

*Transformative Design: Virtual Reality and Augmented Reality in Furniture Design
–A Comprehensive Analysis of an Immersive Learning Experience*

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Abstract

Virtual Reality (VR) and Augmented Reality (AR) are advanced technologies in continuous development. They are already involved in different fields including Academia, for immersive and interactive learning experiences. They are mainly applied to STEM disciplines such as Science, Mathematics, Engineering, and Medicine. This qualitative study aims to examine the integration of VR and AR in an undergraduate Furniture Design course while understanding its impact on the learning experience, the design process, and active learning methodologies. Sixteen junior-level interior design students at the American University in Dubai, UAE developed a piece of furniture project and 3D printed prototype. Following research, some included VR and AR-based approaches, while others adopted typical methods. The faculty member assessed the study through a comprehensive analysis of process and outcomes, comparative evaluations, observations, interviews, literature review, and a survey. The findings indicate that the integration of advanced technologies benefits the design process. Key elements are real-time and real-based design visualizations, user experience for fast customization, human-scale projects for a better understanding of proportions and ergonomics, and the transformation of the learning experiences by creating immersive, interactive, and engaging learning environments. Moreover, VR and AR-based learning activities facilitate collaborative work and active learning; they promote creativity, and technical skills. The limitations involve technological advancements, accessibility to training, equipment, and financial issues. In conclusion, applying VR and AR in the design process supports the design itself and future designers' abilities. A balanced adoption of these technologies in Academia leads to pioneering teaching practices linked to industry requirements.

Keywords: Virtual Reality, Augmented Reality, Furniture Design, Immersive Learning, Transformative Design

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Introduction

Innovative technologies involving daily life and workplace activities continue to emerge. Their application encompasses fields such as STEM disciplines, biology, the medical sector, and engineering. Virtual Reality (VR) is the 3D simulation of environments or elements interacting with the individual through dedicated equipment. It creates a virtual environment for an immersive experience. Augmented Reality (AR) allows the interaction of computer-generated 3D virtual elements with the real world through applications, software, and dedicated equipment; it may include additional sensorial components linked to touch, hearing, and smell senses. The same technologies are applied to various fields, including Design.

Background & Context

1. Design Process Phases

Design is an extremely dynamic area where creativity and technical advancements work together to benefit the entire sector. Many technological tools have been developed and implemented in recent years. From the wide revolution of computer-generated tridimensional visualizations and the introduction of two-dimensional drawing software such as CAD and similar, we are currently experiencing an innovative, impactful transformation by introducing VR and AR in Design, involving all the phases of the design process.

According to Voinea and Opincariou: the creative process does not exclude information of knowledge. It implies a strong relation between critical and creative thinking (Voinea, Opincariou, 2020).

Traditionally, the phases of the interior design process in practice include:

- Assessment and Research
- Preliminary Design & Schematic Planning
- Conceptual Design
- Design Development
- Working Drawings & Specifications
- Site Supervision (optional)

In detail, **Assessment and Research** include a brief with the client, brainstorming, consultation, study of the client's needs, expectations, and requirements, initial program as a result of the activities of research, organization and solution options, initial sketches and perspectives, proposal, and programming.

Preliminary Design & Schematic Planning involve preliminary drawings showing schematic planning, progressively including the client's comments, if any. This phase comprises studying and understanding space, as well as its characteristics and critical elements. It includes the evaluation of the layout according to the location and its requirements, considerations about window orientation and relation to light, overall view, potential noise issues, elements to modify, and finally, space planning.

Conceptual Design represents the passage from idea to realization. Based on approved schematic plans and the client's comments, the designer finalizes the conceptual floor plans and related drawings along with the Mood Board and initial material selection and Material

Board. Consequently, the design is refined and detailed, with the elaboration of schedules, the selection of Finishes, Furniture & Equipment (FF&E), and the budget completion.

During **Design Development**, the designer progressively incorporates the mechanical, electrical, and technical requirements submitted by other consultants and coordinates their impact on the interior design. The designer analyzes and suggests sources for finishes, materials, and features, develops design details, and finalizes the choices with the client. Elevation and section drawings are provided along with visuals, additional plans, and drawings, and detailing.

Working Drawings & Specifications: this detailed documentation phase includes drawings, details, schedules, and specifications and constitutes the basis for the tendering process with Interior contractors, Fit-Out Firms, and suppliers. It usually includes reviewing all the shop drawings.

Site Supervision may be part of the designer's scope of work, intended as a periodic review of construction work progress on site with an assessment of their compliance with the design intention.

In terms of Furniture Design, the phases of the interior design process in practice include:

- Assessment and Research
- Preliminary Design & Schematic Planning
- Conceptual Design
- Design Development
- Working Drawings & Prototyping
- Testing and Final Production

The relevance of sketching during the process is crucial. It is a tool for understanding proportions, shapes, forms, and details. Tridimensional visualizations support the conceptual phase, which involves sketching and elevating the project to realistic and accurate concepts for the client and general audience.

2. VR and AR in Furniture Design

Cumulative evidence suggests that VR is a viable and worthwhile technology for application in the FFE sector that can drastically improve the efficiency of this sector by enhancing design communication and collaboration (Prabhakaran, Mahamadu, Mahdjoubi, Booth, & Aigbavboa, 2023).

VR technology promotes access to simulative visualizations and creates an immersive experience applicable to creative solutions and projects. It is increasingly used in design architecture and related disciplines. It supports the design process for both the designer and the client. Furniture design represents a successful example of the application of these innovative technologies. It allows easy personalization and modification. Several brands also employ interactive 3D visualizations to facilitate e-commerce. The development of VR technologies also supports improving products and furniture and identifying customer trends.

3D VR facilitates visual evaluations and creates virtual experiences by simulating realistic consumption experiences (Oh, Yoon, & Hawley, 2004).

Besides its affordability, other advantages of non-immersive desktop VR include rapid software development, efficient information sharing, collaboration through the Internet, and ease of use. The same software techniques are used for both immersive and non-immersive systems (Oh, Yoon, & Hawley, 2004).

3. The Learning Experience and the Use of Innovative Technologies

Although the topic is still relatively new, several studies reflect on using VR and other mixed methods in higher education and their impact on the Learning Experience. Their introduction to the educational system generates the definition of innovative educational methods and pioneering experiences. It is still a field in evolution, and the future will bring more knowledge and outcomes. The transformation is evolving; from an academic point of view, it creates new opportunities to explore innovative methodologies, opening a new educational scene.

The educational landscape has witnessed a significant shift with the introduction of VR, which has redefined the concept of immersive learning. AR, complementing VR, overlays digital information onto the real world, enriching traditional education materials (Familoni & Onyebuchi, 2024).

In terms of emotions, usually, students demonstrate mixed feelings of excitement and intimidation. A well-structured learning experience can support their comfort. According to the study *Education in the Digital Age: Learning Experience in Virtual and Mixed Realities* on the VR impact on the learning experience, the findings suggest an emotional benefit of learning with VR use (Allcoat, Hatchard, Azmat, Stansfield, Watson, & von Mühlennen, 2021).

In summary, AR and VR have emerged as powerful tools in education, offering immersive and interactive learning experiences that can significantly enhance educational outcomes (Familoni & Onyebuchi, 2024).

Purpose of the Study

This qualitative study examines the integration of VR and AR in an undergraduate Furniture Design studio course in the Interior Design Department at the American University in Dubai (AUD) in the United Arab Emirates (UAE). The research focuses on evaluating the impact of these innovative technologies on the Learning Experience, the design process, and the definition of active learning methodologies.

The class participating in the study was composed of sixteen Junior level Interior Design students who developed the study's project subject as an assignment of the course. After obtaining the brief and its explanation, all students approached the project and its design. The initial stages of Assessment & Research facilitated an understanding of the main theme, including issues and potential strategies. Preliminary & Schematic Design consisted of sketches, evaluation of the shape, form, and proportion with the application of standards, and the preliminary material selection and revisions. At this point, a few students decided to handle the project with VR and AR integration in their studies, aiming to complete the succeeding tasks, while others utilized traditional methods. The faculty in charge supervised the project. It included all phases, technical drawings, work progress and critical thinking demonstration, research and analysis, tridimensional visuals, and a model/prototype.

Method

As mentioned, the studio students developed the project following the design process phases for furniture design. In consideration that it was the first time applying these innovative technologies to the course's project, it is interesting to observe the proportion of students choosing the integrated innovative technologies and the ones deciding on typical methods:

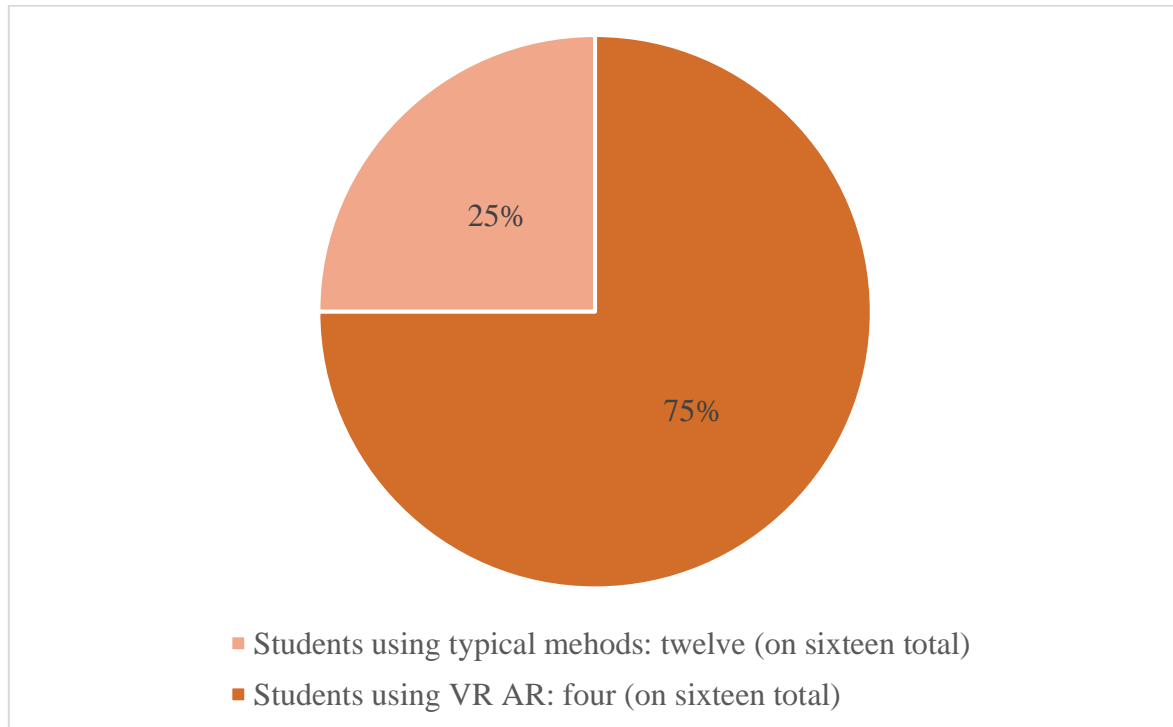


Figure 1: Proportion Selection of VR and AR During the Design Process

The above chart highlights the commitment to test innovative technologies in a design project compared to typical methods: 25% (one quarter) of the class decided to utilize them, and 75% (three quarters) felt more comfortable with traditional methods. This is due to several reasons:

- The consideration of risk for using this not yet fully familiar method while academic assessment is applied.
- Students' concerns about technical management.
- An overall sense of intimidation generated by the potential use of these still recent technologies.

As far as students were fascinated and very interested in the practice, considering that they had already been exposed to VR and AR training, they still felt uncertain about their capacity to manage these technologies for an effective outcome in the specific topic. More practice and integration in assignments and courses will lead to greater confidence, including less anxiety about their application. Again, this activity was introduced as an option for the first time on the Furniture Design topic; the same had an extremely large use in the following session.

Design Process Phases

Following the introduction of the furniture design project linked to an already developed plan and environment, the class began researching Anthropometrical Considerations and Human factors and ergonomics related to Furniture Design.

Students created a furniture Design project inspired by a famous potential client. The assignment was intended to design an innovative sitting element following the principles of anthropometry study and ergonomics.

Requirements of the exercise involved:

- To include a minimum of two varied materials.
- To include sustainable initiatives.
- To include anthropometrical considerations and ergonomics for furniture design and the built environment.
- To include innovative solutions and optional flexibility of uses as opportunities to modify the configuration.

In detail, deliverables included:

- **Assessment and Research:** analysis and research on the main topic with references, including documentation or graphics supporting the design and design decisions.
- **Preliminary & Schematic Design:** Initial Design progress and sketches demonstrating the progress of work and critical thinking in investigating optimal design solutions.
- **Conceptual Design:** “*THE STORY.*” Design Concept Statement, reference images (Mood Board with minimum two materials), project name, and logo. Statement on sustainability and how it has been implemented in the project. Three written objectives the design should achieve (Keywords #).
- **Design Development:** Design and detailed drawings along with 3D visualization. Students decided to follow traditional methods or to integrate innovative technologies (as in the Schematic phase) for the elaboration of the project in terms of forms and space, along with proportions and ergonomics.
- **Working Drawing and Model/Prototype,** again with VR and AR integration options. Some students decided to print their model or prototype in 3D.
- **A Final digital video** expressing all the points mentioned and explaining the project.

An international Jury composed of Professionals evaluated the outcomes.

The faculty member analyzed the study through a comprehensive review of process and results, comparative assessments, observations, interviews, literature review, and a survey.

Case Study – Findings & Discussion

Case Study: students chose the client, the international artist Banksy, for the project, which is inspired-related sitting furniture. The artist has been analyzed and researched; a few reference images have been selected to compose an inspirational Mood Board: a physical or digital board expressing the project concept through colors, reference images, materials, and sketches.

After examining the most relevant aspects of the artist, his art, and its characteristics, students felt ready to translate the acknowledged concept through the design of a chair.

The main inspiration was the spray-painting technique used by the artist, which generates organic and free shapes. Students proceeded to identify design goals and sustainable initiatives included in the project. The initial material section was performed.

Design Goals:

- Flexibility of use
- Inspiration from *Graffiti Art*
- Lightness
- Sustainable

Sustainable materials included algae-based rigid PU foam designed with biotechnology, upcycling fabric made from PET bottles, stainless steel rods, and a lightweight extruded profile.

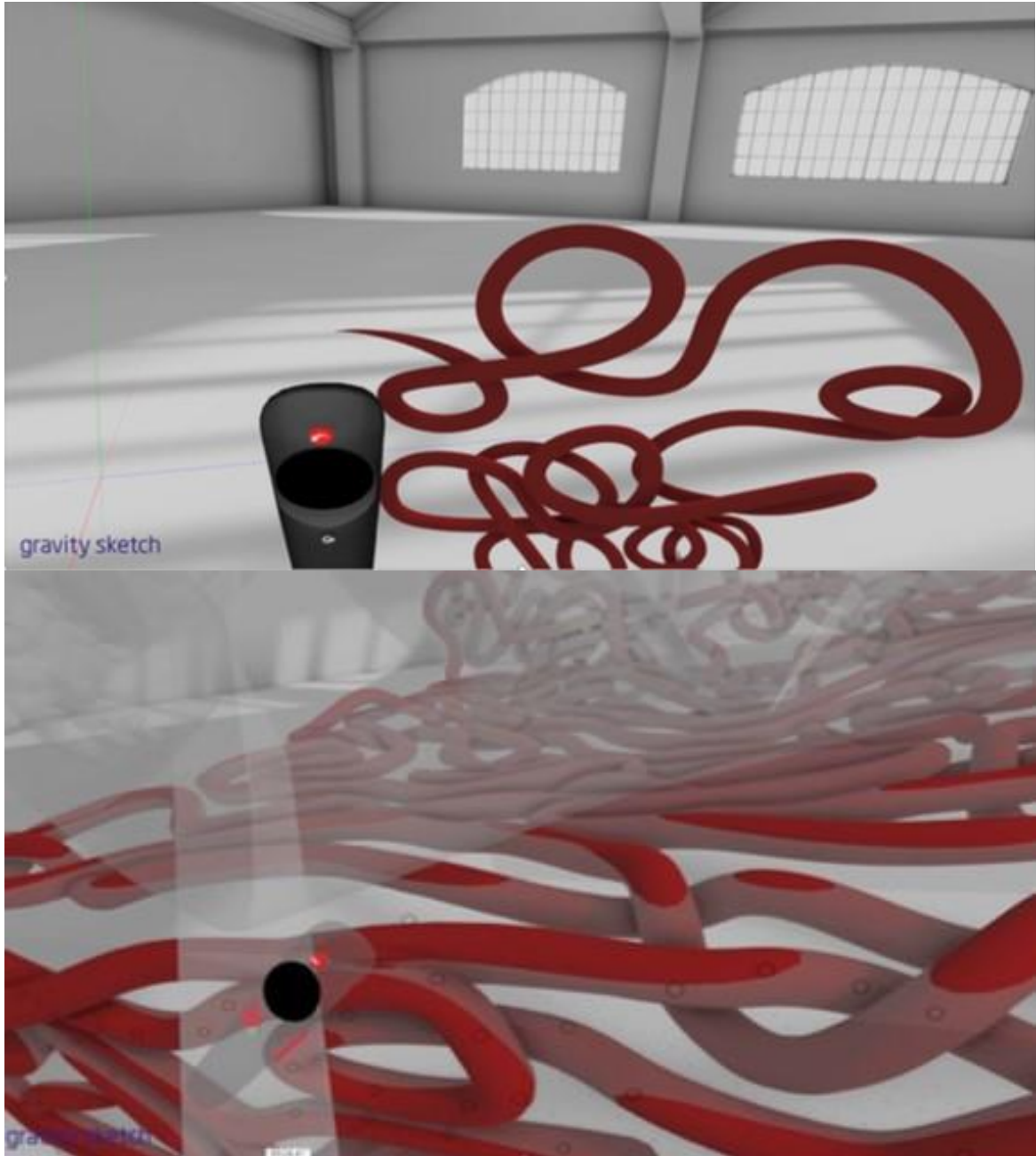
Free-hand sketches on paper supported the study of shape, form, and proportions. These preliminary sketches were then advanced using VR Gravity Sketch software. With dedicated equipment (headset and hand device), students could virtually “enter” the environment and virtually manipulate the design on a 1:1 scale, a real scale. This exercise made the object more visible, understandable, and easy to modify and perceive.



Figure 2: *Bankseat*

Credits: Project by Dalin Abubaker & Mallika Takiar. Mentor Prof. A. Lambri.

The first step was to outline the actual chair where the student was sitting in real life directly in the virtual environment. This stage supported a better comprehension of standards, dimensions, and ergonomics. The outlined shape was developed directly in VR at a tridimensional level, understanding volumes, details, flexibility, and potential general and structural issues.



Figures 3 & 4: *Bankseat* – Progress of Work, Screenshots
Credits: Project by Dalin Abubaker & Mallika Takiar. Mentor Prof. A. Lambri.



Figures 5 & 6: Bankseat – Progress of Work

Credits: Project by Dalin Abubaker & Mallika Takiar. Mentor Prof. A. Lambri.
 Images courtesy Dr. Kachaamy, Director of CRID.

According to students, the process was also enjoyable, comparable to a ‘molding by hand’ operation. The texture and single details were easier to explore than a typical method since it allowed the investigation and better comprehension of the overall object. The 3D objects were then translated to 2D as a consequence.

Typical method: 2D > 3D

VR method: 3D > 2D



Figure 7: *Bankseat* – 3D Visuals

Credits: Project by Dalin Abubaker & Mallika Takiar. Mentor Prof. A. Lambri.

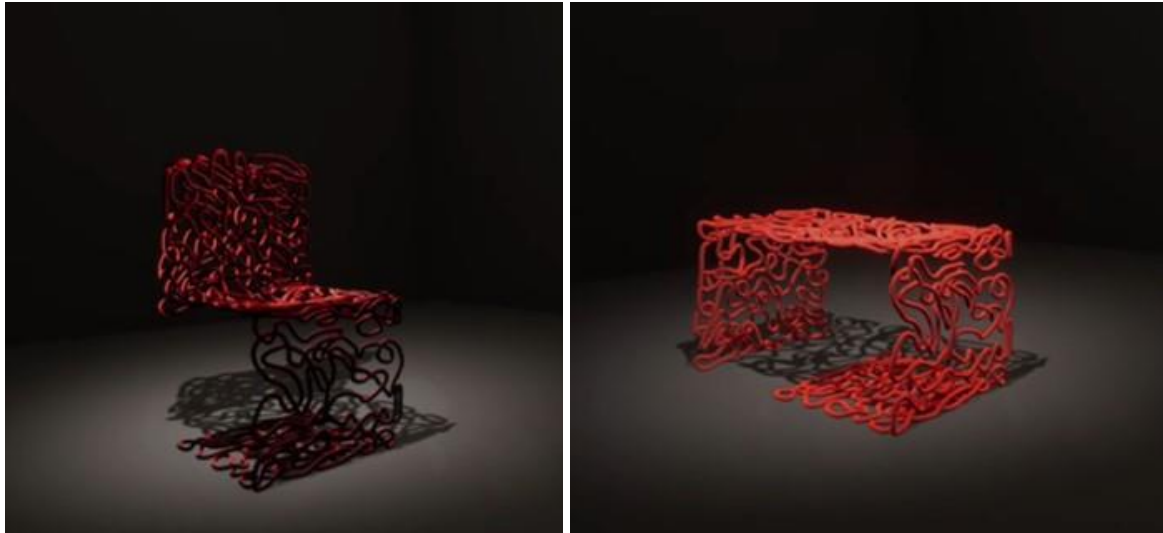


Figure 8 & 9: *Bankseat* – 3D Visuals

Credits: Project by Dalin Abubaker & Mallika Takiar. Mentor Prof. A. Lambri.

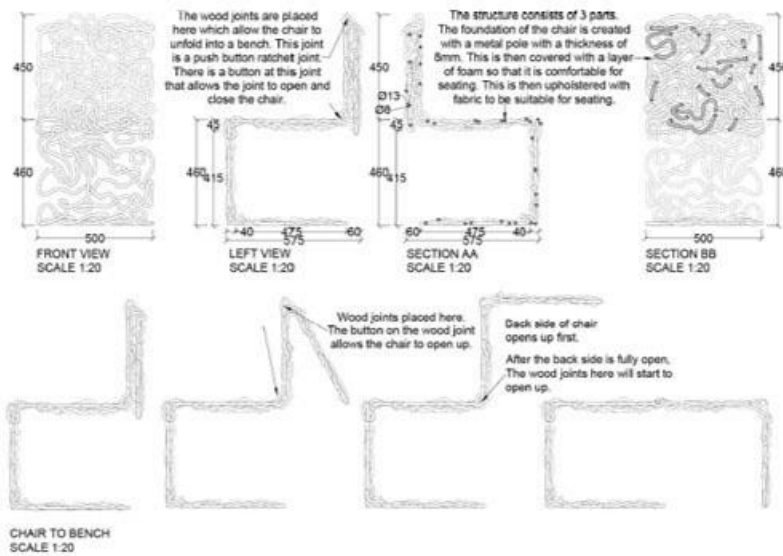
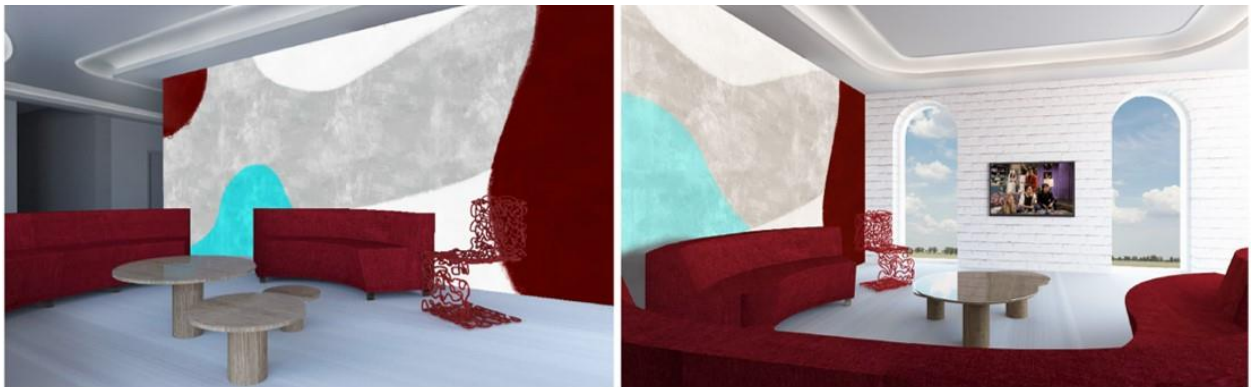


Figure 10: *Bankseat* – 2D Drawings

Credits: Project by Dalin Abubaker & Mallika Takiar. Mentor Prof. A. Lambri.



Figures 11 & 12: *Bankseat* – Visuals of the Furniture in the Environment
Credits: Project by Dalin Abubaker & Mallika Takiar. Mentor Prof. A. Lambri.

The immersive experience facilitated the identification not only of benefits but also of issues or potential ones. Working on human-scale projects simplified the understanding of proportions and ergonomics. In this case, the chair could also be used as a bench seat through flexible settings (openable double-sided backseat); this flexible component has been easily explored through VR to better comprehend its characteristics and details.

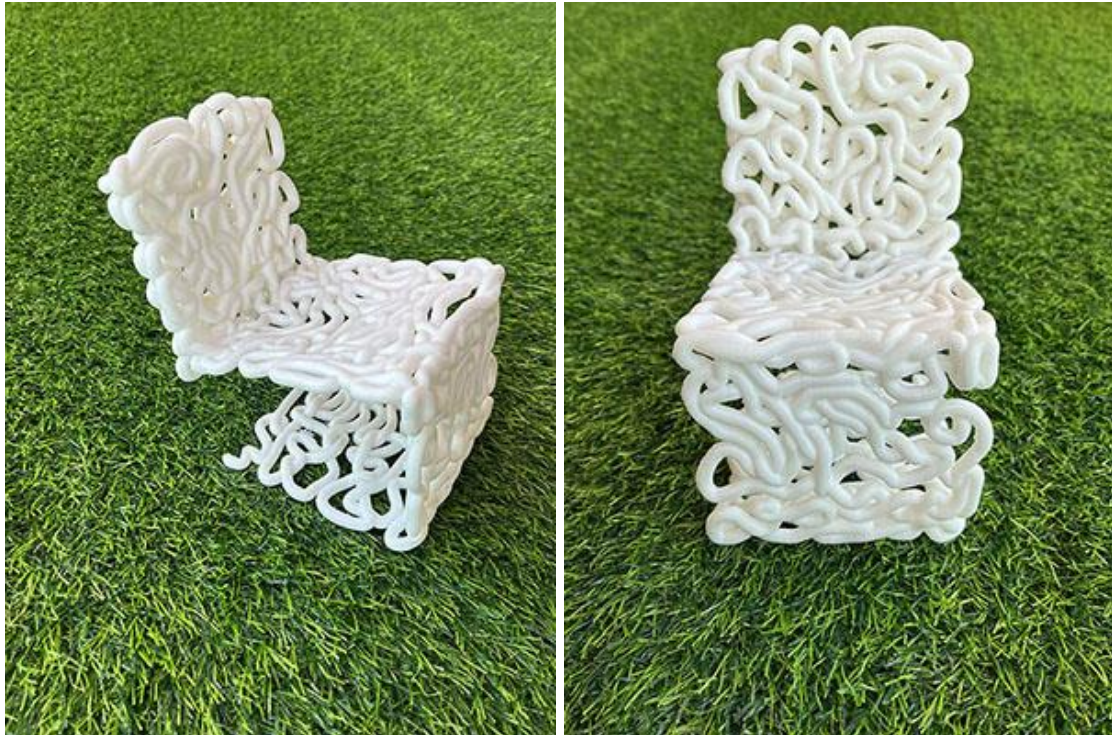
In terms of adjustments, the software allows immediate modification and adjustments to proportions for real-time and real-based design visualizations. In VR, users can quickly customize the project. It also supports collaborative work.

AR was then integrated into the project, locating the object in the real environment on a real scale proportion. Finally, a model/prototype was created using the 3D printing technique.



Figures 13 & 14: *Bankseat* – AR Simulation Images

Credits: Project by Dalin Abubaker & Mallika Takiar. Mentor Prof. A. Lambri.



Figures 15 & 16: *Bankseat* – Model images

Credits: Project by Dalin Abubaker & Mallika Takiar. Mentor Prof. A. Lambri.

Overall, the integration of VR and AR in the design process in a Furniture Design project:

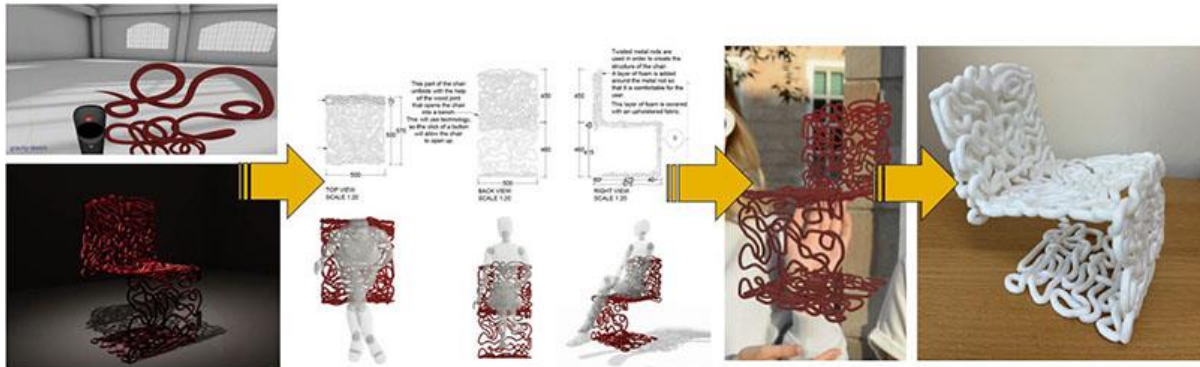
- Promotes creativity and exploration
- Supports freedom in Design
- It is enjoyable (game-related)
- Supports Active Learning
- Improves technical skills
- Supports the identification of proportions, spaces, shapes, and functions in a simulated real space
- Improves communication
- Facilitates the execution of complex shapes and forms
- Facilitates the execution of CAD drawings
- Facilitates the production of 3D visuals, including materials and their suitability
- Facilitates the production of a model or prototype: 3D printed with VR
- It is user-friendly
- The integration of AR generates a proper simulation in space

From the faculty's point of view, the method allowed easier interaction with the student, even in a “virtual world,” and the advantage of simultaneously expressing and transferring critiques/concerns on the project. On the other hand, users must be trained to use these technologies, tools, and dedicated software.

The study describes the effective transformation of the Learning Experience in an immersive, interactive, and engaging Learning Environment.

Furthermore, it must be considered that rapid technological advancement requires continuous updates. The use of the software needs training and equipment supported by investments.

Design Process



Sketches in VR, Visuals 3D>Drawings 2D > AR > Model/Prototype

Figure 17: *Bankseat* – Design Process

Credits: Project by Dalin Abubaker & Mallika Takiar. Mentor Prof. A. Lambri.

Table 1: Comparison Chart Highlighting the Similarities and Differences Between Approaches

Methods	Traditional	Integration of VR and AR	Notes
<i>Phase:</i> Assessment and Research	<ul style="list-style-type: none"> · Analysis and research on the with references, including documentation supporting the design decisions. · Identification of client's needs. 	<ul style="list-style-type: none"> · Same. 	
<i>Phase:</i> Preliminary & Schematic Design	<ul style="list-style-type: none"> · Initial Design Progress. · Free-hand sketches demonstrating design intent. · Developing critical thinking in the investigation of optimal design solutions. 	<ul style="list-style-type: none"> · Same. · Free-hand sketches demonstrating design intent. Parallel use of VR or other tools to sketch in real proportions. · Developing critical thinking in the investigation of optimal design solutions. 	<p>*VR: Better realization proportions/ergonomics. It is like "molding" with hands. IMMERSIVE EXPERIENCE.</p>
<i>Phase:</i> Conceptual Design: "THE STORY"	<ul style="list-style-type: none"> · Design Concept and Statement. Objectives. · Mood Board composition. · Statement on sustainability. · Furniture Design: shape, form, ergonomics, proportions. Details and materials. · Use of AutoCAD or similar. · 3D visualizations: 3D max, SketchUp, similar. · Required practice on software. 	<ul style="list-style-type: none"> · Same. · Mood Board may be integrated with AI. · Same. · VR to sketch/design in real proportions. · VR and AI require practice. 	<p>*VR/AR: easier adjustments and issue identification, work in real scale, better understanding ergonomics, standards, and proportions. Facilitated understanding for the client: simulation and immersive experiences generate additional engagement. Facilitating collaboration. Overall, it supports creativity. *Note: Equipment to be available; investment in equipment and training. The use requires practice.</p>
<i>Phase:</i> Working Drawing	AutoCAD or similar: it requires practice on software.	Same.	
<i>Phase:</i> Model/Prototype	Several methods for Model: manual, Laser Cutter, 3D print.	Several suitable methods: 3D print supported by VR.	

Conclusions

The study emphasizes the potential of these innovative technologies and tools at the service of design. Students demonstrated to be responsive, facilitating the instructor's revision process.

In terms of methodologies, the field allows exploration to define effective and innovative active learning activities.

VR and AR promote clients' engagement thanks to a straightforward perception of the project and an increased sense of involvement. It allows a better understanding of the design and makes it easier to modify it for real personalization. This aspect helps to save time in the process. Still, the human management of these technologies is extremely important.

In conclusion, utilizing VR and AR in the design process supports the design and designers. A balanced adoption of these technologies in Academia leads to pioneering teaching practices linked to the industry needs.

Much is yet to be done to investigate and examine the use of these innovative technologies in both the design and academic fields. Interestingly, the two components collaborate to benefit the overall knowledge and the profession. Many more disciplines will utilize these technologies with different approaches, opening exciting future directions in many fields.

Quote From the Student:

Regarding the final semester project, we had to get inspiration from a famous client and design a furniture piece for them. Since my client was Banksy, I wanted to create a flexible chair that was very organic and complex. I started coming up with ideas on how to apply that vision into a workable design, and I decided to make it out of one upholstered metal piece that keeps intertwining to take the shape of the chair, mimicking a spray-painting stroke.

Imagining and sketching the idea was all fun and nice until I had to model the chair; that's when I had to decide which software to use and what would make the model look as close to my vision as possible, and that's when I realized, modeling it on VR would accomplish all that. I put the headset on and started exploring all the tools I could use until I found what I needed. The process was so much fun because I could use my hands to draw the shape instead of relying on a mouse and a 2D screen. I could also model it in real-life proportions, meaning I could trace over the chair I was sitting on to get a clearer idea of the size. In addition to all that, it was easy to select any shape I made and edit all the vertices, ensuring that the lines do not intersect and that they make a flat surface that's comfortable to sit on.

After being satisfied with the model, I exported it to my computer and added it to the house I needed. It was a little bit of a challenge to figure out which file type I needed and how to modify it to show its flexibility, but through trial and error, I made it all work. This project was the start of using VR to enhance the quality of my projects and create custom shapes that I envision, which made using it for other projects easier and faster than dealing with the limitations of a 2D screen and using the 3D warehouse online.

(Dalin Abubaker, AUD Interior Design student)



Figure 18: Prof. A. Lambri

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Case Study: *Bankseat.*

Credits: Project by Dalin Abubaker & Mallika Takiar.

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