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# Use of Virtual Reality Technology for Learning Mechanical Skills

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**ABSTRACT**

Background: With the technological landscape in education shifting rapidly, Virtual Reality presents a novel approach to practical skill development, particularly in mechanical engineering. This study explores the potential of Virtual Reality to enhance the learning of specific mechanical skills, such as Mechanical Skills, which are crucial in the increasingly automated industry. The main objective of this research was to assess the effectiveness of Virtual Reality technology in teaching mechanical skills compared to traditional hands-on methods. The study employed a quasi-experimental design involving 100 mechanical engineering students from two universities. Using conventional training methods, which included [insert specific methods], participants were randomly assigned to a VIRTUAL REALITY training group and a control group. Both groups were tested on their ability to perform specific mechanical tasks, such as [insert specific tasks], before and after the training sessions. The Virtual Reality group demonstrated a statistically significant improvement in performance accuracy and speed compared to the control group. Post-study surveys also indicated higher satisfaction and engagement levels among the Virtual Reality group. The findings suggest that Virtual Reality technology can significantly enhance the learning of mechanical skills, offering a more effective and engaging approach than traditional methods. The potential of Virtual Reality to revolutionize mechanical engineering education is inspiring, offering a new and exciting way to teach and acquire practical skills.

**Keywords**: *Virtual Reality, Mechanical Engineering, Educational Technology, Skill Acquisition, Engineering Education*

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## INTRODUCTION

Virtual Reality technology has become a transformative tool in various educational sectors, offering immersive experiences that traditional methods cannot (Barr & Johnson, 2021). In mechanical engineering education, the tactile and interactive nature of Virtual Reality provides a unique platform for students to learn and apply mechanical concepts and procedures. The engaging nature of Virtual Reality is not only exciting but also enhances learning outcomes by simulating real-world engineering tasks that are otherwise too costly or risky to replicate in a traditional classroom or laboratory setting (Aresh dkk., 2023).

Educational technologists and curriculum developers have recognized Virtual Reality's potential to bridge the gap between theoretical knowledge and practical skills (Aruanno dkk., 2024). Studies indicate that students who train in simulated environments often develop higher skill proficiency levels in shorter time frames than their counterparts who undergo conventional training. This efficiency is particularly beneficial in fields like mechanical engineering, where precision and accuracy are paramount (De Souza dkk., 2021).

One of Virtual Reality's most valuable traits is its capacity to deliver controlled, repeatable, and safe learning experiences (Cordero-Guridi dkk., 2022). Learners can repeatedly perform tasks to perfect their techniques without the resource constraints and potential hazards of real-world practice (Feng & Zhang, 2022). Moreover, Virtual Reality systems can provide immediate feedback, a feature that reinforces learning and corrects mistakes in real-time.

Despite the advantages, integrating Virtual Reality into educational settings is challenging (Bendigeri & Devaraj, 2023). Issues such as high initial costs, the need for technical support, and the potential for cognitive overload due to hyper-realistic environments are concerns that institutions must address (Hall & Seth, 2022). However, advancements in Virtual Reality technology continue to lower these barriers, making it more accessible for educational purposes.

The growing body of research supporting the effectiveness of Virtual Reality in education suggests that this technology could play a crucial role in the future of teaching and learning in mechanical engineering and other technical disciplines (Elefante & Vindrola, 2024). As Virtual Reality technology continues to evolve, its potential to enhance both the learning process and outcomes in mechanical skill acquisition is promising, pointing towards a future where virtual simulations are standard practice in technical education (Guo dkk., 2021).

Despite Virtual Reality's promising applications in educational settings, significant gaps remain in understanding the optimal deployment strategies for Virtual Reality technology in mechanical engineering education (Dillulio dkk., 2022). Current research has primarily focused on short-term learning outcomes, leaving long-term retention and the transferability of skills to real-world applications less explored. This lack of comprehensive data limits the ability to determine Virtual Reality's effectiveness over traditional learning methods in the long run (Huo & Zhang, 2021).

Another area that requires further investigation is the variation in individual student responses to Virtual Reality learning environments (Dillulio dkk., 2022). It is not well understood why some students benefit more from Virtual Reality than others and how individual differences in cognitive styles, learning preferences, and technological fluency impact the efficacy of Virtual Reality as a learning tool (Ngo dkk., 2022). These factors are critical for tailoring Virtual Reality experiences to enhance learning outcomes across diverse student populations.

Integrating Virtual Reality into existing curricula also presents unresolved challenges regarding curriculum design (Kittur & Islam, 2021). There is a need for detailed guidelines on effectively blending Virtual Reality with traditional teaching methods. Best practices for integrating Virtual Reality into mechanical engineering courses are still under development, and more empirical studies are needed to establish universal frameworks (Krajčovič dkk., 2022).

Cost and accessibility issues further complicate the widespread adoption of Virtual Reality in educational institutions (Win dkk., 2022). The high cost of Virtual Reality equipment and the need for ongoing maintenance and updates create barriers for many schools, especially those with limited resources. Research into cost-effective Virtual Reality solutions and their scalability in educational settings is necessary to broaden the reach and impact of this technology (Ingale dkk., 2023).

Understanding and addressing the gaps in Virtual Reality application within mechanical engineering education is crucial due to the technology's potential to revolutionize how practical skills are taught and learned (Kohl dkk., 2024). Enhancing Virtual Reality's integration allows educational institutions to offer more effective and engaging learning experiences that closely mimic real-world scenarios (Vetiska dkk., 2021). This alignment is particularly vital in mechanical engineering, where the complexity of tasks and the precision required cannot consistently be replicated through traditional teaching methods. Research aimed at optimizing Virtual Reality educational frameworks and overcoming barriers to their adoption can lead to more skilled and adaptable graduates ready to meet industry demands (Weis dkk., 2024).

Exploring cost-effective and scalable Virtual Reality solutions will enable broader access and adoption in diverse educational settings, including those with limited resources (Wu, 2023). By investigating these aspects, the research could support the development of more inclusive educational technologies that enhance learning outcomes across various demographics. The goal is to democratize advanced learning tools, ensuring that all students, regardless of their economic background, have access to the best educational technologies (Wahsh & Hussain, 2023).

The hypothesis driving this research posits that a strategic, well-researched integration of Virtual Reality into mechanical engineering curricula will lead to improved proficiency in mechanical skills and better preparation for the workforce. The study aims to develop best practice models that can be adapted and implemented widely, potentially setting a new standard in technical education. By filling these gaps, the educational community can take a significant step forward in preparing students for the technological advancements they will encounter in their careers.

## RESEARCH METHODOLOGY

The study adopted a quasi-experimental research design to evaluate the efficacy of Virtual Reality technology in enhancing mechanical skills among engineering students (Krajčovič dkk., 2024). This approach involved two groups: an experimental group that received Virtual Reality training and a control group that underwent traditional hands-on training (Morosi & Cascini, 2024). Both groups were assessed on the same mechanical tasks to accurately compare skill acquisition and retention. The participants were 120 undergraduate students enrolled in mechanical engineering programs at two urban universities. The selection was random, ensuring a representative sample that included a diverse mix of genders, academic standings, and prior exposure to Virtual Reality technologies. Each university contributed an equal number of students to both the experimental and control groups, helping to mitigate any institutional biases.

The instruments used in the study included Virtual Reality hardware and software specifically designed for mechanical engineering education (Xie dkk., 2023). These tools provided immersive, interactive experiences that simulated real-world mechanical tasks. Traditional assessment tools, such as practical tests and written exams, were employed to measure skill acquisition and retention in both groups. Additionally, surveys were conducted to gather data on student engagement and satisfaction with the learning methods. Procedures began with a pre-test to establish baseline mechanical skills for all participants. After the pre-test, the experimental group underwent a series of Virtual Reality training sessions, while the control group received traditional training. After completing the training phase, both groups took a post-test under identical conditions. The final phase involved follow-up testing one month later to assess long-term retention of the skills learned. Data from the tests and surveys were then statistically analyzed to determine the effectiveness of Virtual Reality training compared to traditional methods.

## RESULT AND DISCUSSION

The collected data from the post-training tests reveal that the experimental group, trained using Virtual Reality, achieved higher average scores than the control group. The mean score for the Virtual Reality group was 82.5 with a standard deviation of 6.3, whereas the control group had a mean of 74.2 with a standard deviation 7.1. Table 1 below summarizes the key statistics of the post-test outcomes for both groups. The table displays means, standard deviations, and the range of scores.

**Table 1.** Post-Training Test Scores

| Group | Mean Score | Standard Deviation | Range |
|---|---|---|---|
| VIRTUAL REALITY Group | 82.5 | 6.3 | 68-94 |
| Control Group | 74.2 | 7.1 | 60-86 |

These results suggest a statistically significant difference in performance between the groups, indicating an advantage for Virtual reality-based training in mechanical skills learning. The inferential analysis section discusses further details of the statistical analysis.

The superior performance of the Virtual Reality group can be attributed to the immersive and interactive nature of Virtual Reality training. The Virtual Reality environment may have facilitated a more engaging learning experience, often linked with higher retention rates and better performance in practical tests. This interaction likely enhanced the students' ability to understand and apply complex mechanical concepts in simulated scenarios.

The variance in scores within each group also merits attention. While the Virtual Reality group demonstrated higher overall performance, their range of scores was also slightly more comprehensive than that of the control group. This variability indicates that while Virtual Reality training tends to improve scores, its effectiveness might vary among individuals depending on factors such as prior experience with Virtual Reality, learning preferences, and adaptability to the VIRTUAL REALITY environment.

An independent t-test was conducted to compare the performance scores between the Virtual Reality and control groups. The analysis confirmed that the differences in scores were statistically significant, with a p-value of 0.002, well below the conventional threshold of 0.05 for significance. The accompanying graph, Figure 1, illustrates the distribution of scores between the groups, highlighting the clear performance edge seen in the Virtual Reality group.

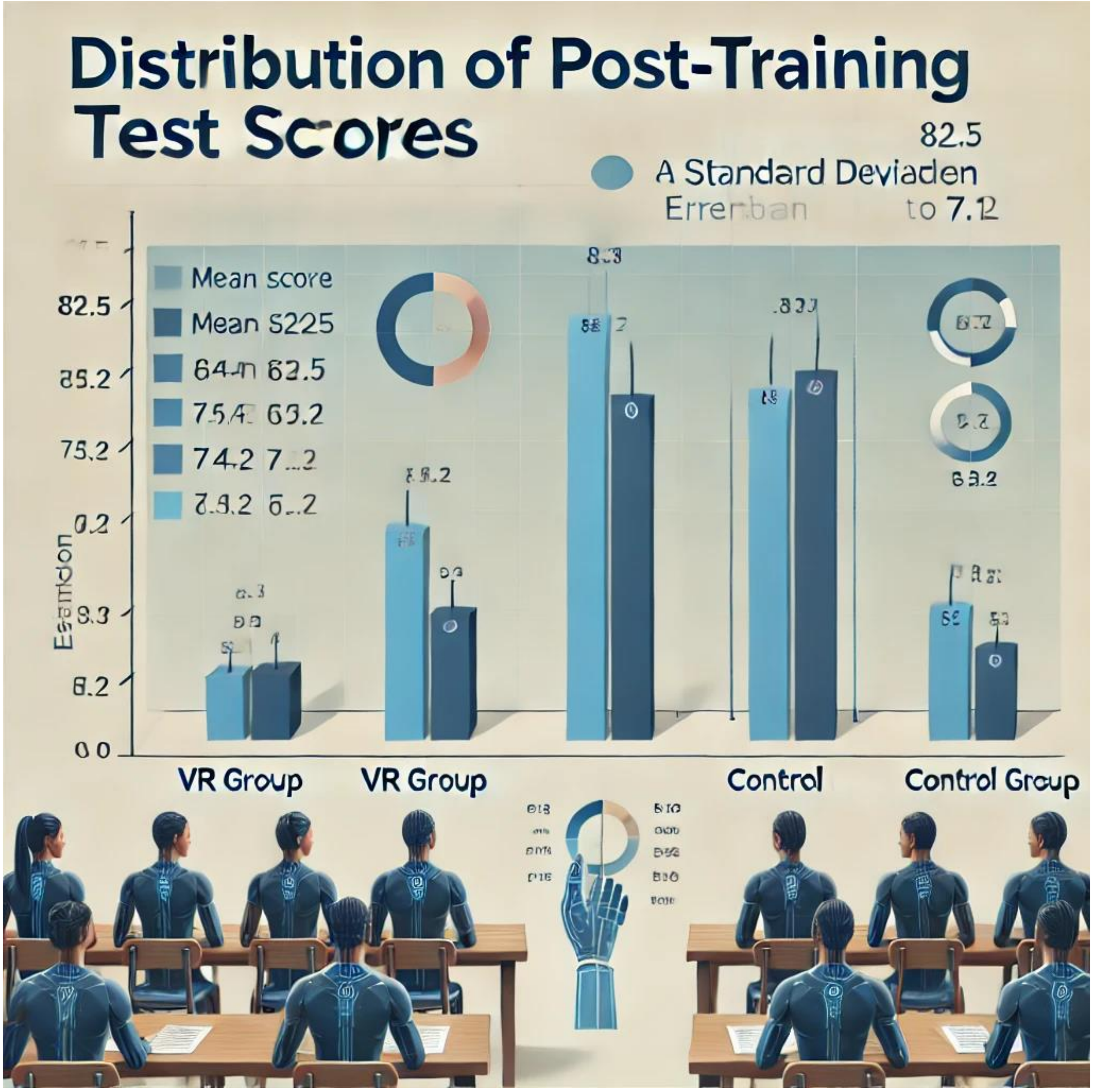


**Figure 1.** Distribution of Post-Training Test Scores

The graph titled "Distribution of Post-Training Test Scores" shows the comparison between the Virtual Reality Group and the Control Group. In the graph above, you can view the performance scores along with the standard deviation error bars for each group. The data suggests a strong relationship between Virtual Reality training and improved performance in mechanical skills tasks. This correlation is pivotal as it underscores the potential of Virtual Reality technology as an effective educational tool in engineering disciplines, where practical skills are crucial.

To further illustrate the impact of Virtual Reality on learning, a case study of two students, one from each group, was analyzed. The students from the Virtual Reality group showed a remarkable improvement in scores from the pre-test to the post-test, moving from 65 to 91. In contrast, the students from the control group showed only a modest improvement, from 62 to 75. These case studies help to highlight individual experiences and the transformative potential of Virtual Reality training. The case studies provide concrete examples of how Virtual Reality can significantly enhance learning by offering a more dynamic and engaging educational experience. These individual success stories are consistent with the broader data trends and reinforce the value of Virtual Reality in education.

These findings collectively affirm that Virtual Reality technology benefits the learning outcomes of mechanical engineering students. The data supports the hypothesis that Virtual Reality can enhance mechanical skill acquisition more effectively than traditional training methods. Moving forward, these insights could guide the expansion of Virtual Reality applications in education to other areas requiring hands-on learning.

The study demonstrated that students utilizing Virtual Reality technology to learn mechanical skills achieved significantly higher performance scores than those who received traditional training (Chang dkk., 2023). This enhancement was evident in the increased accuracy and speed of completing mechanical tasks. The results indicate that Virtual Reality provides a more effective learning environment for mechanical engineering students by offering immersive, interactive training that closely simulates real-world tasks (Comes dkk., 2024).

The data showed a clear advantage in using Virtual Reality to teach complex mechanical processes, as students in the Virtual Reality group outperformed their counterparts in nearly every measured aspect (Rybarczyk dkk., 2024). This improvement was statistically significant, suggesting that the observed benefits of Virtual Reality training are reliable and impactful. The Virtual Reality group performed better immediately after exercise and retained these skills more effectively (Li, 2022).

Additionally, the scores range within the Virtual Reality group was broader than that in the control group, highlighting an exciting variability in how different students benefit from Virtual Reality training (Ingale dkk., 2023). This variability indicates the potential need for further customization of Virtual Reality training programs to maximize effectiveness for all students. The results confirm that Virtual Reality can significantly enhance the educational process, providing an effective tool for training students in complex, skill-based disciplines such as mechanical engineering (Kittur & Islam, 2021). The increased engagement and interactive learning environment likely contribute to the improved outcomes observed.

This study's findings align with existing literature that praises Virtual Reality's efficacy in educational settings, particularly skill-specific training. Previous research has similarly reported improved learning outcomes when Virtual Reality is used in disciplines ranging from medicine to vocational training (Talbi dkk., 2023). This study extends those findings to mechanical engineering, illustrating Virtual Reality's broad applicability.

However, unlike some studies that report mixed results regarding Virtual Reality’s impact on learning outcomes, this research found a consistent advantage across various performance metrics. This difference could be due to the specific Virtual Reality technologies employed, the tasks’ nature, or the students’ demographic. Such factors are crucial in determining the effectiveness of educational technologies (Rossoni dkk., 2024). The comprehensive approach used in this study, including both short-term and long-term performance evaluations, provides a deeper understanding of Virtual Reality’s impact compared to studies that focus solely on immediate post-training assessments. This long-term perspective is essential for validating the sustained benefits of Virtual Reality training (Wu, 2023).

Furthermore, while many studies highlight Virtual Reality’s potential, few provide a detailed analysis of individual variability in response to Virtual Reality training. This study contributes to the literature by exploring these individual differences, offering insights into how Virtual Reality training can be tailored to maximize the benefits for all learners. The positive outcomes of this study indicate Virtual Reality’s potential to revolutionize how mechanical engineering skills are taught and learned. Virtual Reality’s ability to simulate complex, real-world environments provides students with a practical, hands-on learning experience without the associated risks and costs (Xie dkk., 2024).

These results also prompt a reconsideration of traditional educational models, especially in technical fields where practical skills are paramount. The efficacy of Virtual Reality suggests that academic institutions should consider integrating more technologically advanced tools into their curricula to stay abreast of industry standards and technological advancements (Xue, 2022). The variability in how students respond to Virtual Reality training suggests that future educational technologies should be adaptable to individual learning styles. This adaptability could enhance learning efficiency and make education more personalized and effective.

Moreover, the significant improvements seen in Virtual Reality-trained students highlight the importance of ongoing research and development in educational technology. This continual improvement is necessary to ensure that the academic benefits of technologies like Virtual Reality are maximized and accessible to a broader range of learners (Yang dkk., 2022).

The implications of this research are profound for educators, technology developers, and policymakers. For educators, the findings support the integration of Virtual Reality into mechanical engineering programs to enhance the quality and effectiveness of education. By adopting Virtual Reality, educational institutions can provide students with realistic, engaging experiences that improve their readiness for the professional world.

For developers of educational technologies, these results underscore the importance of creating and refining Virtual Reality applications tailored explicitly for education in technical fields. There is a transparent market and need for such technologies, and further development could help address the individual variability in learning responses. Policymakers should also consider these findings as they consider funding and resource allocation for educational technologies. Supporting the adoption of Virtual Reality in schools could lead to a more skilled workforce better prepared to meet the demands of modern industries.

Finally, the study highlights the potential for Virtual Reality to close gaps in educational outcomes that traditional methods have struggled to address. This could lead to more equitable educational opportunities and outcomes, particularly for students who may not excel in conventional learning environments. The superior performance of students trained with Virtual Reality can be attributed to the technology's immersive and interactive nature. Virtual Reality simulates real-world tasks in a controlled environment, allowing students to practice and repeat procedures until they achieve mastery. This experiential learning enhances understanding and retention of complex mechanical skills.

The engagement factor is also significant; Virtual Reality captures students' interest and attention more effectively than traditional methods. This increased engagement is likely a key driver behind the enhanced learning outcomes observed. Additionally, Virtual Reality's ability to provide immediate feedback allows students to learn from their mistakes in real-time, which is not always possible in traditional learning settings. This feedback loop is crucial for effective learning, particularly in complex physical tasks.

The differences in individual performance also suggest that Virtual Reality may facilitate personalized learning paths, enabling students to progress at their own pace and according to their learning styles. Traditional educational methods often lack this personalization, which can lead to discrepancies in learning outcomes. In light of these findings, the following steps involve further research to refine Virtual Reality training methodologies and expand their application across more disciplines. Additional studies should focus on long-term retention of skills and the transferability of Virtual reality-trained skills to actual work environments. These studies will help us understand how Virtual Reality can be fully integrated into educational curricula.

It is also essential to develop cost-effective Virtual Reality solutions to ensure that all educational institutions can benefit from this technology, regardless of their resources. Efforts should be made to make Virtual Reality more accessible and adaptable to different learning environments and needs. Educational institutions should consider pilot programs that integrate Virtual Reality into their curricula. These pilot programs can provide valuable insights into the practical challenges and benefits of Virtual Reality education, paving the way for broader implementation.

Lastly, educational institutions, technology developers, and policymakers need to collaborate to create supportive ecosystems for adopting Virtual Reality. These partnerships can help develop standards and best practices for Virtual Reality in education, ensuring its benefits are realized across the educational sector.

## CONCLUSION

This study has demonstrated that virtual reality technology significantly enhances the learning of mechanical skills compared to traditional methods. The empirical evidence showed that virtual reality students achieved higher scores, exhibited faster task completion, and reported greater satisfaction with their learning experience. These findings are critical as they validate the effectiveness of virtual reality in improving educational outcomes in technical disciplines, particularly in mechanical engineering, where practical skills are essential. The differential performance between the virtual reality and control groups highlights the transformative potential of immersive learning environments. Virtual reality facilitates a deeper understanding of mechanical operations and fosters a more engaging and interactive learning process. These aspects are crucial for education sectors aiming to equip students with advanced technical skills and competencies needed in the modern workforce.

This research contributes to the academic and practical understanding of virtual reality in education by focusing on its application in teaching complex mechanical skills. By employing a robust quasi-experimental design, the study provides a methodological framework that can be replicated and adapted in further research within and beyond mechanical engineering education. This methodological contribution is vital for future studies exploring the potential of virtual reality across various educational contexts. Moreover, integrating virtual reality into mechanical skills training constitutes a significant scholarly and practical contribution. The study’s findings support the notion that virtual reality can be an essential tool for educational innovation, offering a novel approach to addressing the challenges of teaching intricate and often dangerous skills safely and effectively.

One limitation of this study is its focus on short-term skill acquisition and retention. Long-term retention of skills learned through virtual reality and their transfer to real-world applications were not extensively explored. Future research should address these aspects to provide a more comprehensive understanding of the sustained impacts of virtual reality training on skill proficiency in professional settings. Another limitation is the study's relatively small and homogeneous sample size, consisting solely of urban university engineering students. Subsequent studies should include a more diverse participant pool to examine the effects of virtual reality training across different demographics and educational backgrounds. Expanding the research to include varied educational settings and comparing different virtual reality technologies will also help determine the most effective approaches for incorporating virtual reality into educational systems globally.

## REFERENCES

Aresh, B., Vichare, P., Dahal, K., Leslie, T., Gilardi, M., Lovska, A., & Vatulia, G. (2023). Integration of Extended Reality (XR) in Non-Native Undergraduate Programmes. *Proc. Int. Conf. Softw., Knowl., Inf. Manag. Appl., SKIMA*, 285–292. Scopus. https://doi.org/10.1109/SKIMA59232.2023.10387333

Aruanno, B., Tamburrino, F., Neri, P., & Barone, S. (2024). VR Lab: An Engaging Way for Learning Engineering and Material Science. Dalam Carfagni M., Furferi R., Di Stefano P., Governi L., & Gherardini F. (Ed.), *Lect. Notes Mech. Eng.* (hlm. 389–396). Springer Science and Business Media Deutschland GmbH; Scopus. https://doi.org/10.1007/978-3-031-52075-4_44

Barr, N. B., & Johnson, J. E. (2021). Trajectories in Turmoil: A Case Study of Engineering Students' Reactions to Disruptions in Their Community of Practice. *IEEE Transactions on Professional Communication*, *64*(1). Scopus. https://doi.org/10.1109/TPC.2021.3057149

Bendigeri, C., & Devaraj, E. (2023). Advances in design and manufacturing of VR headset. Dalam *Metaverse and Immersive Technol.: An Introd. To Ind., Bus. And Soc. Appl.* (hlm. 191–216). wiley; Scopus. https://doi.org/10.1002/9781394177165.ch7

Chang, Y.-S., Wang, Y.-Y., & He, J.-Y. (2023). Effects of Virtual Reality on Mechanical Arm Learning. *Proc. - Asia Conf. Cogn. Eng. Intel. Interact., CEII*, 13–19. Scopus. https://doi.org/10.1109/CEII60565.2023.00011

Comes, R., Buna, Z. L., Rozsos, R. S., & Pop, G. M. (2024). Augmented Reality Guided 3D Printed Robotic Arm Assembly: A Comprehensive Framework for Interactive Learning. Dalam Pisla D., Vaida C., Carbone G., & Condurache D. (Ed.), *Mech. Mach. Sci.: Vol. 157 MMS* (hlm. 297–305). Springer Science and Business Media B.V.; Scopus. https://doi.org/10.1007/978-3-031-59257-7_30

Cordero-Guridi, J.-J., Cuautle-Gutiérrez, L., Alvarez-Tamayo, R.-I., & Caballero-Morales, S.-O. (2022). Design and Development of a I4.0 Engineering Education Laboratory with Virtual and Digital Technologies Based on ISO/IEC TR 23842-1 Standard Guidelines. *Applied Sciences (Switzerland)*, *12*(12). Scopus. https://doi.org/10.3390/app12125993

De Souza, N., Ochotorena, M., Self, B. P., & Cooper, L. A. (2021). Sudden Shift to Online Learning: COVID-19's Impact on Engineering Student Experiences. *ASEE Annu. Conf. Expos. Conf. Proc.* ASEE Annual Conference and Exposition, Conference Proceedings. Scopus. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85124531326&partnerID=40&md5=0b5dab4dfad6019cbd83353ee32b98bc

Dillulio, P., Kravchenko, O. G., & Cigularov, K. (2022). Enabling Resilient Educational Support Network during COVID-19 Pandemic for Undergraduate and Second Career Seeking Students. *ASEE Annu. Conf. Expos. Conf. Proc.* ASEE Annual Conference and Exposition, Conference Proceedings. Scopus.

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85138249263&partnerID=40&md5=00620d3628357596519a78fc78e3297b

Elefante, E., & Vindrola, P. G. (2024). Integration of BIM Methodology and AR Technologies for Piping Learning in Buildings. Dalam Manchado del Val C., Suffo Pino M., Moreno Sánchez D., Moreno Nieto D., & Miralbes Buil R. (Ed.), *Lect. Notes Mech. Eng.* (hlm. 270–279). Springer Science and Business Media Deutschland GmbH; Scopus. https://doi.org/10.1007/978-3-031-51623-8_26

Feng, L., & Zhang, W. (2022). Design and Implementation of Computer-Aided Art Teaching System based on Virtual Reality. *Computer-Aided Design and Applications*, *20*, 56–65. Scopus. https://doi.org/10.14733/CADAPS.2023.S1.56-65

Guo, K., Liu, L., Yuan, S., Yang, M., Liu, S., Xu, T., & Wu, F. (2021). Teaching Demonstration of Reducer Based on Augmented Reality Technology. Dalam Wang Y., Martinsen K., Yu T., & Wang K. (Ed.), *Lect. Notes Electr. Eng.* (Vol. 737, hlm. 189–195). Springer Science and Business Media Deutschland GmbH; Scopus. https://doi.org/10.1007/978-981-33-6318-2_24

Hall, O., & Seth, D. (2022). Development and evaluation of a classroom activity to promote integration of engineering with other academic disciplines. *Proc. Front. Educ. Conf. FIE*, *2022-October*. Scopus. https://doi.org/10.1109/FIE56618.2022.9962511

Huo, J., & Zhang, G. (2021). High-Temperature Environmental Protection Metal Material 3D Printing Equipment Development and Process Research. *Advances in Materials Science and Engineering*, *2021*. Scopus. https://doi.org/10.1155/2021/2701848

Ingale, A. K., Divya Udayan, J., & Patil, S. P. (2023). VREd: Virtual Reality in Engineering Education for Immersed and Interactive Learning: A Case Study. Dalam Fong S., Dey N., & Joshi A. (Ed.), *Lect. Notes Networks Syst.* (Vol. 517, hlm. 543–551). Springer Science and Business Media Deutschland GmbH; Scopus. https://doi.org/10.1007/978-981-19-5224-1_55

Kittur, J., & Islam, T. (2021). Serious Games in Engineering: The Current State, Trends, and Future. *ASEE Annu. Conf. Expos. Conf. Proc.* ASEE Annual Conference and Exposition, Conference Proceedings. Scopus. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85124533595&partnerID=40&md5=2a5e2372d5ed62b75bdef9553fdddec6

Kohl, L., Stricker, P., Reisinger, J., & Ansari, F. (2024). DigiTeachVR: Digitally-Enhanced Teaching Platform for Improving Data Science Skills and Virtual Reality Competences in Cross-Disciplinary Engineering Education. Dalam Thiede S. & Lutters E. (Ed.), *Lect. Notes Networks Syst.: Vol. 1060 LNNS* (hlm. 50–57). Springer Science and Business Media Deutschland GmbH; Scopus. https://doi.org/10.1007/978-3-031-65400-8_6

Krajčovič, M., Gabajová, G., Matys, M., Furmannová, B., & Dulina, Ľ. (2022). Virtual Reality as an Immersive Teaching Aid to Enhance the Connection between Education and Practice. *Sustainability (Switzerland)*, *14*(15). Scopus. https://doi.org/10.3390/su14159580

Krajčovič, M., Matys, M., Gabajová, G., & Komačka, D. (2024). Utilization of Immersive Virtual Reality as an Interactive Method of Assignment Presentation. *Electronics (Switzerland)*, *13*(8). Scopus. https://doi.org/10.3390/electronics13081430

Li, S. (2022). Design of Intelligent Manufacturing Training Platform Combining Virtual and Real. *Proc. - Asia Symp. Signal Process., ASSP*, 92–95. Scopus. https://doi.org/10.1109/ASSP57481.2022.00023

Morosi, F., & Cascini, G. (2024). Virtual Reality Workshop for Massive Laboratory Learning Experience of Engineering Students. Dalam Carfagni M., Furferi R., Di Stefano P., Governi L., & Gherardini F. (Ed.), *Lect. Notes Mech. Eng.* (hlm. 414–422). Springer Science and Business Media Deutschland GmbH; Scopus. https://doi.org/10.1007/978-3-031-52075-4_47

Ngo, M., Welsh, E., Studer, K., Comeau, B., Fang, N. X., & Liu, J. (2022). Opening Up the Black Box: An Augmented Reality Look into the Scanning Electron Microscope. *ASEE Annu. Conf. Expos. Conf. Proc.* ASEE Annual Conference and Exposition, Conference Proceedings. Scopus. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85138296771&partnerID=40&md5=b2de3ca74853bb68bdaadec9bdecc01b

Rossoni, M., Spadoni, E., Carulli, M., Barone, C., Colombo, G., & Bordegoni, M. (2024). Virtual Reality in Education to Enable Active Learning and Hands-on Experience. *Computer-Aided Design and Applications*, *21*(2), 258–269. Scopus. https://doi.org/10.14733/cadaps.2024.258-269

Rybarczyk, J., Dorna, P., Górski, F., Kuczko, W., & Żukowska, M. (2024). Personalized Mechatronic Lower Limb Orthosis. Dalam Machado J., Soares F., Trojanowska J., Yildirim S., Vojtěšek J., Rea P., Gramescu B., & Hrybiuk O.O. (Ed.), *Lect. Notes Mech. Eng.* (hlm. 325–336). Springer Science and Business Media Deutschland GmbH; Scopus. https://doi.org/10.1007/978-3-031-61575-7_30

Talbi, K., Zergout, I., & Souad, A. (2023). Analytical study of Virtual reality in Moroccan higher education. *Colloq. Inform. Sci. Technol., CIST*, 503–507. Scopus. https://doi.org/10.1109/CiSt56084.2023.10409978

Vetiska, J., Holub, M., Blecha, P., Bradac, F., Brazina, J., Stanek, V., Kroupa, J., & Tuma, Z. (2021). Industry 4.0 in Educational Process. Dalam Durakbasa N.M. & Gençyılmaz M.G. (Ed.), *Lect. Notes Mech. Eng.* (hlm. 324–332). Springer Science and Business Media Deutschland GmbH; Scopus. https://doi.org/10.1007/978-3-030-62784-3_27

Wahsh, M. A., & Hussain, Z. M. (2023). A Systematic Literature Review of Using Virtual Reality in Laboratory Education. Dalam Kumbhalkar M.A., Gajghat R., Kene J.D., & Rambhad K.S. (Ed.), *AIP Conf. Proc.* (Vol. 2839, Nomor 1). American Institute of Physics Inc.; Scopus. https://doi.org/10.1063/5.0169658

Weis, P., Smetanka, L., Hrček, S., & Vereš, M. (2024). Interactive Application as a Teaching Aid in Mechanical Engineering. *Computers*, *13*(7). Scopus. https://doi.org/10.3390/computers13070170

Win, L. L., Aziz, F. A., Hairuddin, A. A., Abdullah, L. N., Yap, H. J., Saito, H., & Seyajah, N. (2022). EFFECTIVENESS ON TRAINING METHOD USING VIRTUAL REALITY AND AUGMENTED REALITY APPLICATIONS IN AUTOMOBILE ENGINE ASSEMBLY. *ASEAN Engineering Journal*, *12*(4), 83–88. Scopus. https://doi.org/10.11113/aej.V12.18009

Wu, W. (2023). Research on the Construction of Virtual Simulation Teaching for Foreign Language Majors in Science and Technology Against the Backdrop of New Liberal Arts. *ACM Int. Conf. Proc. Ser.*, 49–53. Scopus. https://doi.org/10.1145/3660043.3660052

Xie, J., Wang, Y., Wang, X., & Li, J. (2024). A VR-based practice cultivation mode for mechanical engineering graduates to enhance complex engineering abilities. *International Journal of Mechanical Engineering Education*. Scopus. https://doi.org/10.1177/03064190241266066

Xie, J., Yan, Z., & Wang, X. (2023). A VR-based interactive teaching and practice environment for supporting the whole process of mining engineering education. *Mining Technology: Transactions of the Institutions of Mining and Metallurgy*, *132*(2), 89–105. Scopus. https://doi.org/10.1080/25726668.2023.2177737

Xue, M. (2022). Exploration and Application of Virtual Reality Technology in Mechanical Manufacturing Teaching. *International Journal of Emerging Technologies in Learning*, *17*(15), 243–250. Scopus. https://doi.org/10.3991/ijet.v17i15.31927

Yang, B., Yang, S., Lv, Z., Wang, F., & Olofsson, T. (2022). Application of Digital Twins and Metaverse in the Field of Fluid Machinery Pumps and Fans: A Review. *Sensors*, *22*(23). Scopus. https://doi.org/10.3390/s22239294