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# Development of Interactive Virtual Reality Application for Simulating Experimental Tensile Test

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***Abstract .*** *Information technology has significantly transformed traditional educational systems into adaptable forms of learning. Experimental tension test is a practical study included in the mechanical engineering curriculum, specifically as a part of Material and Metallurgy. The fundamental issue arises from the deficiency in comprehending the understanding of mechanical properties, which is a result of traditional educational methods. Virtual reality (VR) technology enhances the comprehension of the study of material properties for students studying mechanical engineering. This study presents a virtual reality tool, called VR experimental tensile test. It is intended to be utilized in flexible learning. Students as a user can investigate and examine the utilization of the program for learning and conducting safety lab orientation. The application evaluation was conducted using the User Experience Questionnaire (UEQ). This study suggests that using 3D model visualization in the virtual reality application enhances user experiences in learning tensile test and follow its lab orientation.*

***Keywords**: Virtual Reality; Virtual Lab; Tensile Test; Engineering education; Material science.*

## INTRODUCTION

Technological advances have directed a significant rise to the current Industrial Revolution. One of the technology enablers of the current industrial revolution is augmented reality (AR) and virtual reality (VR) technology (Rüßmann et al., 2015). Virtual Reality technology is possibly developed to replicate the real world in artificial environment and visualization which can be used for any applications: safety, simulation, working orientation, learning, entertainment, and others.. This technology can stimulate a user to have an immersive ambiance of a virtual environment with an interactive device and can achieve learning objectives effectively (Ahmed & Hasegawa, 2021). Moreover, many large industrial companies have developed virtual reality technology because this technology can simulate a job that is so similar to the real world. But simulation of the job is carried out in cyberspace using artificial environment technology, for example, military training, medical training, and many others relevant task training (Ragan et al., 2015; Stefan et al., 2023).

On the other hand, the expansion work of implemented VR technology is not only in industrial sectors but also in education sectors (Talaba et al., 2010). With its promising scientific development, a large number of researchers from academia have explored VR technology for giving support to the teaching-learning process (Extremera et al., 2022). Some relevant terms of VR technology applications used in academia such as: Online Virtual Laboratories (OVLs) and Virtual Laboratory (VL). Online Virtual Laboratories (OVLs) which included the use of VR technology, is considered as an ICT tool for teaching practical skills

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(Ahmed & Hasegawa, 2021). The OVL platform was developed to support instructors teaching real laboratory experiments in multi-domains. Virtual Laboratories (VLs) based on the use of virtual reality (VR) is developed to facilitate the teaching-learning process in practical applications both academic and professional (Vergara et al., 2022). Virtual Laboratory is designed by creating 3D virtual environment and programming Virtual Laboratory which excessively uses VR technology. The combination of VL dan real laboratories is a new hybrid teaching method: online learning and face-to-face learning.

In addition to supporting learning process, VR technology is also able to present significant opportunities to present into learning environment with potentially dangerous risky laboratory experiments. The use of VR technology has been developed in chemistry (Fombona-Pascual et al., 2022; Li et al., 2023; Tee et al., 2018), medicine (Pelargos et al., 2017), hazard management (Lovreglio et al., 2018), construction (Chacón et al., 2020), mechanical engineering (Extremera et al., 2022; Syed et al., 2017). Furthermore, by using virtual reality, students and users can learn new skills in virtual environments and at the same time they can access laboratory safety orientation and training. One study of VR applications which presented the use in education and training (Jensen & Konradsen, 2018). Other works include that by Chan (Chan, Bernaerts, et al., 2023; Chan, Van Gerven, et al., 2023) and by Poyade (Poyade et al., 2021) which present VR technology used in education and lab safety training in field of chemistry. In mechanical engineering, Hernandez developed VR application both education and training (Hernández-Chávez et al., 2021) and Tang presented a conventional virtual reality modelling language of Material Mechanical Testing for teaching and experimental training. With VR equipment, students can interact with realistic laboratory experience in 3D environments as a safety relevant training and a lab orientation before using experimental equipment and conducting real experiment in laboratory.

Material science and engineering is one of the core subjects in mechanical engineering curriculum to understand material properties. Learning material science can not be separated from experimental lab activities such as non-destructive test, bending test, tensile test, impact test, heat treatment and any other destructive tests. To tackle some risky those laboratory experiments, large numbers of virtual reality applications developed with the purpose of aiding support for teaching and learning process in material science: compression test (Vergara et al., 2014), impact test and creep test (Tang & Wu, 2010), Hardness test (Rubio et al., 2019), tensile test and deep drawing test (Ortelt & Ruider, 2017), alloy material properties (Tarng et al., 2019).

In connection with the mentioned background, the authors are interested in discussing the application of VR technology of tensile test to be implemented into learning process and safety training. The purpose of implementing this technology is to deliver material testing and to minimize workplace accidents so that it can facilitate the experimental orientation practice of tensile testing in laboratory.

## METHOD

To develop an interactive virtual reality application of experimental material testing, it is necessary to conduct real material testing and to create a replicated 3D environment. In this study, an experimental tensile test of stainless-steel material ST42 using ASTM Standard A370 was chosen. The materials needed and the specifications in this study can be seen in Figure 1 and Table 1 below. The tensile test was carried out in a manual universal testing machine. In the development of VR application of tensile test, there are 4 stages required as follows:

1. Material testing preparations
2. Conduct tensile test and result
3. VR application design, development, and testing
4. Conduct User Experience Questionnaire

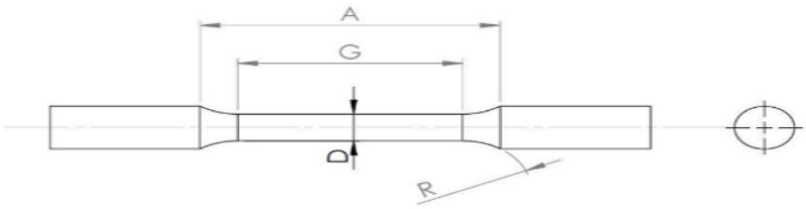


Figure 1 Specimen Stainless Steel ST42

**Table 1 ST42 Steel Specimen Dimensions**

| Symbol | Dimension | Unit (mm) |
|---|---|---|
| G | Gage Length | 50.0±0.10 |
| D | Diameter | 12.5±0.25 |
| R | Radius of Fillet | 10 |
| A | Length of Red Sector | 60 |

In detail of development stages, the first stage comes with tensile test preparation and conducts experimental tensile test including its result analysis. After tensile test observation finished, then the development of VR application begins. The last stage is carrying user experience questionnaire (UEQ) out to students in material and metallurgy science class. Below, Figure 2 is presented to show the VR application research flowchart.

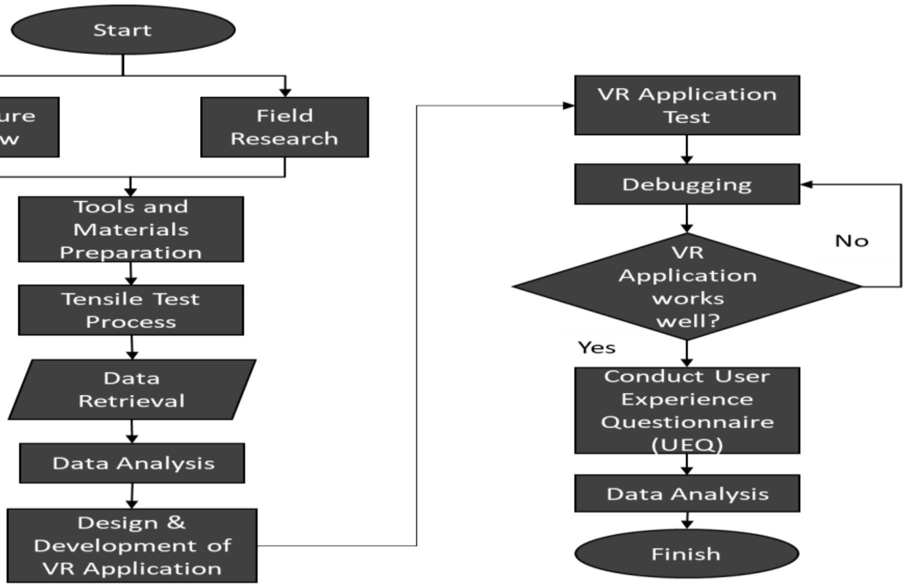


Figure 2 Research methodology flowchart

## SYSTEM IMPLEMENTATION

### 1. Design

There are several designs in the creation of Virtual Reality, including the following:

#### a. User Interface Design

The Tensile Test Virtual Reality User Interface is designed to be as attractive as possible so that users can easily use it. The User Interface design consists of the Initial User Interface and the Preview User Interface

#### b. Architectural Design

Architecture in Virtual Reality contains floor plans. Architectural designs are created using the Sketchup application and then imported into the Unity application. The detailed explanation can be seen in Figure 3.

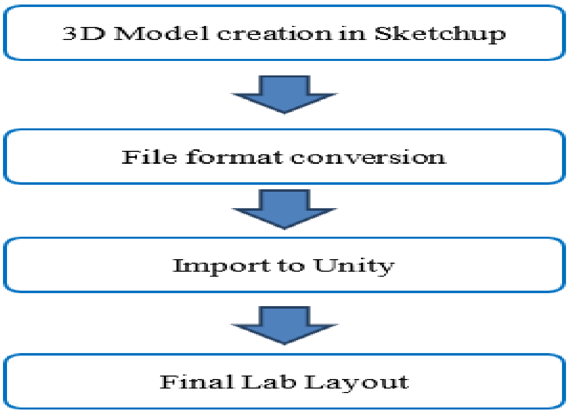


Figure 3 Diagram of architecture design

### c. 3D Modelling Design

The 3D character modeling system using the Unity Engine starts with Meshing or modeling. When the model is finished, then the next stage is rigging or forming bones to run the animation. The next stage is Animating, which is making an animation of the rigged model. The final stage is Texturing or giving texture to the model.

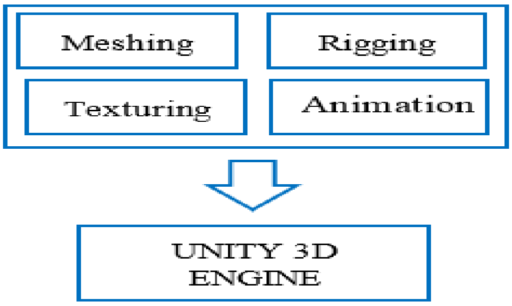


Figure 4 Diagram of 3D modelling design

### d. Graphic Design

This stage is the process of determining the graphics of the Virtual Reality display. Drawing design is an important part and determines success in the Virtual Reality Tensile Test. Images must be designed as attractively as possible to avoid boredom from the user or users. What needs to be designed in this medium is:

1. User Interface (UI)
2. Room Plan Design
3. Object design (Tensile Testing Machine)
4. Giving Textures
5. Animation Design

## 2. Virtual Reality Planning

This planning stage consists of various designs according to Figure 5 below.

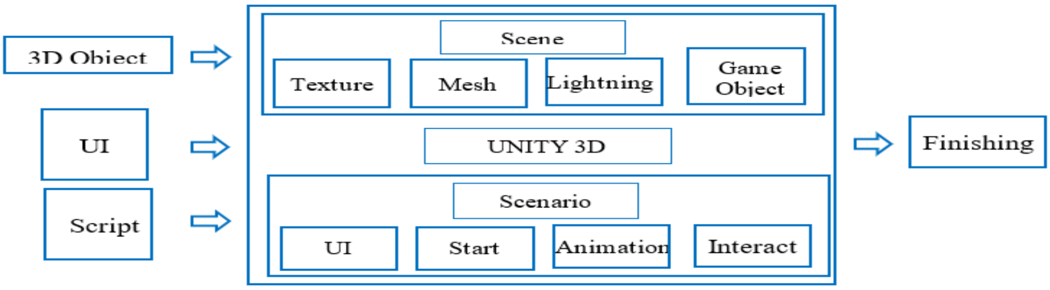


Figure 5 Virtual Reality Planning

In detail, there are 3 general stages in the creation of Virtual Reality. The first stage is making 3D Objects, User Interfaces, and Scripts. The second stage is scene creation and scenario planning in the Unity application. The third stage is finishing covering problem analysis and searching for application bugs. In 3D object design, room plan design of material laboratory and the tensile test machine can be seen in Figure 6 and Figure 7.

After all 3D object finished, then VR planning steps were done in Unity. Figure 8 is a Tensile testing machine design imported into Unity with fbx file format. This format can be separated in parts to facilitate animation.  The final VR tensile test application can be seen in Figure 9.

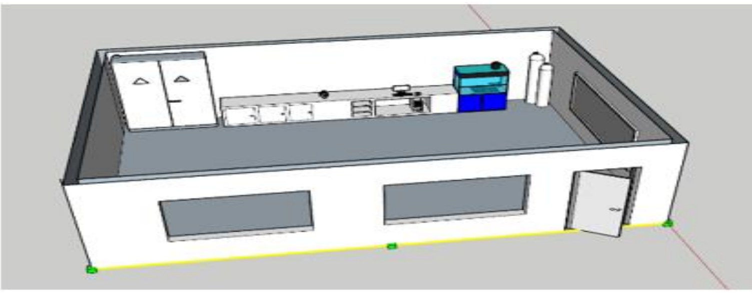

Figure 6 Room plan design

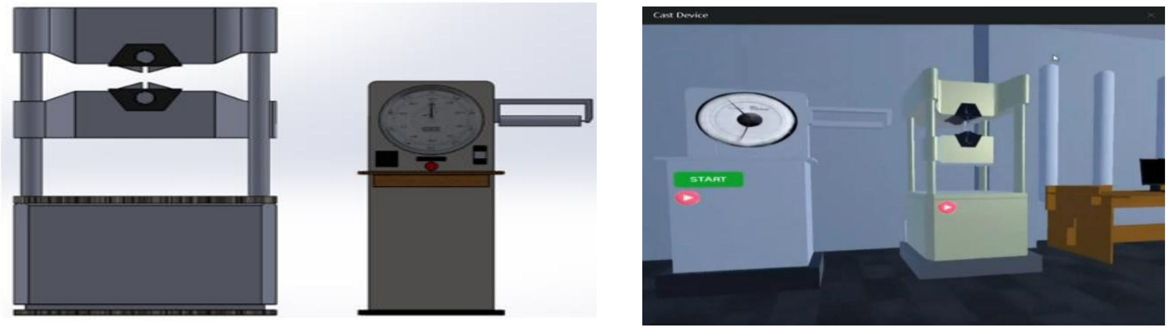


*Figure 7 (a) Tensile Test Machine Design (b) Tensile Test Machine in VR Application*

*Figure 8 Tensile test machine design after export*


Figure 9 Virtual reality application in use

## RESULT AND DISCUSSION

After the development of experimental tensile test's virtual reality application finished, then this virtual technology was tested into our Mechanical Engineering (vocational students) in material and metallurgy class is resulted in multimedia which can be used by students in departments. In this study, we also conducted a quantitative test on virtual reality tensile test that has been developed. This evaluation was conducted to observe the use of this application on studying process of the subject.

The virtual reality tensile test application is an opportunity for unprecedented interaction for students with limitation. For example, students who have limitations in accessing laboratory experiments, especially in the pandemic or other limited condition, which requires activities to be carried out in a limited manner and carried out online. With the virtual reality tensile test, students can still conduct the tensile test experiment with the virtual reality tensile test anywhere and anytime without reducing practical experience and knowledge compared to students who perform practicum directly in the laboratory.

The virtual reality tensile test is an easy-to-use and informative application. There are instructions for how to use the application and testing procedures, and there is detailed information from the test that can be displayed on the screen. By reading the instructions students can easily use the application by following the instructions on how to use the application.


Figure 10 User instructions in the VR tensile test application

Then by following the provided testing procedures and reading the basic theory, students have guidance on how to conduct the test and associate practice with theory. Students can find out detailed information from the test such as specifications of the workpiece and stress-strain graphs of the test results as shown in Figure 11.

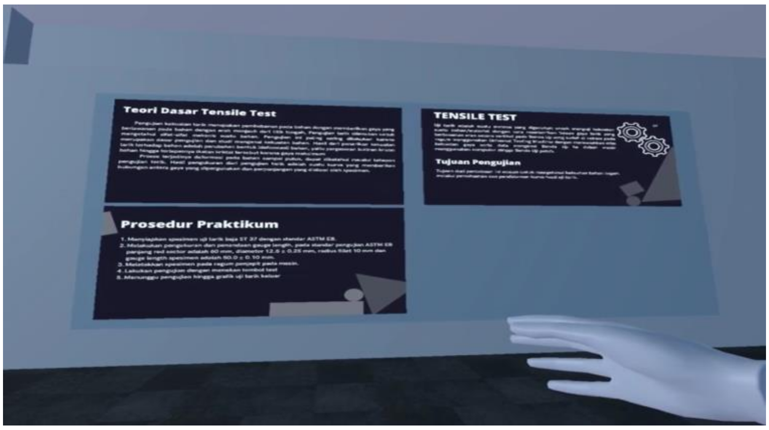


Figure 11 Test procedure and the basic theory of tensile test

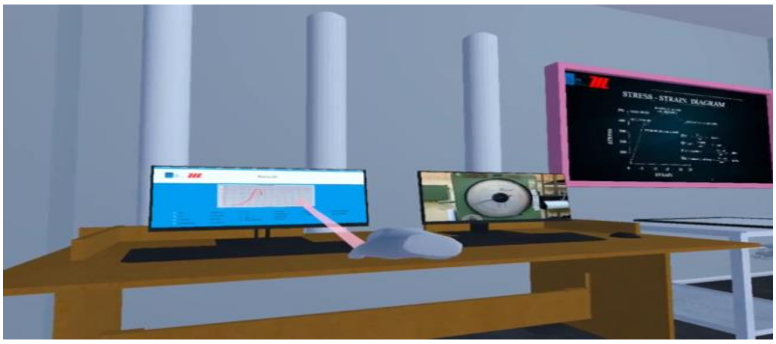

Figure 12 Detailed information display in VR application

In this study, the User Experience Questioner (UEQ) was administered and distributed to 54 students of Materials and Metallurgy class. Students participating in this study had tried the VR application and completed the UEQ form on a smartphone, tablet, or personal computer. The UEQ assessment was distributed into 26 questions and classified them into 6 UEQ categories: attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty (Ahram & Falcão, 2017). Through this study, utility measurement was carried out to determine the level of user perception in using the VR application. The UEQ results of the VR application are presented in the table 2 below. Based on the Figure 13, it can be seen that the attractiveness, dependability and stimulation category have 'excellent' level. This means the students were very interested in using the VR tensile test application. For some other categories, Efficiency, Novelty and Perspicuity (clarity), the users felt the application is supportive learning media, innovative and easily understood by the user.

Table 2 UEQ Scale Result of The VR Tensile Test Application

| Scale | Mean | Std. Dev. | N | Confidence | Confidence interval | |
|---|---|---|---|---|---|---|
| Attractiveness | 1,973 | 0,799 | 54 | 0,213 | 1,760 | 2,186 |
| Perspicuity | 1,513 | 0,940 | 54 | 0,251 | 1,263 | 1,764 |
| Efficiency | 1,589 | 0,934 | 54 | 0,249 | 1,340 | 1,838 |
| Dependability | 1,750 | 0,862 | 54 | 0,230 | 1,520 | 1,980 |
| Stimulation | 1,982 | 1,008 | 54 | 0,269 | 1,713 | 2,251 |
| Novelty | 1,438 | 1,044 | 54 | 0,278 | 1,159 | 1,716 |

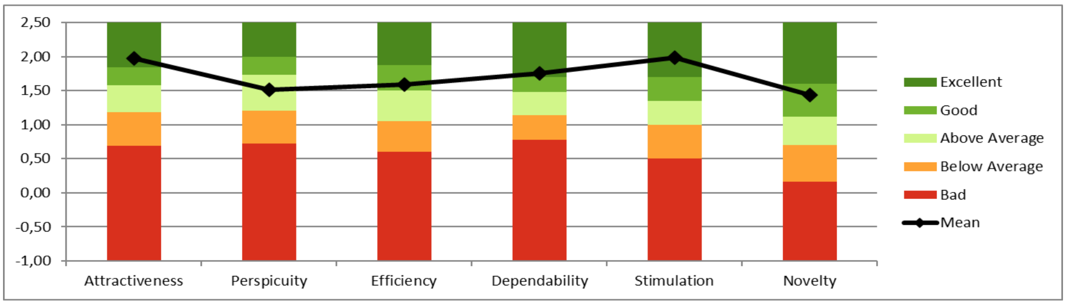


Figure 13 UEQ scale result of the VR tensile test application

And the figure above illustrates the results of the VR application. Based on the data above, the highest value is stimulation. This means that students are excited and motivated to use the VR application and feel it is fun to use it to learn and practice online tensile test.

## CONCLUSION

The conclusion from testing the virtual test application that it can provide information interactively that supports the application function as a virtual safety lab orientation and learning media. The VR application works well and already used by students engaged in material and metallurgy class. In general, the UEQ values are in the ‘above average’ to ‘excellent’ range.

## REFERENCES

Ahmed, M. E., & Hasegawa, S. (2021). Development of online virtual laboratory platform for supporting real laboratory experiments in multi domains. *Education Sciences*, *11*(9). https://doi.org/10.3390/educsci11090548

Ahram, T., & Falcão, C. (2017). *Advances in Usability and User Experience: Proceedings of the AHFE 2017 International Conference on Usability and User Experience, July 17-21, 2017, The Westin Bonaventure Hotel, Los Angeles, California, USA* (Vol. 607). Springer.

Chacón, R., Claure, F., & de Coss, O. (2020). Development of VR/AR Applications for Experimental Tests of Beams, Columns, and Frames. *Journal of Computing in Civil Engineering*, *34*(5). https://doi.org/10.1061/(asce)cp.1943-5487.0000908

Chan, P., Bernaerts, K., Van Gerven, T., & Dubois, J.-L. (2023). *Virtual Reality Serious Game for Chemical Lab Safety Training in Industry and Academia: from Design, Development to Increased Motivation and Engagement*.

Chan, P., Van Gerven, T., Dubois, J. L., & Bernaerts, K. (2023). Study of motivation and engagement for chemical laboratory safety training with VR serious game. *Safety Science*, *167*(July), 106278. https://doi.org/10.1016/j.ssci.2023.106278

Extremera, J., Vergara, D., Rodríguez, S., & Dávila, L. P. (2022). Reality-Virtuality Technologies in the Field of Materials Science and Engineering. *Applied Sciences*, *12*(10), 4968. https://doi.org/10.3390/app12104968

Fombona-Pascual, A., Fombona, J., & Vázquez-Cano, E. (2022). VR in chemistry{,} a review of scientific research on advanced atomic/molecular visualization. *Chem. Educ. Res. Pract.*, *23*(2), 300–312. https://doi.org/10.1039/D1RP00317H

Hernández-Chávez, M., Cortés-Caballero, J. M., Pérez-Martínez, Á. A., Hernández-Quintanar, L. F., Roa-Tort, K., Rivera-Fernández, J. D., & Fabila-Bustos, D. A. (2021). Development of virtual reality automotive lab for training in engineering students. *Sustainability (Switzerland)*, *13*(17). https://doi.org/10.3390/su13179776

Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies*, *23*(4), 1515–1529. https://doi.org/10.1007/s10639-017-9676-0

Li, Z., Cao, Y., & Luo, J. (2023). Proceedings of the 2022 2nd International Conference on Education, Information Management and Service Science (EIMSS 2022). In *Proceedings of the 2022 2nd International Conference on Education, Information Management and Service Science (EIMSS 2022)* (Vol. 2). Atlantis Press International BV. https://doi.org/10.2991/978-94-6463-024-4

Lovreglio, R., Gonzalez, V., Feng, Z., Amor, R., Spearpoint, M., Thomas, J., Trotter, M., & Sacks, R. (2018). Prototyping virtual reality serious games for building earthquake preparedness: The Auckland City Hospital case study. *Advanced Engineering Informatics*, *38*, 670–682.

Ortelt, T. R., & Ruider, E. (2017). Virtual lab for material testing using the Oculus Rift. *2017 4th Experiment@ International Conference (Exp. at'17)*, 145–146.

Pelargos, P. E., Nagasawa, D. T., Lagman, C., Tenn, S., Demos, J. V, Lee, S. J., Bui, T. T., Barnette, N. E., Bhatt, N. S., Ung, N., & others. (2017). Utilizing virtual and augmented reality for educational and clinical enhancements in neurosurgery. *Journal of Clinical Neuroscience*, *35*, 1–4.

Poyade, M., Eaglesham, C., Trench, J., & Reid, M. (2021). A transferable psychological evaluation of virtual reality applied to safety training in chemical manufacturing. *ACS Chemical Health \& Safety*, *28*(1), 55–65.

Ragan, E. D., Bowman, D. A., Kopper, R., Stinson, C., Scerbo, S., & McMahan, R. P. (2015). Effects of field of view and visual complexity on virtual reality training effectiveness for a visual scanning task. *IEEE Transactions on Visualization and Computer Graphics*, *21*(7), 794–807. https://doi.org/10.1109/TVCG.2015.2403312

Rubio, M. P., Vergara, D., Rodr\'\iguez, S., & Extremera, J. (2019). Virtual reality learning environments in materials engineering: Rockwell hardness test. *Methodologies and Intelligent Systems for Technology Enhanced Learning, 8th International Conference 8*, 106–113.

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). Industry 4.0 - BCG Report. *The Boston Consulting Group*, 1–20. https://doi.org/10.1007/s12599-014-0334-4

Stefan, H., Mortimer, M., & Horan, B. (2023). Evaluating the effectiveness of virtual reality for safety-relevant training: a systematic review. In *Virtual Reality* (Vol. 27, Issue 4). Springer London. https://doi.org/10.1007/s10055-023-00843-7

Syed, Z. A., Wang, T., Frady, K. K., Madathil, K. C., Bertrand, J., Hartley, R. S., Wagner, J. R., & Gramopadhye, A. K. (2017). Use of virtual reality tools in an undergraduate mechanical engineering manufacturing course. *ASEE Annual Conference and Exposition, Conference Proceedings*, *2017-June*. https://doi.org/10.18260/1-2--29067

Talaba, D., Horváth, I., & Lee, K. H. (2010). Special issue of Computer-Aided Design on virtual and augmented reality technologies in product design. *Computer-Aided Design*, *42*(5), 361–363. https://doi.org/10.1016/j.cad.2010.01.001

Tang, J. L., & Wu, F. S. (2010). VRML-based laboratory system for material mechanical performance testing. *CAR 2010 - 2010 2nd International Asia Conference on Informatics in Control, Automation and Robotics*, *1*, 202–205. https://doi.org/10.1109/CAR.2010.5456867

Tarng, W., Chen, C. J., Lee, C. Y., Lin, C. M., & Lin, Y. J. (2019). Application of virtual reality for learning the material properties of shape memory alloys. *Applied Sciences (Switzerland)*, *9*(3). https://doi.org/10.3390/app9030580

Tee, N. Y. K., Gan, H. S., Li, J., Cheong, B. H.-P., Tan, H. Y., Liew, O. W., & Ng, T. W. (2018). Developing and demonstrating an augmented reality colorimetric titration tool. *Journal of Chemical Education*, *95*(3), 393–399.

Vergara, D., Fernández-Arias, P., Extremera, J., Dávila, L. P., & Rubio, M. P. (2022). Educational trends post COVID-19 in engineering: Virtual laboratories. *Materials Today: Proceedings*, *49*, 155–160. https://doi.org/10.1016/j.matpr.2021.07.494

Vergara, D., Rubio, M. P., & Lorenzo, M. (2014). Interactive virtual platform for simulating a concrete compression test. *Key Engineering Materials*, *572*(1), 582–585. https://doi.org/10.4028/www.scientific.net/KEM.572.582