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The Roles of Virtual Reality and Augmented Reality During The COVID-19 Pandemic

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ABSTRACT

Abstract: *This paper aims to describe the roles of virtual reality and augmented reality during the COVID-19 pandemic. Method of the study: It is a narrative literature review. Literature was searched in Science Direct and Google Scholar databases. Review and research paper were included. Short notes and commentary were excluded. Results revealed that the invention of Augmented-Reality, Virtual-Reality, and Mixed-Reality technologies gives integrations of virtual and physical objects. Those technologies have many usages in education, experiments, manufacture, and business. Users can have hybrid experiences because the combination of the interactive physical and virtual connections. In business, the interested customers will buy the products. In education, these technologies will help the students in learning process. In healthcare, it can be done to do simulation for preventing the COVID-19 pandemic. In conclusion, the roles of augmented reality and virtual reality are very essential, such as in health, education, business, manufacture, and experiments.*

Abstrak: Tulisan ini bertujuan untuk mendeskripsikan peran *virtual reality* dan *augmented reality* selama pandemi COVID-19. Metode penelitian adalah tinjauan literatur naratif. Literatur dicari di *database* Science Direct dan Google Scholar. Review dan makalah penelitian merupakan kriteria inklusi. Catatan pendek dan komentar diekslusikan. Hasil penelitian mengungkapkan bahwa penemuan teknologi *Augmented-Reality, Virtual-Reality,* dan *Mixed-Reality* memberikan integrasi objek virtual dan fisik. Teknologi tersebut memiliki banyak kegunaan dalam pendidikan, eksperimen, manufaktur, dan bisnis. Pengguna dapat memiliki pengalaman hybrid karena kombinasi koneksi fisik dan virtual interaktif. Dalam bisnis, pelanggan yang tertarik akan membeli produk. Dalam dunia pendidikan, teknologi ini akan membantu siswa dalam proses belajar. Di bidang kesehatan, bisa dilakukan simulasi pencegahan pandemi COVID-19. Hasil penelitian menunjukkan bahwa peran *augmented reality* dan *virtual reality* sangat penting, seperti dalam kesehatan, pendidikan, bisnis, manufaktur, dan eksperimen.

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A. INTRODUCTION

The COVID-19 pandemic has changed almost every aspect of our lives. This pandemic causes many problems in several aspects such as health, social, education, and economics. The new technologies, namely augmented reality (AR) and Virtual reality (VR) are used in many fields. Virtual reality technology is used to prevent the people from

infection by a simulation of human behavior, pathogen structure, and infection transmission. Augmented reality and virtual reality are very beneficial in improving skills management and increasing the safety protection for people and the environment, especially during the COVID-19 pandemic. Virtual reality technology can be used for telecommunication, telehealth, and drug discovery during the COVID-19 pandemic. Various industries also use augmented reality, such as healthcare, marketing, schools, and universities (Asadzadeh et al., 2021).

The four main groups that utilizing the augmented reality and virtual reality technologies are clinical contexts, entertainment, education and training, also business and industry. The benefits of using augmented reality and virtual reality are providing high-resolution audio and video conference communication, and facilitating remote collaboration. The most important usage of virtual reality and augmented reality is emergency management of infectious diseases, especially during the COVID-19 pandemic (Asadzadeh et al., 2021).

The invention of Augmented-Reality, Virtual-Reality, and Mixed-Reality technologies gives a new environment for the customers. In those technologies, there are integrations of physical and virtual objects. It has many usages in education, experiments, manufacture, and business. Customers have hybrid experiences (Flavián et al., 2019).

Recent technological developments change the experiences in physical and virtual environments. Virtual reality is important in some industries such as retail, education, healthcare, tourism, entertainment, and research. Younger generations show interest in virtual reality technology. Sales of these technologies are getting higher and higher. It is predicted to be 20 times higher than previously. These data are important because they show how the positive attitude of customers towards those information and communication technologies (Flavián et al., 2019).

Customer experiences comprise their emotional, sensorial, cognitive, behavioral, and social responses to a product or service. These kinds of experiences will determine their decision-making process. Making the customer experiences richer is paramount for successful sales. The customer experiences are associated with brand management, promotion, advertising, market research, and development. The technology involved in making a product or service will increase the added value. It generates maximum customer satisfaction when combining virtual and physical touchpoints. The virtual reality technology gives customers chances to get more autonomous and dynamic roles in experiences and making the decision (Flavián et al., 2019).

Better experiences give higher added value to the products and services. Several industries provide the customer a richer experience by using advanced technology. For instance, the customer can see how their living room would look like when it is decorated. Another example is the customer can try on virtually any clothes before using the real clothes in the store. It is possible by using augmented reality applications. Anticipating the experience of riding a roller coaster can be accomplished with a virtual reality application. Augmented reality gives us chances to look at real-time GPS information. Meanwhile, in the post-purchase process, the customers could receive assistance about repairing a washing machine, using mixed reality glasses, or create a virtual reality video

about their previous trip. However, the boundaries among augmented reality, virtual reality, and mixed reality are vague. There is no consensus regarding those terms when releasing any new devices. Therefore, the customers' experiences in technological, behavioral, and psychological terms can be used to classify reality-virtual technology. Virtual reality technologies alter customer experiences by empowering and supporting previous experiences. It creates a unique experience. Therefore, the company must try to invent a memorable experience. Finally, the purchase journey will be valuable and unforgettable (Flavián et al., 2019).

Although there are many usages of virtual reality and augmented reality, not all regions implement these technologies. Besides, the boundaries between virtual reality and augmented reality are not clear. Therefore, this study aims to describe the roles of virtual reality and augmented reality during the COVID-19 pandemic.

B. RESEARCH METHODS

This is a narrative literature review. Literature was searched in Science Direct and Google Scholar databases. Keywords were augmented reality, COVID-19 pandemic, virtual reality. Inclusion criteria are review and research paper. Exclusion criteria are short notes or commentary. After screening by the title, abstract, and full text, there were 15 journals. They were selected based on content by one author. To ascertain the quality of the selection, the process was done twice. The selected articles were summarized and narrated descriptively in a qualitative approach.

C. RESULT AND DISCUSSION

1. The concept of Augmented Reality and Virtual Reality

Augmented reality is a fascinating technology within Industry 4.0 manufacturing. It is complex technology. A small Enterprise can create flexible training by adopting the augmented reality technology. The augmented reality technology is a combination of interface design, 3D modeling, spatial tracking, and programming. Infrastructure changes are also detected by using the augmented reality technology. There is also an application for an Augmented Repair Training. It is called an Augmented Repair Training Application (ARTA). We also need end user-friendly templates to make the work easier (Lopik et al., 2020).

From reality to virtual is an essential concept. There should be a particular term, appropriate information, and focus regarding virtual reality, augmented reality, and mixed reality. However, there was no clear-cut categorization of those different realities. It is needed to clarify those terminological issues. There is a lack of consistency regarding the terms' usage in the professional and business fields. The term "Reality-Virtuality Continuum" was first proposed by Milgram and Kishino in 1994. It is the starting point to classify the various reality technologies. The terms can be described as following (Flavián et al., 2019):

a. Real Environments (RE) mean the reality.
   They consist of direct or indirect views. The direct view is a real scene or landscape, meanwhile, an indirect view is a video display.
b. Virtual Environments (VE) are defined as completely computer-generated environments. Therefore, the unreal objects are "displayed" on a device. Users can interact in real-time through an advanced technological interface. Virtual World is categorized as continuous virtual environments. It opens 24/7. It enables users to act as avatars. The users also interact and play with other users/avatars. It occurs in real-time.
c. Virtual Reality (VR) is generated by the computer in this condition, the user navigates and interacts. This condition triggers real-time simulation of the senses

Virtual reality is a special simulated environment. In this condition, computer graphics create realistic-looking virtual appearances. These appearances can give responses to a user's input. This technology was already invented more than twenty years ago, however, it undergoes many improvements. Virtual reality can be applied in many aspects such as business, education, researches or experiments, etc. When virtual reality is implemented in experimental education, it reveals realistic and intuitive experiences. Virtual reality may show complicated scenes in a system. The best system only needs small storage capacities, low computing power, and support mobile devices (Zhang et al., 2020).

Virtual reality and human-computer interactions are new technology. They are widely used in almost all fields nowadays. In education, virtual reality can assist teachers and students. In a company, virtual reality can assist in the production process. Many companies use applied virtual reality and human-computer interaction. A virtual experiment system and classroom have been implemented. However, there is a lack of guidance for users. This condition will decrease efficiency. Therefore, it is essential to develop a new way in guiding the user on how to use the technology in an effective way (Han et al., 2020).

2. Benefits of using virtual reality and augmented reality

There are many positive benefits of using virtual reality and augmented reality in many studies, especially in a laboratory setting and industrial applications. However, it needs some time before implementing augmented reality and virtual reality widely in the business. The process of qualifying and quantifying the human performance enhancement can be done by using electroencephalography. Virtual reality and augmented reality can also be implemented by using audio for the immersive process enhancement experiences. Psychological and physical therapy can use virtual reality and augmented reality for the patients. Virtual patients can be delivered to train the nursing students before entering the real clinical practice. Interesting games such as multisensory and interactive games are created by using virtual reality and augmented reality. Those games use the fusion of four sensory streams simultaneously to achieve realism. By accelerating virtual reality and augmented reality technologies, there will be a wide

chance for industrial applications in the future for improving their products (Yin et al., 2020).

3. Improvement in virtual reality and augmented reality

There is continuous improvement in efficiency and safety regarding using various technologies. Augmented Reality (AR) and Virtual Reality (VR) have the capabilities to create an excellent experience in physical and virtual environments. The training process is important. When training is collaborated with information filtering, this will bring a possibility of giving this technology into a workspace. Virtual reality and augmented reality improve performances by enhancing hand-eye coordination, 3D visualization skills, and a better chance of knowledge transfer. Finally, those benefits will give the feasibility to do the tasks faster and more accurately. These conditions will also reduce the cognitive long and give a better performance. Different scenarios and options are allowed by using the virtual environment. The special situation can be arranged based on users' preferences. The application of virtual reality and augmented reality also reduce cognitive load. Virtual reality and augmented reality keep users in a safe situation. Virtual reality provides a safe environment that is space-saving. It is critical for small countries (Yin et al., 2020).

4. Implementation of virtual reality and augmented reality

The acceptability of virtual reality and augmented reality is high among the operators in technology. This technology can support their work. The operator usually uses instructions to check the screwing torque. The operator needs to check assembly time. If the operator uses augmented reality, this will make the work easier because there will be much important information to display. The managers are pleased with the results. The data which are provided by the augmented reality and virtual reality technology help the managers in seeing the values and threats. Augmented reality can be viewed as an information platform. This technology can support in estimating the operator's readiness and willingness. Adaptation is needed when using this technology. Augmented reality and virtual reality also help in making strategic decisions in the future (Danielsson et al., 2018).

Virtual reality is also used in machine learning-based beer bottle-defect detection. It runs automatically. The image-processing knowledge is increased by the virtual simulation experiments. Complex problems can be solved by virtual reality. Creating a virtual reality needs a power supply, camera, manipulator, light source, conveyor belt, and computer. The software needed is the animation software and 3DS MAX modeling. There is a virtual design room from the game engine. This room is essential in designing interactive operations. Stimulation of the system operation proceeds through this room. The critical functions are manipulator, image shooting and processing, also detection system. The detection system is important in retrieving basic models. A product will be removed when a defect is found. The main result of the virtual simulation is image processing. A good training tool is viewed by using the virtual system in processing necessary images (Zhao et al., 2020).

The Augmented Reality is defined as a special system that supplements the real world with a virtual object. This virtual object is generated by the computer. Although it is virtual, it can be arranged in the same space as in the real world. This is not a new concept. It was found in 1992. It is an advancement of technology that includes the increase of computational power, miniature, and cost reduction. The use of augmented reality within industrial applications is very critical. The other aspects that use the augmented reality are entertainment, tourism, education, and medicine (Lopik et al., 2020; Padovano et al., 2018).

In business, the augmented reality has some added value. In external, the augmented reality can be used to increased customer engagement and marketing activities. Meanwhile, in internal activities, the augmented reality is important in making design, doing a collaboration, and enhancing efficiency during the process. The augmented reality is very valuable because it is rare, non-substitutable, and inimitable. It provides flexibility. Therefore, augmented reality can improve business growth (Lopik et al., 2020; Padovano et al., 2018).

In industrial settings, the augmented reality is a valuable method to share knowledge. The augmented reality is important in remote tutelage, flexible data, and digital information. The augmented reality, together with the digital twin, and the Human-Cyber-Physical Systems (HCPSs) will be valuable in system optimizing and waste reduction. Big Data, Artificial Intelligence, and Machine Learning are flexible. However, those technologies also have complexity. Therefore, accuracy must be enhanced. The tracking and recording process must be accurate as possible. Education, training, and knowledge reminding are needed to support effective team working. The augmented reality is essential in ameliorating discrepancies between a design and the performance of a product. To ensure efficacy, training should be provided routinely. This practice will enhance the business goal achievement. The augmented reality usually needs to be accompanied by smart glasses to have complete features. Maintenance, repair, and assembly must not be forgotten. Those routines are critical in ensuring a smooth process during the augmented reality application (Lopik et al., 2020).

Some challenges in using the augmented reality within the industry are technical, ergonomic, and privacy concerns. Ergonomic and technical issues comprise eye strain, device weight, wearable hygiene, and battery life. By doing evolution, those technical issues will be diminished. Adaptive technology is developed to tackle those obstacles. Changes in legislation and adopting the general data are important ways in dealing with privacy concerns. General Data Protection Regulation (GDPR) business practices have important roles in maintaining the privacy of users (Lopik et al., 2020).

The benefits of the augmented reality are time-saving, utility, and satisfaction of the users. These benefits will enhance key performance indicators in business adoption. The rules of "privacy by design" are implemented to attract end-user buying purposes. Expertise in improving 3D modeling, image processing, programming, and tracking has essential roles. Adaptation to existing manuals can help in dealing with the difficulties during the usage. Continuous updating of the manuals is very crucial in complex assignment techniques. Fiducial markers, mapping procedures, and updating are valuable

processes of management. Image quality should be enhanced. The depth of the sensors must be adjusted. The augmented reality should be flexible to changing processes. Minimalizing interruption to workflow can increase the information capture (Lopik et al., 2020).

A feedback procedure would be essential in refining the process. The users will have a dynamic experience over a long time. Therefore, knowledge sharing is needed to improve the augmented reality technology. Appropriate assessment techniques and monitoring are needed to improve the performance. There is difficulty in identifying skill levels in manual tasks. Therefore, the instruction is better to be individualized based on user. This is an active area to be studied. Personal freedom or autonomy must not be removed to maintaining privacy. Data storage has an important role in maintaining a smooth working environment, processes, and products. Security must be strengthened to prevent the possibility of data leakage. Additional protection may be required. The complexities of the emerging relationship between a user and the environment will give special characteristics of the interface. The interface consists of visual encoding and a platform. This condition requires an ontological approach to handle the interoperability concerns. A huge range of disciplines such as computer scientists, system designers, engineers, analysts, industrialists, and human factors experts has important roles. There should be a standardized approach to the users. The standardization aspects are device, user, visual encoding, and environment (Lopik et al., 2020).

The augmented reality implementation requires the aspiration of the organization. It also needs strategies for sustainable improvement and development. Adopting Industry 4.0 requires a "fit for purpose" mindset. A suitable template will be very valuable in formatting tools and content creation techniques (Lopik et al., 2020).

A full-color video-rate 3D display is also called a multiview-3D display. It is the preference of the users. While the 2D perspective images produce a certain number of views. A 3D display will have the best view when it is combined with a lenticular lens array, parallax barrier, or microlens arrays. Periodic diffractive gratings can be used to redirect the (semi-)parallel emitting light beams. The multiple view angles will be seen through this process. A virtual 3D scene will be seen when there are two perspective images captured by eyes in the different directions (Wan et al., 2019).

Augmented reality (AR) smart glasses are predicted to replace mobile phones. They are widely concerned. However, at the moment, AR smart glasses are designed based on the human normal eyes. Users who have abnormal eyes must wear diopters to get a better experience. For astigmatism users, they can wear AR smart glasses without using a diopter lens. The method is a cylindrical lens waveguide grating is made for external light deflection. This will give a normal viewing of the real world for the users (Wang et al., 2020).

The display technologies evolved from the bulky cathode ray tube to a compact flat panel, namely liquid crystal display (LCD) and the organic light-emitting diode (OLED). The advance is revolutionizing interactions between the users and the environment. The virtual reality (VR) display extends the field of view (FOV). It also blocks the entire ambient. An immersive virtual environment is offered. It is independent of the user's real

environment. The spectrum is an augmented reality (AR) display. The benefits of using augmented reality are having high-quality performance and enriching the real environment due to overlaying digital content. Augmented reality and virtual reality provide attractive performance with advanced optical technology. Those technologies can be implemented in education, health care, manufacturing, engineering design, retail, and entertainment. The display performance is clear like crystal. The images can merge into the surrounding environment and avoid discomfort. However, it is not easy to fulfill those idea images. These are the challenges in providing the best images for the users. Another challenge is power saving. Power efficiency and form factor have essential roles in near-eye display designs for consumer applications (Zhan et al., 2020).

5. Requirement in implementation of virtual reality and augmented reality

The essential parameter of the human visual system for augmented reality is the field of view (FOV). The resolution limit of the eye is determined by the average space of cone cells in the fovea. The low-resolution density causes the screen-door effect. It will compromise the viewing experience. Increasing the display resolution needs a high cost and fast data transport rate. A high resolution is required in the central viewing zone. It will bring out the concept of the foveated display. In foveated displays, the resolution is the optical combination of two display panels, namely the central and peripheral areas. In this way, there will be less burden of display hardware and data-transferring (Zhan et al., 2020).

A temperature-sensing simulation method of virtual chemistry is needed to address the difficulty in identifying temperatures, especially in virtual chemistry experiments. A virtual chemistry experiment temperature simulation platform was conducted based on the development of a wearable temperature generation device. The concentrated ammonium nitrate dissolution and sulfuric acid dilution are used to verify the real effect of the device. The device meets the temperature sensing characteristics of human skin. It also matches the temperature change of virtual chemistry experiments in real-time. This method can show exothermic or endothermic chemistry experiments. It is useful for students to gain an understanding of the thermal energy transformation principle in chemical reactions. Therefore, they can avoid the danger of chemistry experiments effectively. This experience will not be implemented when using the traditional teaching methods. The method is not convenient for the user. Therefore, virtual chemical experiments should be enhanced. The method is developed based on virtual reality. This special method assists in giving virtual chemistry experiments by natural human-computer interaction. Hence, the students can sense endothermic and exothermic phenomena during the virtual chemistry experiments through their skin. The temperature changes in chemical reactions can be sensed by the skin (Xu et al., 2020).

6. Mixed-reality technologies

Mixed-reality technologies consist of augmented reality (AR) and virtual reality (VR). These technologies are considered to have a potential role in science learning and teaching processes. The benefits of these technologies are giving positive emotions,

motivating autonomous learning, and improving learning outcomes. Mixed-reality technologies can be accompanied by a technology-aided biological microscope learning system. The microscope is a three-dimensional (3D) model. There are topological interrelationships and associations among components. There is also the specification of the interactive behavior. Collision detection is used to detect the motion control of components. A virtual microscope subsystem was developed combined with immersive VR equipment and AR technology. A mobile virtual microscope guidance system was also provided (Zhou et al., 2020).

A virtual microscope subsystem consisted of an augmented reality subsystem and a virtual reality subsystem. The virtual reality system allows the users to operate the components of the 3D microscope model. It involves natural interactions. The steps of using the virtual microscope are using a mobile terminal to take a picture of a microscope in the textbook, displaying the structure, functions, and guidance. This system can be tested by the students before or after class in a flexible time and space. There will be a switch between the virtual reality and augmented reality subsystems. This system is useful for recognizing a microscope's structure. It grasps important operational skills by simulating operations through an interactive process. Such technology-assisted education would be very helpful in learning platforms (Zhou et al., 2020).

The limitation of augmented reality classrooms inconvenient for users due to a large number of cards usage and less sense of interaction. The way to tackle the problem is by using the Multimodal Interaction Algorithm based on Augmented Reality (ARGEV). This technology is based on visual and tactile feedback in Augmented Reality. There is also another method, namely a Virtual and Real Fusion Interactive Tool Suite (VRFITS). It uses gesture recognition and intelligent equipment. The ARGVE method fuses gestures, virtual models, and intelligent equipment. A gesture recognition model is used by the combination of the convolutional neural network. The function is to recognize the gestures in augmented reality. It can trigger vibration feedback when the model recognizes a five-finger grasp gesture. A coordinate mapping relationship must be established between real hands and the virtual model. This is important to achieve the fusion of the virtual model and the gestures. The average accuracy rate of gesture recognition was more than 99%. The use of VRFITS in the Augmented Reality Chemistry Lab (ARCL) can reduce the operation load by more than 29% compared to traditional simulation virtual experiments. It is very useful to reduce the operation load, therefore the tools will be advanced and time-saving. A real-time fusion of the virtual model, gesture, and intelligent equipment is achieved in ARCL. ARCL can improve the users' real sense of operation. It also shows interaction efficiency (Xiao et al., 2020).

D. CONCLUSION AND SUGGESTIONS

In conclusion, augmented reality and virtual reality are very beneficial in improving skills management and increasing the safety protection for people and the environment, especially during the COVID-19 pandemic. Usages in education and experiments can help

students in understanding the learning material comprehensively. The teachers can improve themselves in using the technology for delivering the material more interestingly. There will be a wide chance for industrial applications in the future for improving their products and business. It can give new experiences to the customers. The next research is recommended to apply the augmented reality and virtual reality technology in wide application for daily life. This is important to make the daily life activities more practical and effective by using technology.

REFERENCE

Asadzadeh, A., Samad-soltani, T., & Rezaei-hachesu, P. (2021). Applications of virtual and augmented reality in infectious disease epidemics with a focus on the COVID-19 outbreak. *Informatics in Medicine Unlocked*, *24*, 1–8. https://doi.org/10.1016/j.imu.2021.100579

Danielsson, O., Syberfeldt, A., Holm, M., & Wang, L. (2018). Operators perspective augmented as a support 28th CIRP on Design France tool in engine assembly A new methodology to analyze the functional and physical architecture of Holm a family assembly oriented product identification. *Procedia CIRP*, *72*, 45–50. https://doi.org/10.1016/j.procir.2018.03.153

Flavián, C., Ibáñez-sánchez, S., & Orús, C. (2019). The impact of virtual , augmented and mixed reality technologies on the customer experience. *Journal of Business Research*, *100*, 547–560. https://doi.org/10.1016/j.jbusres.2018.10.050

Han, R., Feng, Z., Tian, J., Fan, X., & Yang, X. (2020). An intelligent navigation experimental system based on multi-mode fusion. *Virtual Reality & Intelligent Hardware*, *2*(4), 345–353. https://doi.org/10.1016/j.vrih.2020.07.007

Lopik, K. Van, Sinclair, M., Sharpe, R., Conway, P., & West, A. (2020). Developing augmented reality capabilities for industry 4 . 0 small enterprises: Lessons learnt from a content authoring case study. *Computers in Industry*, *117*, 103208. https://doi.org/10.1016/j.compind.2020.103208

Padovano, A., Longo, F., Nicoletti, L., Mirabelli, G., Mirabelli, G., Padovano, A., Padovano, A., Saddik, E., & Saddik, E. (2018). ScienceDirect Digital Twin based Service Oriented Application for Knowledge tion in the Smart Factory Oriented Application for Knowledge tion in the Smart Factory A Digital Digital Twin Twin based based Service Service Oriented Application for Knowledge tion in Factory tion in the Smart. *IFAC-PapersOnLine*, *51*(11), 631–636. https://doi.org/10.1016/j.ifacol.2018.08.389

Wan, W., Pu, D., Duan, H., Guo, J., Wan, W., Qiao, W., Pu, D., Li, R., Wang, C., Hu, Y., & Duan, H. (2019). Holographic Sampling Display Based on Metagratings Holographic Sampling Display Based on Metagratings. *ISCIENCE*, *23*(1), 100773. https://doi.org/10.1016/j.isci.2019.100773

Wang, S., Du, K., Song, N., Zhao, D., Feng, D., & Tu, Z. (2020). Study on the adaptability of augmented reality smartglasses for astigmatism based on holographic waveguide grating. *Virtual Reality & Intelligent Hardware*, *2*(1), 79–85. https://doi.org/10.1016/j.vrih.2019.12.003

Xiao, M., Feng, Z., Yang, X., Xu, T., & Guo, Q. (2020). Multimodal interaction design and application in augmented reality for chemical experiment. *Virtual Reality & Intelligent Hardware*, *2*(4), 291–304. https://doi.org/10.1016/j.vrih.2020.07.005

Xu, H., Li, S., Song, W., Sun, J., Wu, X., Wang, X., Yang, W., Pan, Z., & Rhalibi, A. E. I. (2020). Thermal perception method of virtual chemistry experiments. *Virtual Reality & Intelligent Hardware*, *2*(4), 305–315. https://doi.org/10.1016/j.vrih.2020.07.003

Yin, J., Chng, C., Wong, P., Ho, N., Chua, M., & Chui, C. (2020). VR and AR in human performance research — An NUS experience. *Virtual Reality & Intelligent Hardware*, *2*(5), 381–393. https://doi.org/10.1016/j.vrih.2020.07.009

Zhan, T., Yin, K., Xiong, J., He, Z., & Wu, S. (2020). iScience ll Augmented Reality and Virtual Reality Displays : Perspectives and Challenges. *ISCIENCE*, *23*(8), 101397. https://doi.org/10.1016/j.isci.2020.101397

Zhang, H., Zhang, J., Yin, X., Zhou, K., & Pan, Z. (2020). Cloud-to-end rendering and storage

management for virtual reality in experimental education. *Virtual Reality & Intelligent Hardware*, *2*(4), 368–380. https://doi.org/10.1016/j.vrih.2020.07.001

Zhao, Y., An, X., & Sun, N. (2020). Virtual simulation experiment of the design and manufacture of a beer bottle-defect detection system. *Virtual Reality & Intelligent Hardware*, *2*(4), 354–367. https://doi.org/10.1016/j.vrih.2020.07.002

Zhou, X., Tang, L., Lin, D., & Han, W. (2020). Virtual & augmented reality for biological microscope in experiment education. *Virtual Reality & Intelligent Hardware*, *2*(4), 316–329. https://doi.org/10.1016/j.vrih.2020.07.004