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Enhancing Design Education with Virtual Reality: Effects on Student Learning and Performance

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Abstract: *This study examines the impact of Virtual Reality (VR) technology on enhancing student learning and performance in higher education design courses. The study aims to examine and evaluate the integration of VR technology in design courses for higher education. A mixed-methods approach was employed in the research, where undergraduate design students in a private University located in Malaysia participated in a VR-enhanced learning process over a six-week period within their Studio Project module. Data collected from quantitative research through pre-test and post-test assessment and project evaluation. Student surveys and observations contributed to the qualitative data. Findings and data analysis reveal that students utilizing VR technology in their educational experience exhibit notable enhancements in spatial awareness, ideation, and performance relative to their counterparts in conventional environments. Besides, students survey reported the increased levels of learning engagement, motivation, and satisfaction. Integrating VR technology into design classrooms is essential for enhancing students' learning outcomes and engagement. The results show that the integration of VR technology has a lot of educational benefits for design education and should be seen as a strategic tool in this area. The incorporation of VR technology in design education has challenges and limitations concerning infrastructure development, cost efficiency, and effective pedagogy.*

Keywords: Virtual Reality (VR), Design Education, Learning Experience, Higher Education

1. Introduction

Design education in digital era faces unique challenges and opportunities (Hu et al., 2022). With the rapid advancement of technology and its integration into every aspect of modern life, design education must adapt to provide students with skills and knowledge necessary to thrive in this digital landscape (Campos et al., 2022). Therefore, design education for new genesis needs to be more interactive with the immersive technology to adapt the demands of constantly changing world.

As the world becomes more advanced in technology and globalization, students need to be equipped with a wider range of skills that extend beyond academic knowledge. To meet the demands, this is necessary. A main challenge in design education is keeping up with rapidly changing technology during knowledge transfer to students (Meyer & Norman, 2020). Despite the challenges, design educators in the digital era have significant opportunities with digital tools to deliver knowledge in creative ways. These opportunities include VR, augmented

reality, 3D modelling and digital 3D printing. These tools allow students to experiment with ideas, concepts and design in a way that was not possible with traditional mediums (Radianti et al., 2020).

The appearance of virtual reality (VR) technology has transformed product design and communication. The concept of Virtual Reality (VR) can be defined as a computer-generated environment with an immersive, interactive, and multisensory experience that mimics reality (Ma et al., 2022). In recent years, VR technology has gained popularity across various fields, including education (Teklemariam et al., 2014). It creates an immersive and interactive environment that allows students to experience and interact with designs in a more realistic way. Viewers can perceive distances and spatial relationships between different objects more realistically and accurately using VR technology (such as traditional CAD tools) (Smith & Lee, 2004).

1.1 Background of Research

Design program subjects rely heavily on visual aids to assist students' understanding on concepts and development of skills (Kolko, 2008). However, traditional 2D media such as paper sketches and digital drawings may not be sufficient for students to have realistic sense of feel in real world to their design development. This may restrict them from having innovative and effective concepts (Radianti et al., 2020). The traditional methods of teaching design, often face limitations in providing students with fully immersive, hands-on experiences where students faced difficulty interpreting ideas into real object. These methods restrict students' understanding of complex spatial relationships and hinder their ability to visualize their designs in a realistic context (Radianti et al., 2020; Gavish et al., 2015). By providing a three-dimensional, interactive environment where students may connect with their projects in a simpler and more experiential way, VR technology solves these restrictions. Thus, VR technology presents a possible answer to this issue since it may give students an immersive and interactive environment that lets them experience their designs in more realistic and dynamic ways (Radianti et al., 2020). Including VR technology into design classes is crucial to improve students' academic performance and interest (Smith & Lee, 2004). The purpose of this paper is to investigate how well VR technology performs for design program student learning and performance.

1.3 Research Objective

The purpose of the study is to examines the impact of Virtual Reality (VR) technology on enhancing student learning and performance in higher education design courses. Besides, the study aims to examine the challenges and limitation associated with the implement of VR technology in design education. Through this dual focus, the study seeks to provide a comprehensive understanding of both benefits and obstacles if incorporating VR in design education.

The objectives of this study are:

1) To examine the engagement of VR technology application in design education.
2) To explore the challenges and limitation on VR technology in design education.

2. Literature Review

2.1 VR technology in industry

In the industry, VR technology was used as a measuring tool in evaluating the design process. The exploration of VR that can verify product designs and reduce the frequency of physical

prototypes making (Smith & Lee, 2004). In addition, this method improves product quality as well as obtaining results in a more intuitive way during the conceptual process phase. Furthermore, VR was found can be used to train manufacturing work force to perform better on jobs.

VR technology also applied in remote engineering for advance engineering development. Particularly after the pandemic, many remote design teams perform efficiently and creatively than office-based counterpart (Spiegel, 2021). Manufacturing industries are focusing on immersive VR technology to achieve mass production and mass customization of different product variants (Eswaran & Bahubalendruni, 2022).

2.2 VR Technology in Design Education

Visual aids like sketches and software-generated drawings are tools to the design process because they assist students in generating ideas and execute them out. Additionally, these tools assist to deliver ideas and concepts and promote communication throughout the design process (Meyer & Norman, 2020). Nonetheless, conventional 2D media may not offer students a realistic perception of how their designs will appear and function in the real world, which is inadequate for meeting the demands of the current era (Teklemariam, Kakati & Das, 2014).

The digital era has provided students with numerous opportunities for enhanced learning environments using technology. Therefore, raising the standard of instruction in design education must be our top priority. VR technology appears to be a promising development in the continuous evolution of education, given its potential to alter how students interact with course materials (Häkkilä et al., 2018).

Students get the opportunity to experience their design in a more realistic and dynamic way with the offer of VR technology to handle problem-solving in an immersive environment (Häkkilä et al., 2018). VR technology also provides students with a platform for collaboration, as they can work on the same design project in a shared virtual space.

By providing students with immersive and interactive learning experiences, VR technology enhance student engagement in design process learning through the improvement of understand complex concepts and facilitate the development of critical thinking skills. Therefore, VR technology shows great potential for enhancing the quality of education in the digital era (Babich, 2019).

2.3 Impact of VR Technology on Student Learning

Numerous studies demonstrate the influence of VR technology on student learning in design programs. A study by Campos, Hidrogo, and Zavala (2022) emphasized the students performed better in experimental group compared to control group in the assignment that performed visualization. In addition, the experimental group rated the VR tool positively, mentioning that they show more favorable in the learning experience and enhanced their understanding in the course content (Bartosh & Anzalone, 2019).

In the study of Häkkilä, Väyrynen and Yliharju (2018), VR was introduced to Industrial Design students in university. Respondents showed positive feedback in the viewing of concept on realistic environment and enthusiasm for the immersive experiences. The use of VR technology in design education improved student engagement, motivation, and learning outcomes.

However, there are some studies reported mixed results. One of the survey results by Gao et al. (2021) indicate that most students found learning design and graphics with the help of VR models enjoyable. VR models helped them visualize 3D objects more effectively (Gao et al., 2021; Ferdousi et al., 2023). However, the effectiveness of VR models may be affected by individual physical reactions. Some students have found importing 3D models into VR environments to be unnecessary or cumbersome, preferring traditional 2D visualizations on monitor screens (Gao et al., 2021). The study suggested that the impact of VR technology on student learning may depend on several factors, including the level of experience with the technology and the nature of the design project (Ferdousi et al., 2023).

2.4 Impact of VR Technology on Design Performance

Design performance is defined as students' ability to create innovative and effective designs that meet their desired objectives and requirements. Design projects and assignments often evaluate design performance, an important measure of a student's ability to create successful designs in design education (Shen et al., 2023).

According to the study by Teklemariam, Kakati and Das (2014), the integration of VR tools allows for more realistic and interactive interaction with a design model. VR technology can aid students in developing a better understanding of complex CAD systems and the design process. It shows better performance than cutting-edge technology.

In addition to increased understanding of complex systems through high-quality graphics that facilitate learning, VR technology offers other benefits such as improved motivation, more efficient communication, and improved engagement (Graeske & Sjöberg, 2021). According to studies by Shana et al. (2007), the use of VR technology has a positive effect on students' design, graphic communication, and spatial abilities. Furthermore, students' attitudes towards the use of VR in the classroom are favorable, as it offers opportunities for collaborative discussion and visualization of ideas and objects for both students and educators.

2.5 Challenges and limitation in Implementing VR Technology in Design Education

Despite the potential benefits of VR technology in design education, there are challenges in implementing VR technology in the teaching syllabus. One of the major challenges confronted is the cost of the technology, as VR hardware and software are extremely costly to setup as well as for future maintenance. According to Häkkilä et al. (2018) and Baniasadi et al. (2020), the practicality of tasks involving multiple users is limited due to a lack of infrastructure. They mentioned that the entire student group had to use only one set of VR equipment, which presented challenges.

According to other researchers (Graeske & Sjöberg, 2021), developing VR content can be challenging for individuals or small teams due to the high cost of the necessary hardware and software. Furthermore, educators must remain current with the latest tools and techniques to stay competitive.

Besides that, developing VR content can be a time-consuming process that requires special skills. The process may require knowledge and skills in creating 3D modeling, specific software knowledge, and expertise in handling the tools (Graeske & Sjöberg, 2021; Alnagrat et al., 2022).

Furthermore, using VR technology may result in physical limitations may occur with the use of VR technology. A study by Baniasadi et al. (2020) shows that it is important to consider

individual characteristics such as gender, age, personality, and history of motion sickness, as well as other unique psychological, may affect the limits of use in the classroom.

3. Methodology

3.1 Research Design

In this study, Mixed methods embedded design was adopted with quantitative and qualitative approaches to assess the impact of Virtual Reality (VR) in design to enhance students' learning outcomes and performance. The embedded design involves the simultaneous collection of quantitative and qualitative data, with the qualitative data integrated into the quantitative data. Data collected from quantitative research through pre-test and post-test assessment and project evaluation. On the other sides, student surveys and observation contributed to the qualitative data collection.

Mixed-methods research are particularly suitable for this research, as complex phenomena like as creativity and engagement are best analysed through a combination of quantitative data and qualitative insights (Creswell & Plano Clark, 2018). The study sought to obtain a holistic perspective of the learning experience in a VR-enhanced environment by triangulating data sources.

3.2 Participants

This study used convenience sampling with respondents from the Faculty of Art & Design, Southern University College, Johor Bahru, Malaysia as the population. The research involved 30 students (n = 30) in the fields of Industrial Design, who have voluntarily agreed to participate. Participants are second year undergraduate students who taking Studio Project module. All students had prior experience with Computer-Aided Design (CAD) software and were familiar with fundamental design principles and digital modelling techniques.

3.3 Instruments and Tools

Three types of instruments were used in the study:

3.3.1 Virtual Reality Platform

VR system was setup in the faculty facility to allowing students engagement in immersive display of their CAD models. The VR tools allowed students' interaction with their product models and design refinements.

3.3.2 Assessment Rubric

A 5-scales rubric was developed to assess the final design projects. The criteria included functionality, concept development, innovation, aesthetic quality, and user-centered design. This rubric was validated by two Industrial Design lecturers from faculty.

3.3.3 Survey and Interview Protocols

Survey questionnaires in Likert-scale, open-ended questions were distributed to participants during the pre- and post-test for quantitative data collection. Instructor observations were documented using behaviour checklist for qualitative data collections. Semi-structured interviews were conducted to focused group.

3.4 Procedure

The participants consist of two group where control group and focus group were conducted in pre- and post-test. Control group undergoing the conventional design process, while focus group refine their design in VR environment.

The following steps were implemented in the process:

3.4.1 Pre-Test

At the beginning of the study, students were assigned a baseline design task completed using standard CAD software without VR. This functioned as the benchmark for evaluating developments in spatial design proficiency and conceptual clarity.

3.4.2 Concept Development

Students defined a design problem and developed their concept with proposed solution. Then, both groups visualized the concept in using CAD software to create 3D models.

3.4.3 VR Integration

When of the initial stage of CAD models were completed, focus group participants imported their files into the VR environment, where they could visualize, refine in the immersive environment. On the other hand, the control group participants continue with their conventional process.

3.4.4 Post-Test

At the end of process, students submitted their final projects. Both control and focus groups were evaluated by two Industrial Design lecturers to the pre- and post-intervention conditions using assessment rubric.

3.5 Data Collection Methods

3.5.1 Comparative Analysis

The research employs a comparative analysis to assess the performance of students in conducting their design refinement in a virtual reality setting against those who employed traditional approaches. This method facilitates a direct comparison of learning results, engagement, and retention rates between the two cohorts.

3.5.2 Quantitative Data

Pre- and post-test scores were collected and analysed to determine changes in design quality and skill development. Descriptive statistics and paired sample t-tests were used to evaluate performance differences.

3.5.3 Qualitative Data

In addition to quantitative measures, sstudent perceptions were captured through survey responses and follow-up interviews. Observational data from instructors provided contextual insight into student behavior, collaboration, and problem-solving patterns during VR sessions.

4. Results

This study's findings will be conveyed through a synthesis of quantitative analysis of test scores and qualitative insights derived from surveys and interviews. This section will offer a detailed analysis of the engagement of VR technology application in design education on student learning and performance.

4.1 Quantitative Findings

To examine the student performance, assessment scores were collected during the pre- and post-test using the assessment rubric. Students from both groups were evaluated based on five criteria: functionality, concept development, innovation, aesthetic quality, and user-centered design. A paired samples t-test was conducted to determine whether the integration of VR shows significant enhancement on student learning outcome.

The analysis revealed a significant improvement in post-test scores on focus group compared to control group. Significant improvements on functionality and user-centered design criteria were analyzed in the data collection. This suggesting the immersive VR environment helped students to have better product visualization compared to the conventional method.

4.2 Qualitative Findings

Data from post-test surveys and semi-structured interviews were analysed thematically. Data collection from focus group were interpreted in the findings.

Three major findings emerged:

4.2.1 Improved Spatial Understanding

Students indicated that VR environment allowed them for better understanding product dimension, especially when the product were improved in term of scale, proportion and spatial relationship. Besides, some students were successfully improved the product interface. One of the students claimed, "Seeing my design in VR helped me realize how cramped the interior space was—I redesigned it after that."

4.2.2 Increased Engagement and Motivation

Many participants described the VR experience as more immersive and motivating compared to traditional methods. Several students described that the experience was "fun," "realistic," "the interaction was great," and "seeing their design in real form" was excited to them.

4.2.3 Iterative Design and Reflection

Majority of the students valued the opportunity to engage with their designs in an immersive environment during the design process. They indicated that they were able to verify problems and apply solutions by revising their designs after engaging in a near-real environment. One respondent mentioned, "I revised my design two times after testing it in VR. It felt like I was walking through my product."

Lecturers' observation supported these themes. Students exhibit more interactive and collaborative during the experiment. Besides, students also demonstrated increased confidence in defending their concept during the presentation. The design progress significantly showing the enhancement of student learnings and performance.

5. Discussion

The findings of this study demonstrate the potential of Virtual Reality as an enhancement tool in design education for higher education. The statistically significant improvement in post-test scores indicates that VR tools enhance not only students' understanding of spatial and problem-solving but also improves overall design quality and learning experience.

The qualitative data support these findings by emphasizing students' personal experiences of learning in a virtual reality environment. The reported increase in engagement and motivation corresponds with previous research indicating that immersive technologies enhance learner interest and interactivity (Freina & Ott, 2015; Radianti et al., 2020). Students able to imagine their concept at full scale and nearly real seems to have enhanced their cognitive engagement, resulting in more thoughtful revisions and reflective strategies.

The study aligns with experiential learning theories, particularly Kolb's (1984) model, which claims that learners participate in a process of direct observation, reflective thinking, abstract conceptualization, and active problem solving. It was easier to do each of these steps in VR than with regular CAD tools.

Participants and observers acknowledged certain limitations despite the positive results. The small number of participants and short study duration limit the generalizability of the findings. Some students also reported difficulties with technology, such as motion sickness and occasional hardware failures. This demonstrated a proper infrastructure shall be implemented to integrate into the syllabus, as well as the support from users.

Even so, this study makes a good demonstration in constructing the concept development by using VR more in design process. VR technology not only improves learning performance, but it also encourages creativity, iteration, and deeper engagement, which are all important for good design practices. Institutions looking at curriculum enhancement may find benefit in investing in immersive technologies, appropriate training to instructor and education integration is in place. So that graduates are equipped with readiness to apply their skills in real world of employment.

6. Conclusion

This study examined the effects of Virtual Reality (VR) technology on student learning and performance in higher education for design program. The participants involved undergraduate students who taking industrial design program with Studio Project module. The study was conducted using a mixed-methods approach. The integration of VR technology in the study indicates the enhancement on students' learning and performance, particularly on spatial understanding, design thinking, and problem solving. Quantitative analysis demonstrates the improvement scores using rubric assessment in post-test result. Qualitative findings revealed improved engagement, creative motivation, and reflective problem solving in the design process.

These findings support existing literature review for immersive learning environment in design education (Radianti et al., 2020; Wojciechowski & Cellary, 2013). Students were able to interact with their design outputs in a more meaningful way because they could simulate real-world contexts, scale, and usability. This is something that regular CAD environments can't fully support (Freina & Ott, 2015). As students engaged in experiential learning cycles involving reflection and experimentation, the study supports Kolb's (1984) learning theory as a framework for immersive design education.

Despite its promising results, the study faced limitations and challenges including a modest sample size, short study period, and the limited access on the facilities and tools. Nonetheless, the results provide strong justification for further investigation and gradual integration of VR

technology into the program syllabus, particularly in programs emphasizing spatial reasoning, human interaction, problem solving and innovative solution.

7. Implications

The outcomes of this study carry several important implications for design educators, program developers, and institutional leaders.

7.1 Curriculum Implementation

The integration of VR tools into subject syllabus should be considered in strategically way. Students' readiness and physical consideration shall be take place when design the syllabus. By integrating VR technology into necessary studio modules can help get ideas from the initial stage till evaluating stage. Immersive environments facilitate students' participation in actual design evaluation and enhancement, closely emulating real-world approaches (Portman et al., 2015; Rauschnabel et al., 2022).

7.2 Faculty and Infrastructure Readiness

Investment of tools setup is costly where institution required to invest VR hardware and software which required long-term maintenance. Besides, staff training and instructional design support to allocate the competency to the pedagogical success (Bower et al., 2017).

7.3 Equity and Accessibility

When the facility was implemented, ensuring student access is the key concern as the use of immersive tools raised. Well planned strategies must be developed to the equipped the needs of students with proper guidance. Ensures the VR learning environments, mobile VR tools were adequate for learners (Radianti et al., 2020).

7.4 Recommendation for Further Research Development

The study shall further investigate for long-term impact of VR technology on program development. Comparative studies across disciplines such as 3D character design, game design, and interaction design could reveal how VR supports different types of creative learning (Johnson-Glenberg, 2018). Institutions may get students ready for future industry standards by carefully integrating VR to design education. This will also make learning more interesting, stimulating, and beneficial.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this study.

References

Alfalah, S. (2018). Perceptions toward adopting virtual reality as a teaching aid in information technology. Educ Inf Technol, 23, 2633–2653.

Alnagrat, A. J. A., Ismail, R. C., & Idrus, S. Z. S. (2022). The opportunities and challenges in virtual reality for virtual laboratories. Innovative Teaching and Learning Journal, 6(2), 73-89.

Babich, N. (2019, September 19). How VR in education will change how we learn and teach. Retrieved from Adobe: https://xd.adobe.com/ideas/principles/emerging-technology/virtual-reality-will-change-learn-teach/

Baniasadi, T., Ayyoubzadeh, S. M., & Mohammadzadeh, N. (2020). Challenges and practical considerations in applying virtual reality in medical education and treatment. Oman Medical Journal, 35(3).

Bartosh, A., & Anzalone, P. (2019). Experimental applications of virtual reality in design education.

Bower, M., DeWitt, D., & Lai, J. W. M. (2017). Reasons associated with preservice teachers' intentions to use immersive virtual reality in education. *British Journal of Educational Technology, 48*(3), 629–641. https://doi.org/10.1111/bjet.12480

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Campos, E., Hidrogo, I., & Zavala, G. (2022). Impact of virtual reality use on the teaching and learning of vectors. Retrieved from Communities in DSpace: https://repositorio.unab.cl/xmlui/handle/ria/24387

Chandrasekera, T., & Yoon, S. Y. (2018). Augmented reality, virtual reality and their effect on learning style in the creative design process. Design and Technology Education: An International Journal, 23(1), 55-75.

Creswell, J. W., & Plano Clark, V. L. (2018). Designing and conducting mixed methods research (3rd ed.). SAGE Publications.

Dede, C. (2009). Immersive interfaces for engagement and learning. Science, 323(5910), 66–69. https://doi.org/10.1126/science.1167311

Eswaran, M., & Bahubalendruni, M. R. (2022). Challenges and opportunities on AR/VR technologies for manufacturing systems in the context of industry 4.0: A state of the art review. Journal of Manufacturing Systems, 65, 260-278.

Ferdousi, R., Faisal, M., Laamarti, F., Yang, C., & El Saddik, A. (2023). Exploring user perceptions of virtual reality scene design in metaverse learning environments. *arXiv preprint arXiv:2311.10256*. https://arxiv.org/abs/2311.10256

Freina, L., & Ott, M. (2015). A literature review on immersive virtual reality in education: State of the art and perspectives. Proceedings of the International Scientific Conference eLearning and Software for Education, 1, 133–141.

Gao, H., Bozkir, E., Hasenbein, L., Hahn, J.-U., Göllner, R., & Kasneci, E. (2021). Digital transformations of classrooms in virtual reality. *arXiv preprint arXiv:2101.09576*. https://arxiv.org/abs/2101.09576

Gavish, N., Gutiérrez, T., Webel, S., Rodríguez, J., Peveri, M., Bockholt, U., & Tecchia, F. (2015). Evaluating virtual reality and augmented reality training for industrial maintenance and assembly tasks. *Interactive Learning Environments, 23*(6), 778–798. https://doi.org/10.1080/10494820.2013.815221

Graeske, C., & Sjöberg, S. A. (2021). VR-Technology in Teaching: Opportunities and Challenges. International Education Studies, 14(8), 76-83.

Häkkilä, J., Colley, A., Väyrynen, J., & Yliharju, A.-J. (2018). Introducing Virtual Reality Technologies to Design Education. Seminar.Net, 14(1), 1–12.

Ho, Y. M. (2020). 3D Modeling and Computer Graphics in Virtual Reality. Mixed Reality and Three-Dimensioning Computer Graphics.

Hu, W., Hu, Y., Lyu, Y., & Chen, Y. (2022). Research on integrated innovation design education for cultivating the innovative and entrepreneurial ability of industrial design professionals. Frontiers in Psychology, 12.

Johnson-Glenberg, M. C. (2018). Immersive VR and education: Embodied design principles that include gesture and hand controls. Frontiers in Robotics and AI, 5, 81. https://doi.org/10.3389/frobt.2018.00081

Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. Prentice Hall.

Kolko, J. (2005). New techniques in industrial design education. In Design-System-Evolution, Proceedings of the 6th International Conference of The European Academy of Design. EAD06.

Madden, J., Pandita, S., Schuldt, J. P., Kim, B. S., Won, A. & Holmes, N. G. (2020). Ready student one: Exploring the predictors of student learning in virtual reality. PLoS ONE, 15(3), e0229788.

Meyer, M. W., & Norman, D. (2020). Changing design education for the 21st century. She Ji: The Journal of Design, Economics, and Innovation, 6(1), 13-49.

Niu, M., Lo, C. H., & Yu, Z. (2021). Embedding Virtual Reality Technology in Teaching 3D Design for Secondary Education. Frontiers in Virtual Reality, 2.

Portman, M. E., Natapov, A., & Fisher-Gewirtzman, D. (2015). To go where no man has gone before: Virtual reality in architecture, landscape architecture and environmental planning. *Computers, Environment and Urban Systems, 54*, 376–384. https://doi.org/10.1016/j.compenvurbsys.2015.05.001

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. Computers & Education, 147.

Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., & Koole, M. (2021). Balancing technology, pedagogy and the new normal: Post-pandemic challenges for higher education. Postdigital Science and Education, 3(3), 715-742.

Rauschnabel, P. A., Felix, R., Hinsch, C., Shahab, H., & Alt, F. (2022). What is XR? Towards a framework for augmented and virtual reality. *Computers in Human Behavior, 133*, 107289. https://doi.org/10.1016/j.chb.2022.107289

Shen, D., Yao, X., Bao, D., & Yu, Y. (2023). Content categorization for memory retrieval: A method for evaluating design performance. PLoS ONE 18(1): e0280459.,https://doi.org/10.1371/journal.pone.0280459.

Smith, S. S., Saunders, K. P., Antonenko, P., Green, T., Peterson, N., & Thompson, A. D. (2007). Experiences in Using Virtual Reality in Design and Graphics Classrooms. International Journal of Engineering Education.

Smith, S. S. F., & Lee, S. L. (2004). A pilot study for integrating virtual reality into an introductory design and graphics course. Journal of Industrial Technology, 20(4).

Spiegel, R. (2021, Dec 21). Design News. Retrieved from www.designnews.com: https://www.designnews.com/design-software/future-virtual-reality-product-design

Teklemariam, H. G., Kakati, V., & Das, A. K. (2014). Application of VR technology in design education. Proceedings of the 16th International conference on Engineering and Product Design Education, Design Education and Human Technology (pp. 04-05). The Netherland: University of Twente.

Wojciechowski, R., & Cellary, W. (2013). Evaluation of learners' attitude toward learning in ARIES augmented reality environments. *Computers & Education, 68*, 570–585. https://doi.org/10.1016/j.compedu.2013.02.014

Yan Ma, Lu Zhang & Min Wu. (2022). Research on the Influence of Virtual Reality on the Learning Effect of Technical Skills of Science and Engineering College Students: Meta-Analysis Based on 32 Empirical Studies. International Journal of Digital Multimedia Broad, vol. 2022, Article ID 6202370.