students on fieldtrips. Though iVFTs are facsimiles and far removed from truly visiting a site, they provide a baseline level of experience otherwise unfound in imagery, videos, and text available online. In a recent study on iVFTs, “students showed large and statistically significant gains in content knowledge” which also has catalyzed research into further integration of adaptive feedback and interactivity in this VR medium (Mead, 2019). These types of virtual tours are generated using consumer-grade cameras capable of documenting an entire 360-degree field of view. Both still photos and looping videos may be interactively viewed on computer screens but for a truly immersive effect, users are able to navigate the space with a VR headset mounted upon their face. In parallel, mobile hardware and software have become quite robust enough to readily view, edit, and broadcast 360 VR content. Regarding the widespread accessibility of the medium, VR sets have dramatically fallen in price and combined with the ubiquity of smartphones, the use of VR to experience existent environments both afar and from the past has led to its integration into academia. This medium is currently used in pedagogical practice for a range of disciplines and applications including virtually bringing art
curation students from parochial universities to famous galleries around the world through to simulating crime scenes for forensic science students (Tawhai, 2017).

While there is undoubtedly much to be learned from historical architectural literature and model making, the sensorially immersive nature of VR goes a step further to provide experiential understanding of historic, and oftentimes distant, architectural sites. Despite the wealth of resources available to Ryerson’s Architectural Science first year students learning about historic ruins and iconic structures, these resources are predominantly literary and photographic. While this exposes them to significant quantitative and qualitative information about these sites, this pedagogical approach alone requires that students piece together information from miscellaneous sources and varying mediums in order to complete the modeling exercise. This results in gaps in their understanding of the ways in which volume, materiality, light, sound, texture and other design qualities impact occupants, seeing as the students are left to imagine how the spaces feel. Through the integration of VR into such an activity students are able to understand the space beyond architectural orthographic drawings and are immersed in a visceral learning experience. Instructors are also able to ensure that all students have a better comprehension given that their varying abilities to synthesize textual and photographic information may result in a disparity in their understanding.

In terms of volumetric spatial apprehension, VR immersion allows students to tour the sites in full-scale. This grants viewers the opportunity to observe the intricacies of the ruins and sites as they are. In translating this information to a model, it allows students to make better informed decisions when representing the space. Students would otherwise have to develop models through their understanding of scaled drawings and two-dimensional images, which would unfortunately simplify some of the complexities of the spaces. Consequentially, the inclusion of VR in this exercise would enrich students’ understanding of supplementary teaching material and further their awareness of technicalities otherwise lost in translation from scaled drawings to models.

During the summer after their third year, students in the Ryerson Architectural Science program have the opportunity to enroll in an upper level elective called Kultour. This destination
course is a 10-day academic tour that exposes students to the built environments in different geographic regions each year. Such field trips transcend traditional lecture format in dispersing academic material to student through interactive tours where the urban landscape becomes the classroom. Instructors engage student in a unique cultural exploration of the places and spaces that are significant to the context of the course and the course concludes with report style presentations of each students chosen topic of interest. During the trip students are able to capture moments through 360-degree images and videos at different sites using VR cameras. As a documenting strategy, VR footage is invaluable to students as it allows them to revisit this material when preparing their final reports and presentations. This frees up pupils to pay more attention during site visits since note taking and further analysis can be conducted later. Later viewing of VR photographs is likely to increase confidence in the observations and analyses made of their chosen research subject.

Beyond allowing for future viewing, students use the VR material gathered during Kultour course at their final presentations. The value of this technology is further emphasized when students are able to share collected footage to other students who may have been unable to take the course due the expenses inherent in such trips. Their peers are not only able to view the 360 captures, but are also allowed the auditory experiences of some of the tourists sites recorded. Further demonstrations of student research and their captured material take place at open house events such as Doors Open Toronto where the public are welcomed into the Ryerson’s architecture building. Through such communal ceremonies, iVFTs are made accessible to a wide range of viewers, some of whom may have otherwise not had access to opportunities where they could view urban landscapes in other parts of the world.

Additionally, simulating architectural experiences from different places, VR also affords the ability to experience architecture from different times. The onset of advanced digital simulation and reconstruction technologies has afforded a wealth of assets to be available to a range of
disciplines ranging from academia to entertainment. The tragedy of the irreversible loss and damage caused by the Notre Dame fire made the interdisciplinary interconnectivity between industries including computer simulation, architecture, history, archaeology, and video gaming abundantly clear when the prospects of using digital scans and models of the lost portions of the cathedral for potential reconstruction and remediation came to light (Hanussek, 2019). This instance merely epitomizes the increasing trend towards digitization of historic assets for greater accessibility and experience for both the general public and research communities.

Rather serendipitously, a collaborative VR initiative emerged within the Ryerson University community during the Winter of 2019. Spearheaded by Professor William Carter, an interdisciplinary team of faculty and students from video game production, archaeology, and architecture created a VR experience of one of the largest indigenous cities in North America. This collaborative effort was instrumental in transporting users into the Mantle site during the pre-contact era discovered on a site in the town of Stouffville, Ontario, Canada. Consisting of over approximately one hundred longhouses, with infrastructure characteristic of cities including garbage collection and a fire department, the archaeological value of the site is remarkable. Beyond formally serving as one of the first North American cities, it also served as a home to multiple different indigenous peoples displaced by the strife brought about from European settlement (Birch, 2015).

The Archeology Alive initiative led to the collaboration of three of different post-secondary institutions to the creation of a multi-sensory virtual recreation of a traditional Huron-Wendat longhouse. This installation, displayed at the Whitchurch-Stouffville museum, would serve as a vessel for educating the public on the Canadian indigenous peoples’ architecture and cultures. Virtual reality allowed for the user to not only experience the reconstruction of the longhouse itself but also the natural context in which it would be built. Architects and archeologists alike advocate for the importance of understanding events and the built environment in context, be it physical, natural or societal and the medium of VR was able to provide ample context for the user to gain a complete understanding of the era.

Alongside the digital aspects of the installation, the architectural science students were also to contribute a physical enclosure for the longhouse, one which would stimulate a user’s tactile, auditory and olfactory senses as they were engrossed in the virtual environment. The subtle features such as murmurs of Indigenous language, crackles of the fire, coughs due to the buildup of smoke as well as crickets and wind were critical elements to add to the overall impressiveness of the experience. Combined with the fragrance of the sweet grass and the various pelts and accessories available for users to touch and interact with as they navigate within the virtual longhouse, all these various elements provide a more robust sense of place, which would not be possible due to spatial and cost limitations without the use of VR.

Furthermore, exposure to VR of existing sites allows for Ryerson’s Architectural Science students to engage in conceptual design activities such as imagining the future of the Thomas Fisher Library for the Doors Open event hosted at the Toronto City Hall. VR application in this task allowed students to closely examine the current state of the space in order to brainstorm proposals to answer the question of this building’s future appearance and use. The incorporation of VR further allowed students to edit current condition footage with their innovative schematics.
in order to generate imagery capable of communicating their design intentions. The flexibility in using digital tools and software such as Adobe Photoshop in combination with VR allows for easy manipulation and superimposition that is desirable in design iteration. This meant that students could cycle through ideas and explore their design developments in order to evaluate their own designs. This activity not only demonstrated the value of VR in showcasing highly conceptual work, but asserted the value of this technology in earlier design phases.

*Figure 4 & 5: Current-condition VR of Thomas Fisher Library and student-reimagined design.*
DESIGN PEDAGOGY: CREATION AND DESIGN

Though VR use in education tends to reside in visualization and simulation of real world conditions, technological advances have empowered students to integrate beyond existent environments and instead generate their own in VR. While different disciplines require different levels of accuracy, interaction, and robustness, within design disciplines, specifically architecture, the ability to conceive of an idea and access immersive experiences of it is invaluable (Portman, 2015). Architectural institutions with the resources and research initiative to bring VR into the design studio have mushroomed globally with a range of impacts on contemporary praxis, from basic visualization within months of commencing the curriculum in a Toronto-based department through to advanced phenomenological explorations of theoretical space in graduate studies within the most prestigious architectural institutions in the world (Da Silva, 2016). Unsurprisingly, based upon the convergence of computer ubiquity and accessibility with a long-standing desire to thoroughly examine their design work, architecture instructors integrating VR into their coursework have anecdotal and clinical validation that VR use will remain prevalent as it continues to be a medium of choice even upon completion of VR-related courses or projects (Miltiadias, 2018)

Directed research at the pedagogical benefits in a design studio has become a new frontier as VR tools have become more accessible to institutions (based upon financial, knowledge, and hardware requirements). Without exception, published studies have indicated three notable components: that the use of VR is instrumental in “communicating design work to a diverse audience”, that VR is an invaluable component to ensuring students were “more aware of the 3-dimensional character” of designs, and more importantly, an incredible high percentage of VR designers “would be interested in designing using VR in the future” (Hill, 2019)

Capitalizing upon VR as an accessible medium, curriculum was developed and deployed within architecture design studios. Rather than simply view works that were afar or from the past, the use of VR in this instance was to provide an opportunity for students to develop and investigate their own design work. Students were able to readily adapt VR into their workflow on account of software, Yulio, that seamlessly allowed them to transition between 3D computer model generation into a basic virtual reality experience of their design work.

Conventional architectural workflows are cyclical whereby designs are developed, documented in drawings and models, and then reviewed whereupon the process repeats. Inefficiencies and demotivation aside, this process neither has an immediacy nor iterative agility that comes about from developing ideas, bringing them quickly into VR, and refining on the computer model. Throughout this VR paradigm, the ability to experience design work from a conventional perspective of an end user and occupant serves as an invaluable design tool. Specifically, with first year students, it is often a challenge to engage students on architectural design projects beyond exterior forms. While preoccupied with formal spectacle, like many famous contemporary practitioners, they create forms that are incredible feats of engineering yet fail to yield functional, programmed spaces. The likes of famous architects such as Zaha Hadid perversely serve as their flawed precedents; To better inform students about the relationship between a work of architecture and its context and users, VR affords a high degree of depth for designers as the medium essentially forces nascent architects to consider multiple dimensions of a
project simultaneously. Rather than adhere to an old paradigm of drafted orthographic drawings, students throughout the program from first years to graduating students were easily able to engage and refine their design work.

VR INTEGRATION

As outlined in the aforementioned figure, VR use is a consistent component in the architectural design curriculum within the Department of Architectural Science from 1st year through to their graduation. While this is an invaluable component in better understanding designs from the past as well as their own, VR is not without its criticism.

A significant challenge with VR use in architecture design curricula is the fundamental accessibility of the hardware and software. As described earlier, while packages such as Yulio and Twinmotion are low-cost and relatively intuitive to use (provided the institution’s curriculum has a standardized computer aided design curriculum), the viewing hardware is not necessarily as readily available. Two notable factors, the rising processing capability of ubiquitous smartphones and the dropping costs of specialized VR hardware (such as the Oculus Rift), have opened opportunities for a growing audience to adopt VR yet the pricing remains high for students and institutions. Though some benefits from VR include the experience of environments with minimal physical space demands, the use of VR hardware, specifically navigable conditions, requires volumes that, when dispensed with across an entire program, aggregates to a salient footprint within any building.

Another challenge with VR is the range of software that is available. While this may initially seem to be a function of a flourishing market economy, the lack of consolidation around a specific suite is difficult to manage within the academy and professional practice alike. The ecosystem of architectural VR software is far from saturated and the diversity of platforms only

---

Figure 6: A diagrammatic breakdown of the tools used by students at Ryerson University
makes it more challenging for confident adoption of one over another. The AEC (Architecture, Engineering, and Construction) industry tends to be conservative, and barring massive consolidation in the marketplace or codified standardization, there is little hope that VR integration under a single platform will come about in the near future. Architecture programs poised to adopt any VR platform should look to the industry in determining what would be best suited for student integration on account of enhancing their value for entry into the professional market.

At Ryerson University’s Department of Architectural Science, students in Communications Studio and Design Studio, both mandatory first year courses, are given project outlines ranging in scale, from small and temporary pavilions to permanent mixed-use retail and residential spaces. The use of VR technology as a communication tool, both throughout the iterative design process as well as the final product, was highly encouraged and well-integrated into the curriculum. Many students were only beginning to grasp design software and programs such as Rhinoceros 5.0, V-Ray, AutoCAD, and the Adobe Suite. In 2016, Yulio, a VR Rendering software was introduced to many students for the first time, few have heard of this tool although many were interested in its capabilities and having access to produce 360-degree visualizations for their own projects. Students had modelled their projects on Rhinoceros and used a 360-degree camera to capture the project’s site, later to be used to superimpose their models on. The workflow is very similar to that of a traditional image render, although the product presents itself to be quite different as it becomes an immersive experience for students, professors, and guest critics to understand the scale, materiality, and ambience.

An example of a 360-degree rendering completed in Yulio by first year student, Tommy Gomez is shown above. This is exemplary of rendering throughout the design process to gauge nuances in architecture such as lighting and scale. Through this, students can understand different views of the space; rendering the project from multiple different viewpoints can also be achieved easily as the student can navigate themselves using the 3D model to pick a location and Yulio is able to stitch the views to produce an image that’s compatible for viewing on its platform.

Figure 7 & 8: Project completed by Tommy Gomez, first year Communications Studio, the project outline is for an Amphitheatre at Ryerson University

An example of a 360-degree rendering completed in Yulio by first year student, Tommy Gomez is shown above. This is exemplary of rendering throughout the design process to gauge nuances in architecture such as lighting and scale. Through this, students can understand different views of the space; rendering the project from multiple different viewpoints can also be achieved easily as the student can navigate themselves using the 3D model to pick a location and Yulio is able to stitch the views to produce an image that’s compatible for viewing on its platform.
This project is outlined as a mixed-use cabin in the woods designed for a water ecologist to reside and conduct research in. It was completed by Shengyu Cai, also a first-year student at Ryerson University, in Design Studio. The VR image stitching allows us to understand the effectiveness of the field of depth shown through the software and tool. It’s able to capture light and materiality to communicate the ambience of the space, additionally, the scale of furniture of openings within the space can be investigated at full scale during the design process. Many of these aspects may be extremely difficult to capture or understand through the limitations of a 3D model.

**CONCLUSION**

Despite its commonplace use as an entertainment medium, VR is no longer a vapid visualization tool. While there are inherent challenges currently in adoption of the medium in architectural curricula, it is evident that it serves as a robust tool for students to better understand design work from other locations and times as well as better inform them of their own work. The initiatives presented within this paper asserts that there are strategies that can be adopted by design
programs with limited resources and how to optimally gain the best pedagogical value from each type of use case. As this is an ongoing research initiative, this only serves as a survey of the initial years of the research into VR integration in architectural education and the authors and investigators anticipate that with decreased learning curves and associated costs, VR will become another ubiquitous medium at the disposal of future architectural praxis.

**BIBLIOGRAPHY**


