Construction Education through Virtual Reality: A Game-based Approach for Interior Architecture Students

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Abstract: This study investigates a novel method of instructing interior architecture students on building specifics pertaining to walls by utilizing the combination of virtual reality (VR) and game-based learning. The creation and application of a virtual reality game called "VR ConstructED," which aims to improve knowledge of wall construction methods, materials, and design consequences, is the study's focus. This project intends to improve students' understanding of wall-related construction elements and their applicability in real-world circumstances by utilizing the immersive and interactive properties of virtual reality technology in conjunction with gamification methods. Through a case study involving academic staff and students at Bahçeşehir University, the efficacy of this pedagogical strategy will be assessed. Using a mixed-methods approach, the study collects quantitative data from surveys and qualitative data from semi-structured interviews. These questionnaires will evaluate the academic performance, contentment, and VR game participation of the students. The main goal is to clarify the advantages and difficulties of using virtual VR to teach construction features, such walls, so that curriculum designers and teachers may make informed decisions. Additionally, by illustrating how gamification and the integration of VR technology may greatly improve student engagement and academic achievement, this study hopes to contribute to the larger area of design education. The results of this study are anticipated to add to the body of knowledge in architectural education and stimulate more research into specific VR applications for design pedagogy.

Keywords: Virtual Reality (VR) Education, Game-Based Learning, Construction Details, Interior Architecture, Wall Construction Techniques

Hypothesis: Utilizing virtual reality technology to create a design education game-based approach in interior architecture, will enhance students' learning experiences, increase engagement, and improve knowledge memory in construction education, particularly wall construction, compared to traditional design education methods.

Research Questions:

- How does Virtual Reality enhance understanding of wall construction techniques among interior architecture students compared to traditional teaching methods?
- What are the key factors in designing a VR game that effectively teaches wall materials, properties, and application methods?
- How do students perceive the use of VR in learning about wall construction details, and what impact does it have on their engagement and motivation?
- What challenges and barriers do educators face when integrating VR game-based learning into the interior architecture curriculum, specifically for teaching about construction?

Motivation: The idea to use walls as the main focal point of the Virtual Reality (VR) educational game was informed by the importance of walls in both interior and architectural design. Walls are among the first ideas taught in architecture and design schools since they are essential structural elements and have a significant impact on a building's usability and beauty.

There is significant educational benefit to concentrating on walls. Because walls are intricate constructions involving many different materials, techniques, and codes, they are a perfect topic for academic investigation. For instructing students on load-bearing capacities, insulating qualities, acoustics, moisture control, and much more, they offer a comprehensive context. Walls are a broad field of study because of the important theoretical and practical ramifications of each of these elements. Additionally, walls offer multidisciplinary learning opportunities since they touch on a variety of architectural and construction-related fields, such as environmental studies, structural engineering, and materials science. This multidisciplinary method supports a comprehensive educational experience and fits in nicely with VR's immersive qualities, which allow various disparate subject areas to be smoothly integrated.

Furthermore, a VR platform can be an efficient way to handle the actual difficulties involved in wall construction and design, such as choosing materials suitable for a given climate or guaranteeing adherence to building requirements. This helps students practice and learn from errors without facing real-world scenarios, which improves their ability to solve problems and make decisions.

VR education about walls takes advantage of the physical and visual qualities of these building components. Compared to typical 2D drawings or passive lectures, virtual reality offers a hands-on learning experience that can be more engaging and memorable. It promotes a deeper knowledge of wall assemblies' construction and design implications by enabling students to see and manipulate wall assemblies in a three-dimensional space.

Although interior architecture involves many other building features, the emphasis on walls was chosen because of their basic significance and potential for education. This doctoral thesis is the first of a planned series of studies. If it is effective, more construction elements will be added to future games, broadening the breadth of instruction, and utilizing virtual reality technology even further to improve architectural education. This methodical approach to expansion enables a comprehensive investigation of every aspect of construction, guaranteeing a strong basis of understanding and proficiency prior to delving into more intricate subjects.

1. Introduction

Virtual reality and game-based learning are emerging as revolutionary technologies in the rapidly changing field of architectural education, having the potential to completely upend conventional pedagogical approaches. Through immersive and interactive virtual settings, VR offers students a unique opportunity to engage closely with building details and explore architectural spaces in three dimensions, so enabling experiential learning. Through this immersive interaction, students are better able to bridge the gap between theoretical knowledge and practical application by comprehending complicated spatial relationships and design principles.

By including challenges, rewards, and interactive tasks in the learning process, the incorporation of game-based learning principles also improves student motivation and engagement. This method facilitates the practical application of theoretical information in a controlled yet dynamic environment by encouraging active engagement and problem-solving. As active players or designers in these virtual environments, students take on decision-making responsibilities that directly affect their learning outcomes, which increases their level of engagement with the learning process.

Even with these improvements, there are still many obstacles in the way of modern design education. Conventional techniques frequently make use of two-dimensional or static graphics, which fall short of accurately capturing the intricacies of architectural elements and spatial relationships. This restriction makes it more difficult for students to successfully convert conceptual concepts into real-world construction projects. To address these shortcomings and improve design education, there is thus a pressing need for cutting-edge teaching resources that make use of virtual reality and game-based learning.

Although interior architecture involves numerous building features, walls are the emphasis because they play a crucial role in defining the boundaries of space, both physically and aesthetically. In addition to being essential structural components, walls play a major role in establishing the usefulness and personality of architectural spaces. This thesis investigates the educational potential of virtual reality in strengthening understanding of wall building specifics. It is the first of a planned series of investigations by the researcher. If this initial focus proves to be successful, it is expected to serve as a springboard for further research into other construction elements, ultimately leading to the creation of a VR game series covering the whole gamut of architectural construction education.

2. Literature Review

2.1 Historical Background of Architecture and Interior Architecture Education

The education of architects originated in ancient times, although it did not take the form of formalized schools. In ancient Greece and Rome, individuals acquired knowledge of architecture through apprenticeships and practical involvement, supplemented by the study of geometry and technical principles. Vitruvius, a prominent Roman architect of the 1st century BCE, wrote "De Architectura," a seminal work that served as a cornerstone for architectural education for many years (Vitruvius 15 BCE).

The Renaissance era was characterized by a significant shift in the resurgence of classical architecture and the rise of notable figures like Leon Battista Alberti, who authored "De Re Aedificatoria" during the mid-15th century. Alberti's work, influenced by Vitruvius, established essential principles of architecture, and served as an instructional resource in the emerging architectural academies of Italy and other regions (Alberti 1452).

The establishment of the Académie Royale d'Architecture in Paris in 1671, under the patronage of Jean-Baptiste Colbert during the reign of King Louis XIV, marked a notable advancement in formal architectural education. The establishment mentioned here was the inaugural educational institution solely focused on architecture. It introduced a structured program encompassing theoretical lectures, drawing instruction, and the examination of mathematical and scientific principles in relation to construction (Blondel 1675).

Walter Gropius established the Bauhaus in Germany in 1919, which brought about a groundbreaking method of teaching design that combined aesthetics and practicality with the concepts of large-scale manufacturing. The Bauhaus curriculum integrated crafts and fine arts, prioritizing practical workshops above academic lectures. This approach had a significant impact on both architecture and the emerging field of interior design (Gropius 1919).

Architecture and interior architecture education had significant global expansion throughout the 20th century. In 1927, the Carnegie Institute of Technology in the United States established one of the earliest interior design programs, indicating an increasing acknowledgment of interior design as a separate professional subject from architecture (Abercrombie 1990).

The formation of professional organizations such as the American Institute of Architects (AIA, established in 1857) and the American Society of Interior Designers (ASID, established in 1975) played crucial roles in establishing educational standards and professional practices for both industries (Pile 2003).

Contemporary architectural and interior architecture education frequently incorporates cutting-edge technology, such as computer-aided design (CAD) and virtual reality (VR), to demonstrate the professions' embrace of digital advancements. Contemporary educational programs prioritize sustainability, ethical principles, and the social dimensions of design, to address worldwide difficulties and changes in societal requirements (Kostof 1985).

2.2 Historical Background of Construction Education

The inclusion of construction education has always been an essential component of architectural instruction, dating back to the skilled craftsmen of ancient civilizations such as Egypt, Greece, and Rome. In those times, the transmission of knowledge regarding construction processes relied on apprenticeships rather than formal schooling. Architects were required to possess an extensive understanding of both design and the pragmatic elements of building construction.

In the Renaissance period, the education of architecture started to become more structured, focusing on the theoretical elements of building, such as construction. Architects such as Leon Battista Alberti and Andrea Palladio authored treatises that encompassed comprehensive examinations of construction methods as an integral component of their extensive architectural education. These works frequently drew concepts from classical architecture and played a crucial role in instructing the connections between architectural design and structural soundness.

The inception of the Académie Royale d'Architecture in Paris in 1671 signified the commencement of a more structured type of architectural education, which therefore encompassed education in construction. However, it was in the 18th and 19th centuries, with the emergence of polytechnic schools in Europe, that construction education started to adopt a more organized framework. Institutions such as the École Polytechnique in France and the Bauakademie in Berlin included sophisticated mathematical and scientific concepts into their educational programs, instructing aspiring architects on the technical aspects of constructing structures.

The advent of the Industrial Revolution had a profound impact on construction education since the introduction of novel materials such as steel and concrete revolutionized the realm of architectural possibilities. To ensure that architects and designers have a comprehensive understanding of these materials, changes were made to the curriculum to incorporate courses in engineering and material sciences. The integration process was further assisted by the founding of engineering schools and technical institutions in the 19th century.

In the 20th century, there were significant changes in the way architecture and building were taught, leading to various philosophical shifts. The Bauhaus movement exemplified the fusion of craftsmanship, artistic expression, and technological innovation. It provided students with comprehensive education on both the practical elements of construction and the principles of design. Following World War II, the emergence of modernism placed a strong emphasis on practicality. This resulted in a curriculum that not only focused on aesthetic design, but also on efficient construction methods and the practical use of contemporary materials.

Presently, the field of construction education in architecture and interior design is significantly impacted by digital technology. Programs include instruction in software such as CAD (Computer-Aided Design), BIM (Building Information Modeling), and now VR (Virtual Reality), which provide intricate simulations of construction procedures. Contemporary educational programs prioritize sustainable construction methods, demonstrating an increasing recognition of environmental concerns in architectural training. Nowadays, universities and colleges frequently provide specialized courses on sustainable construction processes, energy-efficient design, and green building standards.

2.3 VR and Games in Architectural Education

According to Barab et al. (2001), traditional educational settings only expose students to the representational learning stage, which is equivalent to rote learning. According to Alkhalifa (2004), current learning methods are no longer an effective educational method because it places less emphasis on the learner's aptitude and on their creativity. According to Starkey (2011), the current method of teaching presents a challenge in terms of transforming theoretical education into inventive practice that is better suited to cultivating the new generation of individuals who were born in the digital age. According to Allcoat et al.'s research from 2021, virtual reality (VR) has introduced a hybrid experience that combines the real and digital worlds with its interactive methods.

Using "hands-on" and "interactive" teaching methods (Senthamarai 2018), additional benefits will be added to the process of perception (Hu-Au and Lee 2017). The primary advantage of interactive learning is that it encourages students to focus on learning activities and achieve the objectives set by instructors.

Advancements in technology have significantly impacted the field of architecture and design education, transforming the way students learn and interact with their environment. Traditional methods have given way to computer-aided design, virtual reality, augmented reality, 3D printing, and modeling applications, revolutionizing the design process. With the advent of technologies like 3D printers and visualization programs, students can create realistic models and immersive experiences, allowing for faster iterations and more complex designs. The shift to online platforms, exemplified during the Covid-19 pandemic, has further emphasized the potential of virtual online studios. Virtual Reality (VR) one of these technologies, has emerged as a vital tool in design education, offering immersive and interactive experiences for students.

2.4 Game-based Learning (GBL)

With the use of games' interactive elements, game-based learning (GBL) has become a popular and innovative method of teaching that encourages learning and participation. Digital game-based learning was first conceptualized formally by Prensky (2001), who proposed that educational games might improve learners' motivation and engagement in addition to making learning more fun. Constructivist learning theory, which holds that knowledge is constructed by learners by experiences and interactions with their surroundings, forms the theoretical foundation of GBL (Piaget 1976). Further investigation into the educational potential of GBL was conducted by Gee (2003), who noted that well-designed games may provide players a sense of agency, possibilities for problem-solving, and quick feedback, all of which are conducive to learning effectively. Gee's research established the groundwork for comprehending the learning concepts that video games may specifically promote.

2.5 Game-based Learning or Gamification?

Applying game design features and game ideas to non-gaming environments is known as gamification. This strategy offers competition or prizes for players who complete objectives to keep users interested. Point systems, leader boards, badges, awards, and other components are used in gamification to encourage and boost user participation in non-gaming activities. Gamification in the context of education might refer to enhancing standard tasks like quizzes with points or levels or using a badge system to incentivize students to turn in assignments on time. The important thing to note in this case is that while game components are used to boost motivation and engagement, the primary activity is not a game. On the other side, using games to accomplish learning objectives is known as "game-based learning" (GBL). The primary instrument for facilitating education in GBL is the game itself. This method makes use of games' natural ability to be participatory and interesting teaching tools for new ideas, skill development, and behaviour modification.

2.6 Educational Gaming

In recent years, educational gaming has emerged as a promising strategy for revolutionizing traditional teaching methods and enhancing learning experiences across all academic disciplines. Educational gaming provides an engaging and interactive platform that encourages active participation, critical thinking, and skill development by incorporating the principles of game design with educational objectives. In this case, it is possible to mention a method based on the constructivist approach, which asserts that experience is one of the most important methods in learning (Papert 1980). This element is also utilized in educational games. In an environment that adheres to the constructivist learning philosophy, the student will actively participate in the learning process. Earlier research (Chu and Chu 2010) indicates that perceived interaction is a crucial element in the formulation of a constructivist learning environment. Using "hands-on" and "interactive" teaching methods (Senthamarai, 2018), additional benefits will be added to the process of perception (Hu-Au and Lee 2017). The primary advantage of interactive learning is that it encourages students to focus on learning activities and achieve the objectives set by instructors.

2.7 Educational Gaming or Serious Games?

Constantly, the terms educational games and serious games are used interchangeably. In a broad sense, these definitions encompass games that are employed not just for entertainment, but also for the purposes of imparting knowledge and instructing. Educational games may be defined as the use of game technology for the goals of learning and teaching, with the inclusion of subject matter and the goal of achieving the desired educational outcomes for students (Ibrahim and Jaafar 2011). Act (1970), who introduced the notion of serial games to the literature for the first time, asserted that such games offer significant advantages due to risk-free active exploration. Achieving the objective, which is the primary objective of games, and rewarding the player for achieving this objective are also applicable to serious games. This circumstance is constrained by the game's rules. The characteristic that most differentiates the distinction between serious games and regular games comes into play at this stage. Whereas the primary objective of traditional games is to entertain the player, the primary objective of serious games is to educate the player. When doing so, entertainment and other considerations should be considered. There must be a balance between the user's attention, curiosity, and ability to learn.

Perhaps the most critical aspect in educational games is striking a balance between game elements and educational components. According to Brody (1993), the combination of education and gamification has led to games that are either not educational enough or not entertaining enough. To prevent this, it should be remembered that the primary focus in educational games is to teach the subject matter. Using digital technologies and interactive simulations, educational gaming creates immersive learning environments. Educational gaming's benefits reside in its capacity to promote engagement, motivation, and active learning. By integrating game mechanics such as challenges, rewards, and progression systems, educational games instill in learners a sense of accomplishment and motivation. The interactive nature of video games promotes exploration, experimentation, and collaboration, thereby enhancing comprehension and knowledge retention (Michael et. al 2006). In addition, educational gaming facilitates personalized learning by adapting to the requirements of each student and providing immediate feedback (Aldrich 2003). This approach to adaptive learning allows students to progress at their own pace, receive individualized instruction, and address their specific learning deficiencies.

Through an extensive review of the literature, it becomes evident that numerous studies have explored the integration of construction courses within the field of architecture. However, there appears to be a significant gap in the research when it comes to the specific domain of interior architecture. While construction plays a crucial role in shaping the built environment, it is essential to acknowledge the distinctiveness of interior architecture and the unique challenges it presents. Given the scarcity of studies focusing on construction courses within interior architecture programs, this research aims to address this gap and shed light on the specific educational needs and opportunities within this specialized field. By narrowing the scope to interior architecture, this study aims to contribute valuable insights and practical recommendations that are tailored to the context and requirements of this discipline.

3. Methodology

This study employs a comprehensive two-phase methodology aimed at systematically assessing the efficacy of the Virtual Reality game, "VR ConstructED," in instructing architectural construction elements, with a specific emphasis on walls. The methodology is designed to both develop an instructional tool and evaluate its influence

on the learning outcomes of interior architecture students. Every stage of the technique is carefully designed to target specific elements of the study objectives, guaranteeing a methodical approach to the creation and evaluation of the educational intervention.

3.1 Phase 1: VR Game Design and Development

The first stage of the process is on the creation and advancement of "VR ConstructED." The first stage of designing a VR game as a teaching aid is crucial, as its success depends on careful planning and ensuring that it aligns with educational ideas. The development process will integrate concepts from multimedia learning theory, constructivist learning principles, and experiential learning models to establish a dynamic and interactive learning environment. The VR titles will be created using Unreal Engine 5, a game engine, and will be compatible with major VR headsets such as Meta Quest Oculus and HTC Vive. A review of the literature on VR game development and pedagogical game design principles will precede the design and development of the VR game. This stage encompasses:

Designing the User Interface (UI): Developing a user-friendly and inclusive UI that enables effortless navigation and interaction within the virtual reality (VR) environment.

Content Development: Creating the teaching materials, such as 3D models, interactive components, and instructional text or audio, that will be utilized to educate students on wall construction procedures and materials.

Technical Implementation: Developing the required features of the game using an appropriate virtual reality (VR) development platform, ensuring that the game is compatible with widely used VR gear in educational environments.

During this phase, comments from potential users and subject matter experts will be included into the design process to enhance the educational efficacy and user involvement of the game.

3.2 Phase 2: VR Game Evaluation

The second stage of the process entails conducting an empirical evaluation of "VR ConstructED" to determine its influence on student learning and engagement. This stage is crucial for verifying the educational worth of the game and for pinpointing areas that require more improvement. The assessment will be carried out using a mixed-methods approach, which will offer both quantitative and qualitative insights into the success of the game:

Quantitative Assessment: Employing a pre-test/post-test strategy to objectively measure the learning results of pupils utilizing the virtual reality (VR) game. In addition, questionnaires will be conducted to assess students' level of involvement and contentment with the learning process.

Qualitative Assessment: Administering semi-structured interviews and conducting focus groups with participants to collect comprehensive feedback regarding their experiences, perceptions, and any discernible advantages or difficulties related to the utilization of the virtual reality game for educational purposes.

Participants of the study will be a sample of students studying interior architecture that will be split into two groups at random. The study will involve students enrolled in the Construction for Interior Architecture I (INT2051) course at Bahçeşehir University. Participants will be randomly assigned to either the experimental group (using the VR game) or the control group (receiving traditional methods).

The data gathered during this phase will be examined to ascertain the efficacy of "VR ConstructED" in enhancing students' comprehension of architectural construction specifics and to evaluate the overall usability and educational influence of the game.

Control Group: This group should use conventional teaching techniques like lectures, textbooks, and two-dimensional drawings.

Experimental Group: To guarantee a mixed learning strategy, the experimental group should employ the VR game in addition to conventional techniques.

Pre-Selection Survey: Before choosing participants for the virtual reality group, there will be a survey to ascertain their degree of comfort and familiarity with virtual reality and related technology. In this survey, there will be questions about frequency of use, perceived ease of use, and previous familiarity with VR devices. This pre-test

will be called "technological validity" survey. Candidates must have a rudimentary grasp of VR navigation and controls. The study will exclude anyone who find virtual reality extremely uncomfortable or difficult to use, as this could distort the game's educational efficacy findings.

4. Case Study: “VR ConstructED”

"VR ConstructED" is an immersive Virtual Reality game created exclusively for interior architecture students to enhance their education. The game's primary objective is to educate essential construction components, with a particular focus on walls. The game utilizes virtual reality technology to establish an interactive educational setting, enabling students to engage with digital models, replicate real-life situations, and implement theoretical understanding in a hands-on and captivating manner.

4.1 Game Structure and Levels

The game is structured into multiple levels, each designed to address different aspects of wall construction and design:

- **Level 1: Introduction to Wall Types**

Objective: Learn about various wall types (load bearing, partition, retaining walls) and their appropriate uses in architectural design.

Activities: Interactive tutorials that guide students through the identification and application of different wall types in virtual buildings.

- **Level 2: Materials and Properties**

Objective: Understand the materials used for wall construction (brick, concrete, wood, glass) and their properties (thermal insulation, soundproofing, fire resistance).

Activities: Virtual labs where students can experiment with different materials to see how they affect the overall structure and performance of walls.

- **Level 3: Construction Techniques**

Objective: Master the step-by-step processes involved in constructing walls, including framing, insulation, and finishing techniques.

Activities: Simulated construction projects where students must choose the correct techniques and tools to build walls according to specific design requirements.

4.2 Educational Instruments and Tools

"VR ConstructED" incorporates a variety of educational tools and instruments designed to facilitate learning:

Interactive 3D Models: Detailed models of walls and construction components that students can manipulate and explore within the VR environment.

Simulation Tools: Tools that simulate real-world physics and material properties, allowing students to see the practical impacts of their design choices.

Guided Tutorials: Step-by-step instructions embedded within the game to help students learn processes and techniques as they play.

Assessment Tools: Built-in quizzes and review sections that provide immediate feedback on students' knowledge and application skills, reinforcing learning objectives.

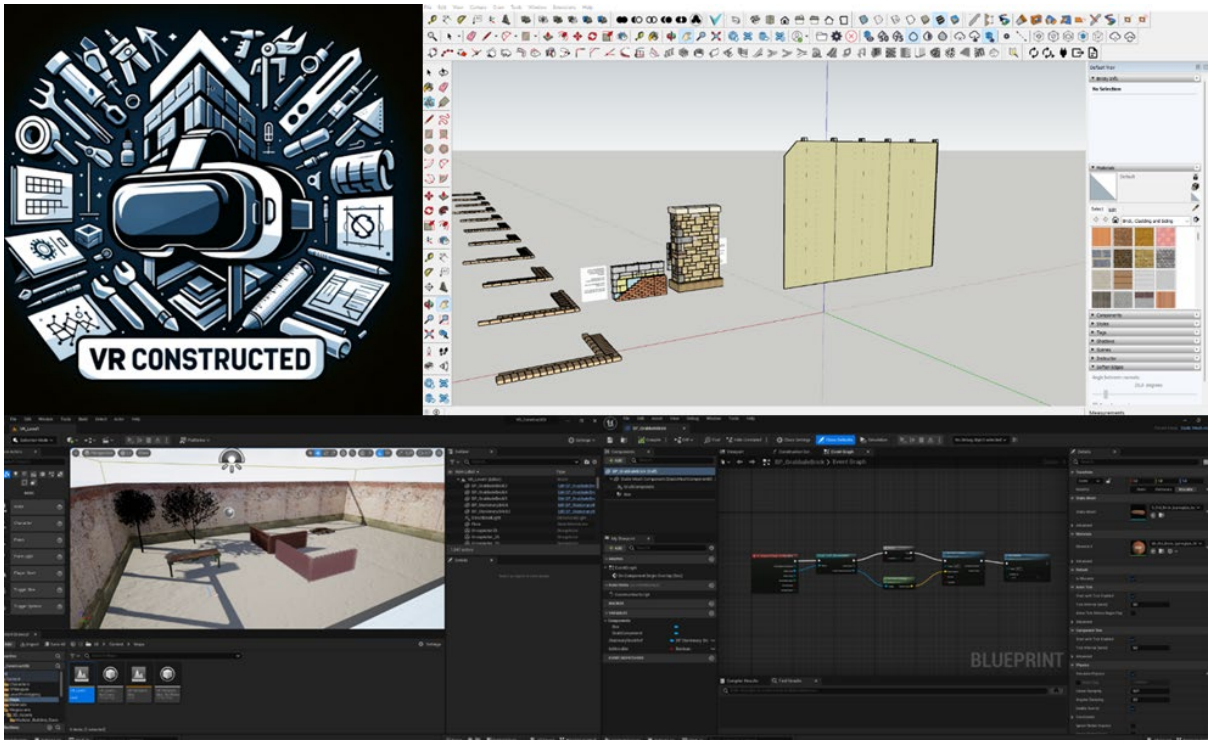

Figure 1: Development process of the VR game.

5. Time Schedule of the Thesis

- **Game Conceptualization and Preliminary Design**

Duration: October 2024- January 2025

Activities: Developing the initial design and concept for "VR ConstructED." This phase includes outlining the game's educational goals, user interface design concepts, and preliminary technical architecture. Collaborating with VR developers and subject matter experts.

- **Development and Initial Testing of VR ConstructED**

Duration: February 2025- July 2025

Activities: Beginning the actual development of the VR game. This stage involves programming, creating interactive content, and integrating educational materials into the game. Conduct initial internal testing and make iterative revisions based on feedback.

- **Pilot Testing and Refinement**

Duration: August 2025- December 2025

Activities: Performing pilot testing with a select group of users to collect initial feedback and identify any operational issues. Refining and adjusting the game based on the pilot feedback. Setting up comprehensive data collection methods for the full-scale evaluation.

- **Full-scale Evaluation and Data Analysis**

Duration: January 2026- June 2026

Activities: Implementing the full-scale evaluation of "VR ConstructED" with a larger participant group. Collecting quantitative and qualitative data. Beginnig data analysis to assess the educational impact of the VR game.

- **Finalization and Defense of Thesis**

Duration: July 2026- September 2026

Activities: Analyzing all collected data, draw conclusions, and draft the final thesis document. Revising the thesis based on feedback from supervisors and peers. Preparing for the thesis defense presentation, conduct the defense, and submitting the final thesis.

6. Conclusion

This study explores the possibilities of using a virtual reality (VR) game-based approach as an instructional tool for interior design students taking construction courses. The study exposes complex opinions and experiences of students playing with virtual reality games by utilizing a thorough approach that integrates quantitative data and qualitative insights obtained through techniques such as semi-structured interviews and theme analysis. The results highlight how VR may enhance construction education and even change preconceived notions about design education. In order to fully exploit the educational potential of virtual reality in design disciplines, future research areas include enhancing VR game applications in educational settings, which will require collaborative efforts among educators, industry experts, and game developers.

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