INTERNATIONAL JOURNAL OF RESEARCH AND TECHNOPRENEURIAL INNOVATIONS (IJRTI)

Volume 1 Issue 1 (April 2024)

Central Instrument Laboratory, University of Port Harcourt, Nigeria
E-mail: centralinstumentlaboratory@uniport.edu.ng

Impact of Virtual Reality Technology (VRT) on Chemistry Laboratory and Learning Outcomes of Chemistry Education Students in Nigerian Universities

Rosemary C. Ugonwa[1, *], Ijeoma J. Agbai[2], Leo C. Osuji[3,4]

[1]Department of Science Education, University of Port Harcourt, Choba, Port Harcourt, Nigeria
[2]Department of Pure and Industrial Chemistry Abia State University, Uturu, Abia State, Nigeria
[3]Department of Pure and Industrial Chemistry, University of Port Harcourt, Choba, Port Harcourt, Nigeria
[4]Uniport Foundation, Delta Park, University of Port Harcourt, Nigeria.

Email address:
[*]Corresponding author: rosemary.ugonwa@uniport.edu.ng

To cite this article:
Ugonwa, R.C., Agbai, I.J. and Osuji, L.C. Impact of Virtual Reality Technology (VRT) on Chemistry Laboratory and Learning Outcomes of Chemistry Education Students in Nigerian Universities. *International Journal of Research and Technopreneurial Innovations* 2024; 1(1): 109-119.

Keywords:
Virtual Reality, Technology, Chemistry, Laboratory

ABSTRACT

This research investigates the impact of Virtual Reality Technology (VRT) on Chemistry Laboratory and Learning Outcomes of Chemistry Education Students in Nigerian Universities. The study adopted a descriptive survey design. Lecturers of Science Education and Chemistry departments in public universities in Nigeria make up the population for the research. The sample for data collection comprises of the 30 Lecturers of Science Education and Pure and Industrial Chemistry Departments of the University of Port Harcourt and Rivers State University, Port Harcourt, which were selected using purposive sampling technique. The study was guided by three specific objectives, three research questions and three hypotheses. The instrument for data collection was a 4-point Likert scale structured questionnaire, captioned Virtual Reality Technology Chemistry Laboratory and Learning Outcomes Questionnaire (VRTCLLOQ). The reliability of the instrument was estimated to be +0.85 using Cronbach alpha method. Mean and standard deviation were used to answer the research questions while t-test was used to analyze the hypotheses at 0.05 level of significance. Findings from the study revealed that incorporation of VRT in Chemistry Laboratories makes the use of Laboratories very effective. Also, the use of the VRT in Chemistry Laboratory improves the learning outcomes of Chemistry Education students in public universities. There was a significant impact of the use of the VRT on the engagement of Chemistry Education Students in the University. It was recommended among others that public universities should employ the use of VRT in the chemistry Laboratories to enhance and promote effective learning and learning outcomes,

1. INTRODUCTION

Chemistry is a branch of science that makes use of specific terms to define relationships and changes that exist in real-life phenomena [1]. Due to the reactions of the particles and the experimental results, explanations of the reaction mechanism and the nature of matter are made explicit. Chemistry

being a subject that is required in our day-to-day activities and an integral part of other science disciplines requires both theory and practical learning [2]. Practical experiential learning has been known to improve motivation to learning and and help students develop science process skills which enables them to deal with abstract knowledge [1]. Proficiency in experimental chemistry is imperative for chemistry education students to be able to provide first hand practical experiences un proposing and testing various hypotheses. Contemporary education worldwide has embraced digital learning as the most effective tool for technological advancement, economic productivity and sustainable development. Nigeria not left out, chemistry education play vital role on students understanding of science and expertise in the world of technology. However, there are limitations with the use of traditional laboratory approach including lack of resources, safety issues and students learning inattentiveness [3]. Several approaches to learning have been implored over the years including the constructivist learning theory which emphasizes learner autonomy and a co-constructor of knowledge. This theory asserts learning is a function of interaction, social and interpersonal involvement [4][5]. Meanwhile, cognitive load theory (CLT) which seeks to optimize instructional design by managing cognitive load has been applied in different domain including understanding clinical practices [6][7]. However, incorporation of virtual reality technology (VRT) is seen as a tool to enhance socio-cultural interactions, allow students engagement, enhance creativity and create inclusive learning for the disables [8-10]. In order to bridge the gaps with traditional laboratory approach, universities explore incorporation of virtual reality technology (VRT).

Virtual reality (VR) is a simulated experience that makes use of pose tracking and 3D near-eye displays to give the user an immerse feel of a virtual world. VR can be applied in areas of entertainment (particularly videogames), education and business. Other distinct type of VR-style technology include augumented reality and mixed reality, also referred to as extended reality. Virtual reality technology engages computational techniques, sensory interface and cognitive to create virtual environment which allow total participation [11][12]. A person using VR equipment is able to work around the artificial world, move around in it and interact with virtual features or items. The VRT creates synthetic reality that allow users to interact with digital object as if they are real. This technique is made possible with combination of tactile input, geographical tracking and computer graphics [13][14]. Interdisciplinary cooperation is made possible with virtual reality from different domains of study. Medically, VRT intervention improves cancer patient's emotional well-being [15], treatment of alcohol dependency [16].

In Engineering sector application of VRT enhance task performance [17], increases safety competencies [18]. VRT is also found efficient and relevant in weather forecast [19] as well as in sports including diving, trampoline, golf and gymnastics [20]. Communication fosters progress in scientific enterprise. This link is not well established among scientist in Nigeria. This could be as a result of so many constraints face by Nigerian scientist. Incorporation of VRT will in no doubt bridge this gap and enhance productivity in understanding and teaching chemistry.

According to Aliyu and Talib [21], VRT is required for effective and efficient delivery of knowledge content. The study revealed pre service chemistry teacher were better equipped as VRT integration eliminated abstract concept associated with studying chemistry. The challenge of proximity is also handled with VRT as Mirza et al. [22] reported the use of cross platform game engine and 3D model to create immersive and interactive experience which enabled people to work from home during Covid - 19. High demand on cognitive, abstraction and spatial ability required in nanoscience which involves study at atomic level is

overcome with the use of VRT. VRT provide access to up to date and expensive instrument for large class as well as eliminated barrier between lecture room and laboratory [23]. Virtual reality technology enables students to engage in realist laboratory experiments, carry out intricate reactions and manipulate molecular structures [24].

Furthermore, Virtual reality technology allows access to understanding of abstract phenomena and enable students conduct experiment repeatedly without limitation of time, resources of safety concern [25]. Several reports on impact and learning outcome with the use VRT exist. Kounlaxay, et al. [26] found out that VR system improved students' learning outcomes in experimental chemistry from performing experiment based on simulated three dimensional (3D) models. Sari et al. [27] who employed Rasch model's assessment over difficulties encountered with oral teaching and advantages of VR based pedagogy asserts most educators encounter challenges with oral methodologies. The study proved incorporation of VRT enhanced student motivation, engagement and comprehension. VRT serves as accessible education tool and enhanced student learning outcome is achieved with simulating laboratory circumstances via VR technology. Kolil et al. [28] conducted empirical study on factors that cause low experimental self-laboratory experimentation and explore interventions to reduce the impact. The study identified four major factors as conceptual understanding, laboratory hazard, procedural complexity and insufficient resources. The statistical study showed 88% to 233% of students exposed to virtual learning had their experimental self-efficacy improved. Despite the essence of the use of VRT, virtual reality technology is not without challenges which are seen as system design and quality of experience evaluation, cost of equipment and software. It is evident that incorporation of virtual reality technology is relevant on chemistry education laboratory and learning outcome lack of research on its impact on chemistry education laboratories and learning outcomes in the Nigerian context. The study therefore adopted a descriptive survey design with the study focus on Port Harcourt in Rivers State (Nigeria) to examine the effectiveness of Virtual Reality Technology on the use of Chemistry Laboratory in the public universities, to ascertain the effect of virtual reality technology in the chemistry Education Laboratory on Students engagement in learning and investigate the implications of the use of virtual reality technology on the academic performance/learning outcomes of the chemistry Education students in the public universities in Rivers State.

This study's novelty lies in the participation of the public-school lecturer whose experience and assessment with the use VRT in classroom serve as a firsthand information on impact and the learning outcome of implementation of VRT. Therefore, this study in no doubt will contribute to body of research on VRT education and serve as an insight into effect and learning outcome in real life application from educators' perspective.

2. MATERIALS AND METHODS

2.1. Research Questions

1. To what extent does the use of VRT make Chemistry Laboratory more effective for use in teaching and learning?
2. How does the use of VRT in Chemistry Laboratory affect Chemistry Education Students engagement in learning chemistry?
3. What is the implication of using VRT in Chemistry Laboratory on the Learning Outcomes of Chemistry Education Students in the university?

2.2. Research Hypothesis

2.2.1. Null Hypothesis 1.

There is no significant difference in the effectiveness of the use of VRT in Chemistry Laboratory on Chemistry Education in the Universities.

2.2.2 Null Hypothesis 2.

There is no significant effect of the use of VRT in the Chemistry Laboratory on
Chemistry Education Students engagement in the Universities.

2.2.3 Null Hypothesis 3.

There is no significant implication of the use of VRT in Chemistry Laboratory on the Academic Performance or learning outcomes of the Chemistry Education students in the universities.

2.3. Description of Research Design

The study adopted a descriptive survey research design. The area of this study was Port Harcourt, Rivers state. A target population of 1,480 Pure and industrial chemistry and Chemistry Education Lecturers in the public universities in Nigeria was used for the study. Purposive sampling technique was used to select 30 Lecturers from Pure Chemistry and Science Education departments respectively, in University of Port Harcourt and Rivers State University in Port Harcourt, which formed the sample size for the study. A structured questionnaire captioned Virtual Reality Technology on Chemistry Laboratory and Learning Outcomes Questionnaire (VRTCLLOQ) which was developed by the researchers for data collection was used to collect primary data for the study. The questionnaire contains open ended statements. Ordinal level of measurement which is a 4-point Likert scale was used to measure items in the questionnaire. The face and content validity of the instrument confirmed the suitability of the instrument. With a reliability coefficient of 0.85 using Cronbach alpha method. Mean and standard deviation was used to answer the research questions while t-test was used to analyze the hypotheses at 0.05 level of significance.

3. RESULTS AND DISCUSSION

3.1 Research Question 1:

To what extent does the use of VRT make Chemistry Laboratory more effective for
use in teaching and learning?

Table 1: Mean and standard deviation on the effectiveness of the use of VRT in Chemistry Laboratory for teaching and learning of Chemistry.

S/N	Items	SA	A	D	SD	$\bar{x}$	St.D	Remark
1	Virtual Reality Technology (VRT) experience in education is rear in Nigerian institutions.	8 (32)	17 (51)	2 (4)	3 (3)	3.00	0.86	Agree
2	Virtual Reality Technology (VRT) experience in education in Nigerian institutions is really interesting.	9 (36)	16 (48)	1 (2)	4 (4)	3.00	0.93	Agree
3	Virtual Reality Technology (VRT) can enhance laboratory experiences in chemistry education.	10 (40)	16 (48)	1 (2)	3 (3)	3.10	0.88	Agree
4	VRT simulates laboratory experiments compared to traditional hands-on experiments.	12 (48)	10 (30)	3 (6)	5 (5)	2.95	1.08	Agree
5	Challenges and limitations encountered in traditional chemistry education outweighs its benefits	9 (36)	14 (42)	2 (4)	5 (5)	2.9	1.02	Agree
6	Adequate training and support would be essential for educators to effectively utilize VRT in chemistry education.	13 (52)	12 (36)	1 (2)	4 (4)	3.13	1.00	Agree
7	More resources and technicalities are required to implement VRT in chemistry education laboratories.	10 (40)	13 (39)	2 (4)	5 (5)	2.93	1.03	Agree
	Average					**3.00**	**0.97**	

Table 1indicated that for the research question 1, the Lecturers responded to the items 1-7 with mean scores of 3.00, 3.00, 3.10, 2.95, 2.90, 3.13 and 2.93 with corresponding standard deviation of 0.86, 0.93, 0.88, 1.08, 1.02, 1.00 and 1.03 respectively. This shows that all the items sampled had mean values that were above the criterion mean score of 2.50 used for decision making and implies that the respondents agreed to all items. The average mean of 3.00 with average standard deviation of 0.97 indicates that most of the Lecturers agree with the opinion that the use of Virtual Reality Technology in the Chemistry Laboratory makes the laboratory more effective for use in teaching and learning of Chemistry.

Research Question 2: How does the use of VRT in Chemistry Laboratory affect Students engagement in learning chemistry?

Table 2: Mean and standard deviation on the impact of the use of VRT on Chemistry Students engagement in chemistry teaching and learning.

S/N	Items	SA	A	D	SD	$\bar{x}$	St.D	Remark
8	Traditional chemistry education method impedes effective learning.	11 (44)	12 (36)	2 (4)	5 (5)	2.97	1.06	Agree
9	Most aspects of digital chemistry education are engaging.	12 (48)	14 (42)	1 (2)	3 (3)	3.17	0.90	Agree
10	VRT encourages student engagement in chemistry education.	14 (52)	12 (36)	1 (2)	3 (3)	3.23	0.93	Agree
11	Incorporation of VRT impact positively on engagement and interest in learning chemistry.	12 (48)	15 (45)	0 (0)	3 (3)	3.40	0.88	Agree
12	Positive changes in students' participation or enthusiasm are observed with utilizing VRT.	10 (40)	14 (42)	2 (4)	4 (4)	3.00	0.97	Agree
13	The advantages of incorporating VRT into chemistry education is enormous.	10 (40)	13 (42)	2 (4)	5 (5)	2.93	1.05	Agree
14	Effective implementation of VRT in chemistry education laboratories does not require much technicality.	13 (52)	12 (36)	1 (2)	4 (4)	3.13	0.99	Agree
	Average					**3.12**	**0.97**	

Table 2 indicated that the Lecturers responded to the items 8 - 14 for research question 2 with mean scores of 2.97, 3.17, 3.40, 3.40, 3.30, 2.93 and 3.13 with corresponding standard deviation of 1.06, 0.90, 0.93, 0.88, 0.97, 1.05 and 0.99 respectively. This shows that all the items sampled had mean values that were above the criterion mean score of 2.50 used for decision making and implies that the respondents agreed to all items. The average mean of 3.12 with average standard deviation of 0.97 indicates that most of the Lecturers agree with the opinion that the use of VRT in the chemistry Laboratory positively affects student's engagement in teaching and learning of Chemistry.

Research Question 3: What is the implication of using VRT in Chemistry Laboratory on the Learning Outcomes of Chemistry Education Students in the university?

Table 3: Mean and standard deviation on the implication of the use of VRT in Chemistry Laboratory on the Learning Outcomes of the chemistry Education students.

S/N	Items	SA	A	D	SD	$\bar{x}$	St.D	Remark
15	Widespread adoption of Virtual Reality Technology is envisioned in the future of chemistry education laboratories.	12 (48)	13 (42)	1 (2)	4 (4)	3.10	0.98	Agree
16	Several considerations are required when designing courses that incorporate VRT in chemistry education.	10 (40)	15 (45)	2 (4)	3 (3)	3.07	0.89	Agree
17	Using VRT in chemistry education laboratories can positively impact students' academic achievement.	13 (52)	13 (39)	0 (0)	4 (4)	3.17	0.97	Agree
18	The future implications of VRT integration in chemistry education laboratories for student learning outcomes is positive.	12 (48)	14 (42)	1 (2)	3 (3)	3.17	0.90	Agree
19	There is zero negative implication of VRT on learning outcome of university student in learning chemistry.	10 (40)	16 (48)	0 (0)	4 (4)	3.07	0.93	Agree
20	There are several challenges to be addressed to maximize the benefits of VRT for student learning.	11 (44)	13 (39)	2 (4)	4 (4)	3.03	0.98	Agree
	Average					**3.10**	**0.94**	

Table 3 indicated that the Lecturers responded to the items 15 -20 for research question 3 with mean scores of 3.10, 3.07, 3.17, 3.17, 3.07 and 3.03 with a corresponding standard deviation of 0.98, 0.89, 0.97, 0.90, 0.93 and 0.98 respectively. This shows that all the items sampled had mean values that were above the criterion mean score of 2.50 used for decision making and implies that the respondents agreed to all items. The average mean of 3.10 and standard deviation of 0.94 indicate that most of the Lecturers agreed to the opinion that the use of VRT in Chemistry Laboratory has a positive implication on learning outcomes of the students in the universities.

Hypothesis 1: There is no significant difference in the effectiveness of the use of VRT in Chemistry Laboratory on Chemistry Education.

Table 4: T-test statistics showing the significant difference in the effectiveness of the use of VRT in Chemistry Laboratory on Chemistry Education.

Variables	N	$\bar{x}$	St.D	Df	t-cal	t-tab	Sig.	Remark
	30	3.00	0.97	29	16.6838	1.70	.05	Reject

The results in table 4 shows that the Lecturers have a mean and standard deviation score of 3.00 and 0.97 respectively. The calculated test of 16.68 which is greater than the critical t-tab of 1.70 at 29

degree of freedom and 0.5 alpha level, indicated that the null hypothesis 1 was rejected. This implies that there is a significant impact of the use of Virtual Reality Technology in Chemistry Laboratory on Chemistry Education in Nigerian Universities.

Hypothesis 2: There is no significant impact of the use of VRT in Chemistry Laboratory on the engagement of Chemistry Education Students in the universities.

Table 5: T-test statistics showing the significant impact of the use of VRT in Chemistry Laboratory on the engagement of Chemistry Education Students.

Variables	N	$\bar{x}$	St.D	Df	t-cal	t-tab	Sig.	Remark
	30	3.12	0.97	29	17.3512	1.70	.05	Reject

The results in table 5 shows that the Lecturers have a mean and standard deviation score of 3.12 and 0.97 respectively. The calculated test of 17.35 which is greater than the critical t-tab of 1.70 at 29 degree of freedom and 0.5 alpha level, indicates that the null hypothesis 2 was rejected. This implies that there is a significant impact of the use of Virtual Reality Technology in Chemistry Laboratory on the engagement of chemistry Education students in the Nigerian Universities.

Hypothesis 3: There is no significant implication of the use of VRT in Chemistry Laboratory on the Learning Outcomes of the Chemistry Education Students in Nigerian universities.

S/N	Items	SA	A	D	SD	$\bar{x}$	St.D	Remark
15	Widespread adoption of Virtual Reality Technology is envisioned in the future of chemistry education laboratories.	12 (48)	13 (42)	1 (2)	4 (4)	3.10	0.98	Agree
16	Several considerations are required when designing courses that incorporate VRT in chemistry education.	10 (40)	15 (45)	2 (4)	3 (3)	3.07	0.89	Agree
17	Using VRT in chemistry education laboratories can positively impact students' academic achievement.	13 (52)	13 (39)	0 (0)	4 (4)	3.17	0.97	Agree
18	The future implications of VRT integration in chemistry education laboratories for student learning outcomes is positive.	12 (48)	14 (42)	1 (2)	3 (3)	3.17	0.90	Agree
19	There is zero negative implication of VRT on learning outcome of university student in learning chemistry.	10 (40)	16 (48)	0 (0)	4 (4)	3.07	0.93	Agree
20	There are several challenges to be addressed to maximize the benefits of VRT for student learning.	11 (44)	13 (39)	2 (4)	4 (4)	3.03	0.98	Agree
	Average					**3.10**	**0.94**	

Table 6: T-test statistics showing the significant implication of VRT in Chemistry Laboratory on the Learning Outcomes of the Chemistry Education Students.

Variables	N	$\bar{x}$	St. D	df	t-cal	t-tab	Sig.	Remark
	30	3.10	0.94	29	17.5129	1.70	.05	Reject

The results in table 6 shows that the Lecturers have a mean and standard deviation score of 3.10 and 0.94 respectively. The calculated test of 17.51 which is greater than the critical t-tab of 1.70 at 29 degree of freedom and 0.5 alpha level, indicates that the null hypothesis 3 was rejected. This implies that there is a significant implication of the use of VRT in Chemistry Laboratory on the Learning Outcomes of the Chemistry Education Students.

3.2 Discussion of Findings

The findings of research question 1 and hypothesis 1 as shown in table 1 and 4 respectively indicate that majority of the Lecturers agreed that the use of VRT in Chemistry Laboratory makes the use of Laboratory more effective and that there is a significant in the effectiveness of the use of VRT in Chemistry Laboratory for teaching and learning of Chemistry. This finding agrees with the findings of Aliyu and Talib [21] which submitted that VRT is required for effective and efficient delivery of knowledge content. It also agrees with Hu-Au and Okita [25] who reported from their findings that VRT allows access to understanding of abstract phenomena and enables students conduct experiments in the laboratory repeatedly, without limitation of time and resources of safety.

The findings of research question 2 and hypothesis 2 as shown in table 2 and 5 respectively indicate that most of the Lecturers agreed that the use of VRT in Chemistry Laboratory positively affects students' engagement in the teaching and learning of Chemistry and that there is a significant impact of the use of VRT in Chemistry Laboratory on the engagement of the Chemistry Education Students. This finding agree with the findings of Shadev et al [8] and Akdere et al [9] that incorporation of VRT is a tool to enhance socio-cultural interaction, allow students engagement and enhance creativity. It also agrees with Sari et al [27,28] who's study proved that incorporation of VRT in Chemistry Laboratory enhanced Students 'motivation, engagement and comprehension.

The findings of research question 3 and hypothesis 3 as shown in table 3 and 6 respectively indicate that majority of the Lecturers agreed that the use of VRT in Chemistry Laboratory has a positive implication on the Learning Outcomes of the Chemistry Education students and that there is a significant implication of the use of VRT in Chemistry Laboratory on the learning outcomes of the Chemistry Education students in the universities. These findings agree with the findings of Kounlaxy et al [26] who found out that the use of Virtual Reality system improved students learning outcomes in experimental chemistry from performing experiments based on simulated 3D models. Kounlaxy et al [26] also asserted that VRT served as accessible education tool and enhanced student learning outcomes.

4. CONCLUSION

From the findings of this study, it was concluded that the use of Virtual Reality Technology in Chemistry Laboratory has a positive impact on the use of the chemistry Laboratory, on the Chemistry Education students' engagement and on the learning outcomes of the Chemistry Education students in the public universities in Nigeria.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Lecturers of pure chemistry and chemistry Education should embrace the use of Virtual Reality Technology in Chemistry Laboratory in order to engage students more actively and make learning of chemistry more effective for improved learning outcomes.
2. Government should provide adequate digital technologies, particularly Virtual Reality Technology tools in the chemistry laboratory for use in chemistry teaching and learning.

Conflict of Interest Declaration

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

References

[1] Macrothink Institute (2023). Integrating Virtual Reality Laboratories (VRLs) in Chemistry Education: A systematic literature review. International Journal of Education. Retrieved 14-03-2024 from http://Ije.macrothink.org.

[2] Dike, J. W. and Ugonwa, R. C. (2021). Practices of Innovative Technologies on the Academic Achievement of Science Students in Port Harcourt City Secondary Schools. *Australian Journal of Arts and Scientific Research (AJASR).* **26(1),** 49-58.

[3] WASET (2023). Internal Conference on Software testing organized by the World academy of Science, Engineering and Technology

[4] Jumaat, N., Tasir, Z., Halim, N. and Ashari, Z. (2017). Project-based learning from constructivism point of view. *Advanced Science Letters,* **23,** 7904-7906.

[5] Brau, B. (2020). Constructivism. United Nations peace operations and International Relations theory. https://doi.org/10.4135/9781483375519.n148.

[6] Jong, T. (2010). Cognitive load theory, educational research, and instructional design: some food for thought. *Instructional Science,* **38**, 105-134. https://doi.org/10.1007/S11251-009-9110-0.

[7] Sweller, J. (2020). Cognitive load theory and educational technology. *Educational Technology Research and Development,* **68,** 1-16.

[8] Shadiev, R., Wang, X. and Huang, Y. (2020). Promoting Intercultural Competence in a Learning Activity Supported by Virtual Reality Technology. The International Review of Research in Open and Distributed Learning. https://doi.org/10.19173/irrodl.v21i3.4752.

[9] Akdere, M., Acheson, K. and Jiang, Y. (2021). An examination of the effectiveness of virtual reality technology for intercultural competence development. *International Journal of Intercultural Relations*, **82,** 109-120.

[10] Gao, L., Wan, B., Liu, G., Xie, G., Huang, J. and Meng, G. (2021). Investigating the Effectiveness of Virtual Reality for Culture Learning. *International Journal of Human–Computer Interaction,* **37,** 1771 - 1781.

[11] Ding, X. and Li, Z. (2022). A review of the application of virtual reality technology in higher education based on Web of Science literature data as an example. *Frontiers in Education,* **7.** https://doi.org/10.3389/feduc.2022.1048816.

[12] Radianti, J., Majchrzak, T A., Fromm, J. and Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons

learned, and research agenda. Computers & Education, 147, 103778-103778. https://doi.org/10.1016/j.compedu.2019.103778

[13] North, M. and North, S. (2016). Virtual Reality Therapy, 141-156. https://doi.org/10.1016/B978-0-12-802075-3.00006-1

[14] Maples-Keller, J., Bunnell, B., Kim, S. and Rothbaum, B. (2017). The Use of Virtual Reality Technology in the Treatment of Anxiety and Other Psychiatric Disorders. *Harvard Review of Psychiatry,* **25,** 103–113.

[15] Chirico, A., Lucidi, F., Laurentiis, M., Milanese, C., Napoli, A. and Giordano, A. (2016). Virtual Reality in Health System: Beyond Entertainment. A Mini-Review on the Efficacy of VR During Cancer Treatment. *Journal of Cellular Physiology,* **231**. https://doi.org/10.1002/jcp.25117.

[16] Son, J., Lee, S., Seok, J., Kee, B., Lee, H., Kim, H., Lee, T. and Han, D. (2015). Virtual Reality Therapy for the Treatment of Alcohol Dependence: A Preliminary Investigation With Positron Emission Tomography/Computerized Tomography. *Journal of Studies on Alcohol and Drugs*, **764**, 620-7.

[17] Osti, F., Amicis, R., Sanchez, C., Tilt, A., Prather, E. and Liverani, A. (2020). A VR training system for learning and skills development for construction workers. *Virtual Reality*, **25**, 523-538.

[18] Nykänen, M., Puro, V., Tiikkaja, M., Kannisto, H., Lantto, E., Simpura, F., Uusitalo, J., Lukander, K., Räsänen, T., Heikkilä, T. and Teperi, A. (2020). Implementing and evaluating novel safety training methods for construction sector workers: Results of a randomized controlled trial. *Journal of Safety Research,* **75**, 205-221.

[19] Zhang, Y., Stensrud, D. and Zhang, F. (2019). Simultaneous Assimilation of Radar and All-Sky Satellite Infrared Radiance Observations for Convection-Allowing Ensemble Analysis and Prediction of Severe Thunderstorms. Monthly Weather Review. https://doi.org/10.1175/mwr-d-19-0163.1.

[20] Song-ping, Y. (2006). Application of VRT in Sports Technology Simulation. China Sport Science.

[21] Aliyu, F. and Talib, C. (2019). Virtual Reality Technology. *Asia Proceedings of Social Sciences.* https://doi.org/10.31580/APSS.V4I3.856.

[22] Mirza, I., Sasithong, P., Jearavingtakul, S., Sinpan, N., Le-aidee, P., Chaudhary, S., Wuttisittikulkij, L., Bajpai, A., Vanichchanunt, P., Wei, X. and Tang, X. (2022). Reconstruction of Digital Chemistry Lab by Incorporating Virtual Reality Platform. *37th International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC)*, 1011-1014. https://doi.org/10.1109/ITC-CSCC55581.2022.9895095.

[23] Tian, Y., Fu, H., Liu, J., Wang, L.and Xu, X. (2020). Virtual Reality Educational Tool for Connecting Chemistry Lecture with Remote Laboratory Demonstrations. . https://doi.org/10.26434/chemrxiv.12040173.v1.

[24] Chirico, A., Lucidi, F., Laurentiis, M., Milanese, C., Napoli, A. and Giordano, A. (2016). Virtual Reality in Health System: Beyond Entertainment. A Mini-Review on the Efficacy of VR During Cancer Treatment. *Journal of Cellular Physiology,* **231**. https://doi.org/10.1002/jcp.25117.

[25] Hu, M., Luo, X., Chen, J., Lee, Y., Zhou, Y. and Wu, D. (2021). Virtual reality: A survey of enabling technologies and its applications in IoT. J. Netw. Comput. Appl., **178**, 102970. https://doi.org/10.1016/j.jnca.2020.102970.

[26] Kounlaxay, K., Yao, D., Ha, M. and Kim, S. (2022). Design of Virtual Reality System for Organic Chemistry. Intelligent Automation and Soft Computing. https://doi.org/10.32604/iasc.2022.020151.

[27] Sari, I., Sinaga, P., Hernani, H., Mudzakir, A., and Santria, A. (2023). Using Virtual Reality as Learning Tools on Chemistry: Advantages and Challenges. Tadris: Jurnal Keguruan dan Ilmu Tarbiyah.https://doi.org/10.24042/tadris.v8i1.14593.

[28] Kolil, V.K., Muthupalani, S. and Achuthan, K. (2020). Virtual experimental platforms in chemistry laboratory education and its impact on experimental self-efficacy. I*nt J Educ Technol High Educ* **17**, 30