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# Effects of Virtual and Augmented Reality in Chemistry Education: Systematic Literature Review

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***Abstract*—*Contribution:*** This article provides additional findings to the result of other systematic literature reviews where, more attention has been focused on natural science subjects however, giving limited attention to individual subjects, particularly in the field of chemistry education. Sufficient evidence is therefore, required to ascertain the effectiveness of implementing virtual and augmented reality technologies in chemistry education at the secondary school and undergraduate levels where result of this study would be of tremendous benefit.

***Background****:* The 4th industrial revolution has highlighted the need for embracing modern technology in many sectors of the society, which did not leave educational sector behind. This led to the exploration and implementation of educational technology in teaching and learning of chemistry towards promoting a fascinating educational experience and enhancing teachers' and students' overall academic performance.
***Research Questions: 1)*** What are the advantages of VR and AR systems in teaching and learning chemistry? *2)* What are the disadvantages of VR and AR systems in teaching and learning chemistry? *3)* What are the challenges of VR and AR systems in teaching and learning chemistry?

**Methodology***:* Selection of articles was done via manual and automatic search from Scopus, Science Direct, springer link and Web of Science databases spanning from 2015 to 2020. 778 articles were retrieved but only 46 were found relevant for this study.

***Findings****:* It was found that the most reported advantage of adopting VR and AR in teaching and learning chemistry is enhancing better understanding followed by improving learning achievement. However, the highest reported disadvantage and challenge are that they cause fatigue /nausea and technical problems, respectively.

**Index Terms*:*** *Virtual Reality, Augmented Reality, Chemistry Education, 3D Technology*

## I. INTRODUCTION

APPLICATION of technology in science education to facilitate better teaching learning has necessitated a paradigm shift from the traditional way of teaching and learning to an advanced digital mode of education. Virtual and Augmented reality technologies have been of great impact in science education [1] and particularly in chemistry where it is proven to be good interactive tools for students to explore varieties of chemical compounds and their structures, interactions and how they undergo motion [2]. The education sector is currently experiencing an increase in the use of technologies such as virtual reality (VR) and augmented reality (AR), coupled with other interactive simulations for teaching and enriching students' educational experiences towards enhancing better learning [3]. The chemical laboratory has been an atmosphere for exhibition of various

technology inclined learning experiences where students engage in virtual interactions coupled with simulations and interactions with augmented virtual objects [4]. The use of virtual reality in chemistry education is becoming increasingly important as safety measures and other prerequisite knowledge and skills required for effective physical laboratory experiments are effectively acquired through this set of technologies [5]–[9]. Before the application of virtual reality in education, chemistry experiments were performed taking into account the high danger, chemical substances could inflict on instructors and students [10]. That made it scary to students and instructors thereby not allowing students to have a critical observation of a substance and its interaction with other substances.

However, with the introduction of VR and AR into education, students find it safe and comprehensive to engage in multiple observation at their conveniences about any chemical or scientific substances and processes in the science virtual laboratory [5]. This then offers students opportunity to develop and redevelop their learning outcomes in science. Looking at various human and environmental challenges that happens in life such as the currently happening of Covid-19 movement control order which has been placed by relevant authorities in order to tackle the global pandemic, distance learning would be encouraged so as to keep the education of our students ongoing [5], [11], [12]. Chemistry education would find VR of tremendous help in the education of its students by engaging them not only in theoretical concepts but also experiences in practical experiments which would have taken place in the laboratory. The use of many learning models and themes in chemistry are usually integrated into virtual reality laboratory to offer a more comprehensive learning experience. Studies shows that involving learning models such as the use of Sustainability Innovation Experiential Learning Model, Interactive Molecular Dynamics, structural equation model into VR labs improves better learning [13]–[15].

This article, therefore, intends to provide knowledge about some other research articles which focused on the use of virtual and augmented reality in science education particularly in chemistry education. The articles analysed were those published within the year 2015 to 2020 by several Journals indexed in Scopus, Science Direct, Springer Link and Web of Science (WOS). These journals include; Journal of Technology and Education, Journal of Chemical Education, British Journal of educational Technology, Chemistry Education Research and Practice, International Journal of Instruction, Asia Pacific Education Research, Journal of Science Education Technology, Learning and Instruction, Educational Research Review and Computers in Human Behaviour.

This study aimed to answer the following questions:

(a) What are the advantages of VR and AR discussed in these articles?

(b) What are the disadvantages of VR and AR discussed?

(c) What are the common challenges encountered using VR and AR in teaching Chemistry?

## II. LITERATURE REVIEW

### *A. Definition of Virtual and Augmented Reality*

Virtual reality and Augmented reality are technological computer systems which are very critical in our modern-day teaching and learning, where they offer students with opportunity to develop better skills and conceptual understanding about the real world using virtual computer-generated simulations and live interactions with the virtual objects [13], [16], [17].

### *B. Previous Review Articles*

There have been several systematic review articles in recent years on VR and AR in different fields of study such as medicine, engineering, and agriculture. Most review articles concerning education were not directly

related to effects of using VR and AR in teaching and learning of chemistry. However, three of these articles that are considered of relevance to this paper were reviewed.

The first was titled 'advantages and challenges associated with augmented reality in education: A systematic literature review' written by [18] and cited by 501 readers based on google scholar data base. It reviewed 68 research articles through a full range of SSCI journals. Its findings revealed that there was increase in number of studies in AR within the past four years from the study period. Also, the major advantage recorded by these articles was that AR promotes enhanced learning achievement of students. Furthermore, the main disadvantages associated with AR in teaching and learning was identified as usability issues and technical problems.

The second review article titled "systematic review of virtual reality in education" was written by [19] and cited 33 times based on google scholar. The article reviewed 90 articles but only 33 discussed the importance of VR in relation to limited access materials for experiments in science related learning areas; 8 of the articles discussed in relation to distance learning. In relation to implementation of VR in education, 32 stressed on increased motivation and closely related to motivation, 20 shows increase in students' enjoyment.

The third article titled " Systematic review and meta- analysis of augmented reality in educational settings" written by [20] was cited 18 times according to google scholar. The article studied 61 papers published between the year 2012 and 2018.The findings indicate that AR has a medium effect on learning effectiveness. The highest advantages of AR systems reported in education were learning gains and motivation of students. the main disadvantage recorded was that only one of the AR systems of the studies includes accessibility features and perhaps presents a drawback in terms of social inclusion [20].

## III. METHOD

### *A. Data Sources and Search Strategies*

The search query by means of academic databases resulted in 778 results, 431 after the title examination were removed. The original exclusion included duplication and irrelevant articles. 347 articles were analysed abstractly and 183 articles not meeting the requirements of inclusion were omitted. For full-text analysis 605 articles were evaluated. A total of 46 papers were chosen for the final evaluation after the full text analysis based on eligibility criteria. Figure 1 provides a summary of the selection process for publications

### *B. Data Extraction*

Information on the affiliation of authors, publishing site, database sources, keywords, issues discussed, characteristics of sampling, context, and domain of research, as well as the country of setup were collected. In addition, research design and methodology, methods, and analysis for collecting data, and key results (including limitations and potential directions) were also gathered. Later, two reviewers independently reviewed the results, and any differences were resolved through discussion. See figure 1

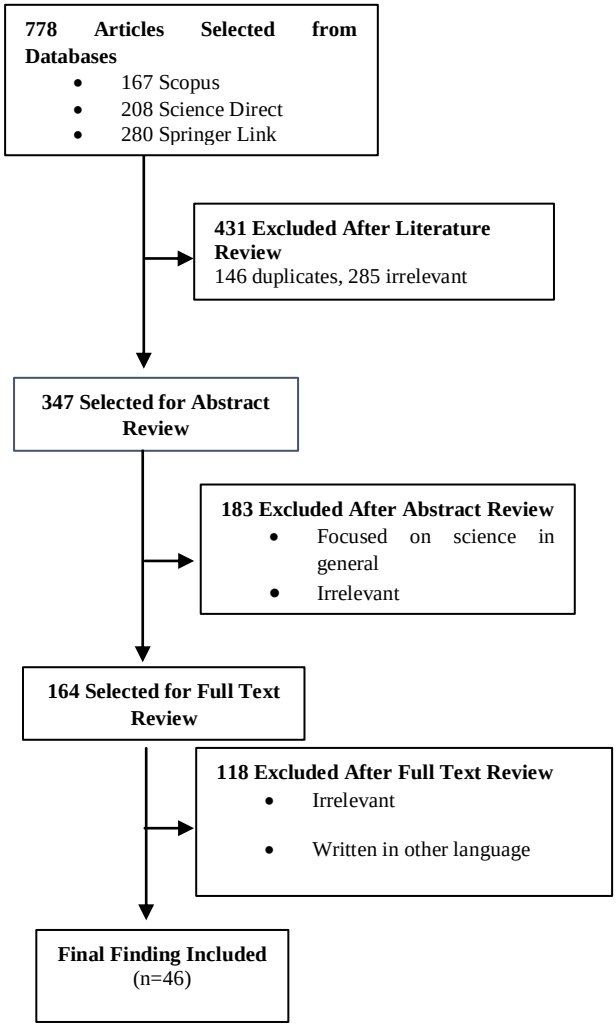


Figure 1: Diagram Showing the Extraction Process of the Articles

## IV. RESULTS

### *A. Research Question 1*

*What are the advantages of VR and AR discussed in these articles?*

The need for teaching and learning using virtual reality in chemistry laboratories back then was a necessity when university lecturers were faced with much work load for introductory chemistry where both lecture classes and laboratory classes needed to take place simultaneously thereby maintaining quality education [16]. Recently, implementation of VR learning in teaching and learning of chemistry has received good reception by students as it offers wide range of benefits as compared with traditional way of teaching and learning [21]. The ability of VR and AR to display chemical entities and processes in 3D dimension enables students to develop 3D spatial reasoning, which ordinarily would be very difficult for students to achieve through 2D representation [22]. Based on review of 20 article, researchers found the advantages of using educational VR and AR in teaching and learning chemistry. The result is shown in table1 and figure 1 below.

Table 1: Percentage and number of articles showing advantages of VR and AR

| **ry** | **Advantages** | **No. of Articles** | **Percentage (%)** |
|---|---|---|---|
| **1.Affective domain** | a) interesting to use | 10 | 21.7 % |
| | b) motivate students | 13 | 28.3 % |
| | c) improves students' self-efficacy | 1 | 2.2% |
| | d) students are well engaged in learning | 3 | 6.5% |
| | e) it is enjoyable | 1 | 2.2% |
| | f) reduces fear of lab hazards | 2 | 4.3% |
| | g) improves students' attitude | 6 | 13.4 % |
| | h) reduces lab anxiety | 1 | 2.2% |
| **2.Realisation of Learning Objectives** | a) improves tactile perception | 1 | 2.2% |
| | b) improves technological skills | 1 | 2.2% |
| | c) enhance better understanding | 19 | 41.3 % |
| | d) improves visualization of abstract content | 14 | 30.4 % |
| | e) reduces experimental error | 6 | 13.4 % |
| | f) improves memorization of experiences | 4 | 8.6% |
| | g) improves learning efficiency | 1 | 2.2% |
| | h) improves students' science process skills | 4 | 8.6% |
| | i) improves research or inquiry skills | 2 | 4.3% |
| | j) improves scientific literacy | 1 | 2.2% |
| **3.Learning Outcome** | a) Improves learning achievement | 18 | 39.1 % |
| | b) enhance critical thinking | 2 | 4.3% |
| **4.Time Management** | a) better time management | 1 | 2.2% |
| **5. pedagog** | a) effective for distant learning | 3 | 6.5% |

| | | | |
|---|---|---|---|
| **y/ Flexibility** | b) easy to use | 2 | 4.3% |
| | c) improves teaching efficiency | 1 | 2.2% |
| | d) effective for pre-physical lab hands-on learning | 7 | 15.2 % |
| | e) enhances collaborative learning | 2 | 4.3% |
| **6. Cost/ Resource Management** | a) no wastage of reagents | 1 | 2.2% |
| | b) reduces chemical accidents | 1 | 2.2% |
| | C) reduces cost of physical experiments | 3 | 6.5% |

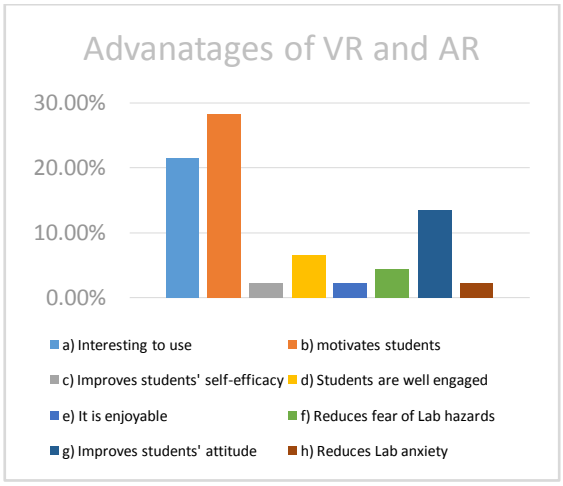


Figure 1.1; Percentage of Articles Showing Advantages of VR And AR Based on Affective Domain

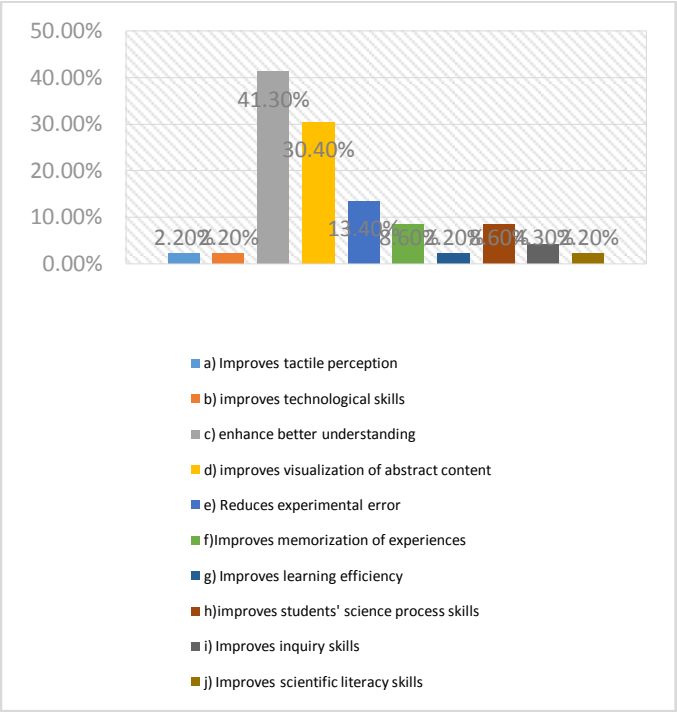


Figure 1.2; Advantages of VR And AR Based on Realization of Learning Objectives

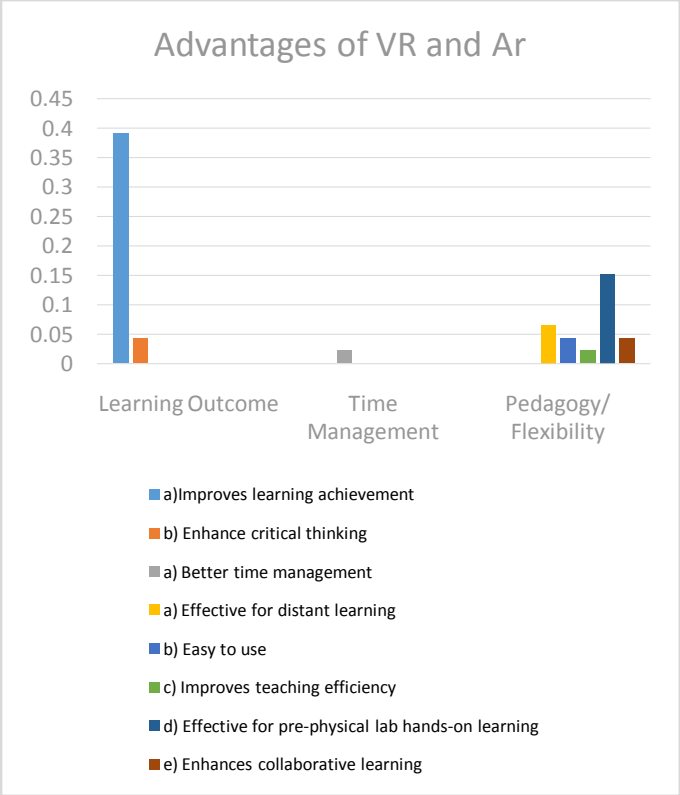


Figure 1.3; Percentage of articles showing advantages of VR and AR based on learning outcome, time management and pedagogy/flexibility.

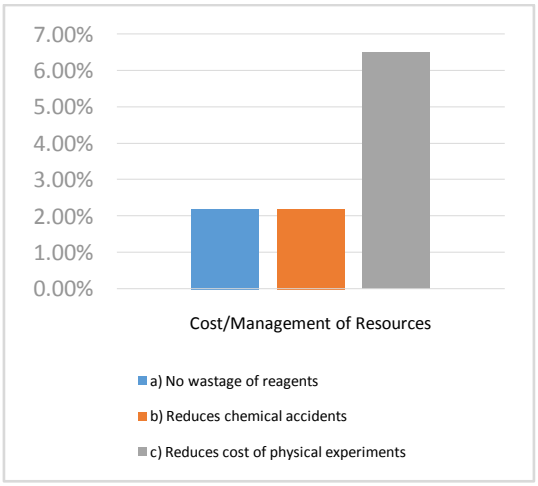


Figure 1.4; Percentage of Articles Showing Advantages of VR and AR Based on Cost/Management of Resources

From table 1 above, it is observed that 28.3% (13) of the total articles reported increase in students' motivation towards learning chemistry. This advantage among others in relation to students' affective domain is the most recorded by the research findings concerning learning chemistry through VR and AR. The second most reported advantage within the affective domain as observed in Figure 1.1 above, is that the VR and AR are interesting. 21.7% (10) of the reviewed articles reported this in their findings which means, problems usually associated with boredom and lack of interest in learning chemistry using the traditional methods can be potentially be mitigated by adopting the effective use of VR and AR in teaching and learning of chemistry most especially within secondary and first year undergraduate chemistry students. However, the least observed advantage(s) under the affective domain whereby only 2.2% (1) article reported is regarding enjoyment and increasing students' self-efficacy. This, coupled with a study done by [3] and [12] suggest the need for more research regarding use of VR and AR in education as it relates to affective domain involving both students and teachers. It is of great significance to observe the impact of VR and AR on students' attitude towards learning chemistry. This study shows that, 13.4% (6) articles reported a positive impact or advantage of implementing these reality technologies in teaching and learning of chemistry. A good number of studies can be tailored towards this direction to help us have affirmatory evidence regarding effect of using VR and AR on students' attitude.

Considering realization of learning objectives which is an aspect of cognitive learning where most research on VR and AR were carried out is essential in determining the efficiency of these technology in chemistry education. Table 1 and figure 1.2 above shows that, the highest percentage (41.3%) of articles under review

reported the advantage of using VR and AR to enhance better understanding of content. This followed by improving visualization of abstract content which was reported at 30.4% (14). Next third most reported advantage in which 13.4% (6) articles showed that VR and AR reduces experimental error. However, 8.6% (4) of articles reported that VR and AR improved science process skills (SPS) as well as improves memorization of learning experience. These percentage of articles do not entail that each article which showed improvement in SPS also reported improvement in memorization of learning experience. Other advantages such as improving tactile perception, technological skills, learning efficiency and scientific literacy, all were reported by the least percentage (2.2%;1) of the 46 articles reviewed.

Other aspects of understanding the advantage of VR and AR in teaching and learning of chemistry are learning outcome, time management, pedagogy, and flexibility. In these aspects, significant percentage (39.1%;18) of articles reported advantage of VR and AR to enhancing learning achievement. Improving pre-physical hands-on learning was the advantage of using VR and AR with second highest percentage (15.2%;7) of articles reviewed in these aspects. 6.5% (3) of the articles showed that the VR and AR technology systems are good for distant learning whereas, 4.3% (2)7 reported that they enhance critical thinking, are easy to use, and enhances collaborative learning. The least percentage of articles (2.2%;1) reported that VR and AR enable better time management and improves teaching efficiency.

The last aspect, which is cost/management of resources experience limited number of studies associated with VR and AR in relation to teaching and learning of chemistry as observed in figure 1.4 above. In this aspect, 6.5% (3) of these reviewed articles reported that, VR and AR reduce cost of physical experiments and 2.2% (1) reported that VR and AR reduces chemicals accidents and wastage of reagents.

*B. Research Question Two*

*What are the disadvantages of VR and AR discussed?*

Using new educational technology like VR and AR create an appropriate opportunity for teachers to teach chemistry concept easily and effectively and these tools are very helpful to learn the chemistry concept meaningfully, there are still, some disadvantages of using VR and AR in teaching and learning chemistry. Table 2 and figure 2 indicate some disadvantages of using VR and AR in teaching and learning chemistry.

Table 2: Percentage and number of articles showing disadvantages of using VR and AR

| **Disadvantages** | **No. of Articles** | **Percentages (%)** |
|---|---|---|
| a) Distraction and noise | 2 | 4.3% |
| b) System's delay | 1 | 2.2% |
| c) Causes fatigue/nausea | 4 | 8.6% |
| d) Less interaction compared with video games | 1 | 2.2% |
| e) Increases students/teacher's workload | 2 | 4.3% |
| f) Difficult to use | 1 | 2.2% |
| g) Less useful | 1 | 2.2% |
| h) Ineffective for science process skills mastery | 2 | 4.3% |
| i) Less support for collaborative learning | 1 | 2.2% |
| j) Reduces students' resilience | 1 | 2.2% |
| k) Reduces students' attentiveness | 1 | 2.2% |
| l) Time wastage | 1 | 2.2% |
| m) Induces motion sickness | 1 | 2.2% |
| n) Not completely better than physical lab | 1 | 2.2% |
| o) Lacks assessment feedback | 1 | 2.2% |
| p) Negative effect on education if poorly implemented | 2 | 4.3% |

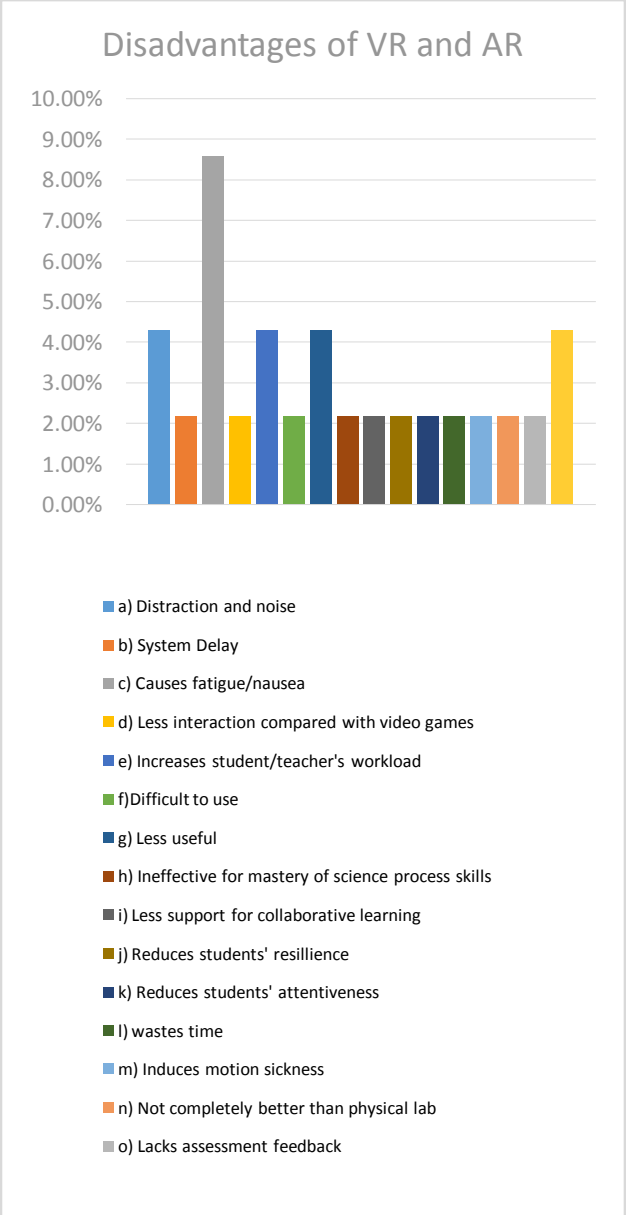


Figure 2: Disadvantages of using VR and AR in teaching and learning of chemistry.

From table 2 above 8.6% (4) of articles show that VR and AR systems causes fatigue and nausea most particularly for head and hand-mounted systems. 4.3% (2) attribute negative effect of VR and AR to noise and distraction, increase in teacher/students' workload, ineffectiveness for mastery of SPS and poor education if not properly implemented. Other disadvantages such as system's delay, less interaction, difficult to use, less useful, less support for collaborative learning, reduction of students' resilience, reduction of students' attentiveness, time wastage, motion sickness induction, not better than physical lab and lack of assessment feedback all were reported by only 2.2% (1) of articles reviewed.

*C. Research Question Three*

*What are the most challenges encountered using VR and AR?*

Beside the benefits of new educational technologies such as VR and AR in educational system, there are some challenges toward using educational technology in the class. Among all new educational technology, VR and AR are very important and useful in science, especially in chemistry. By using VR and AR, all students are likely to understand the abstract content in which the sub-microscopic representation of chemical concepts can be meaningfully understood thereby making it interesting. Table 3 and figure 3 presents the challenges reported by the articles reviewed, toward using VR and AR in teaching, and learning chemistry.

Table 3: Challenges of using VR and AR in teaching and learning of chemistry.

| **Challenges** | **No. of Articles** | **Percentage (%)** |
|---|---|---|
| a) Lacks sound of moving fluid | 1 | 2.2% |
| b) Technical problems of hardware and software | 6 | 13.4 % |
| c) Inadequate VR and AR learning environment | 1 | 2.2% |
| d) Lack of operational skills | 5 | 10.9 % |
| e) Lack of actual sense of reality | 1 | 2.2% |
| f) Internet failure | 1 | 2.2% |
| g) High cost | 5 | 10.9 % |

From the table 3 above, the most challenge associated with use of VR and AR in chemistry education was technical problems. These were reported by 13.4% (6) of the reviewed articles. Lack of operational skills and high cost of VR and AR systems were reported by the next highest percentage of articles 10.9% (5) reviewed. The remaining challenges such as lack of sound of a moving fluid in the virtual systems, inadequate VR and AR learning environment, lack of actual sense of reality and internet failure were reported by the least percentage (2.2%;1) of the 46 reviewed articles. These challenges crucial towards improving the effectiveness of VR and AR systems in chemistry education.

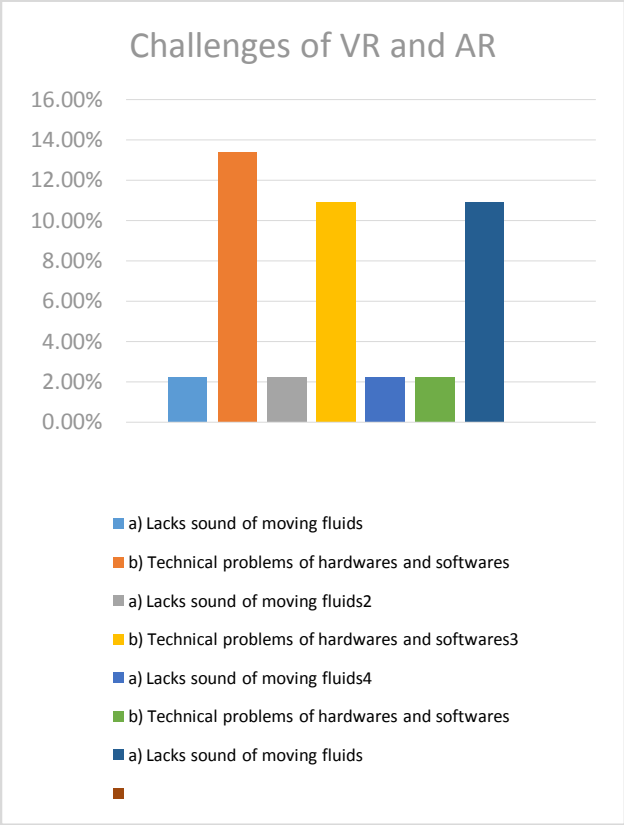


Figure 3: Challenges of using VR and AR in teaching and learning of chemistry

## V. DISCUSSION

### *A. Advantages of VR and AR in Teaching and Learning Chemistry*

Results obtained in figure 1 shows that the advantages of using VR and AR in learning chemistry as reported by the highest number of articles is that VR and AR improves better understanding followed by improvement in learning achievement [23]. The 21st century students' system of learning in this technological era lead to 28.3% and 21.7% of the reviewed articles reporting increase in motivation and interest after learning using VR and AR systems. Furthermore, students' attitude was reported to increase after learning through these technology systems but with only 13.4% (6) articles confirming this impact. More research on students' attitude towards learning chemistry using VR and AR systems can help to obtain sufficient evidence regarding this fact.

The continuous trend in technological advancement in which very soon, 5th industrial revolution may emerge bringing forth more sophisticated technologies which can be applied also in education thereby making VR and AR systems slightly obsolete. The challenging technological demands in education where students and their instructors can engage in teaching and learning processes over a distance with the aid of relevant computer applications offers ample opportunity to deploy VR into chemistry education as it offers almost equal learning outcomes to the students when compared with normal traditional learning in the physical laboratory with the lecturer [11]. The use of augmented reality teaching and learning of chemistry has offered instructors with less work and have increased learning outcome of students being the fact that, most of the objects we see are viewed based on 2 dimensions. Whereas AR allows students to see real objects in more comprehensive way in 3D. We shall elaborate more on some of these advantages of using VR and AR systems in chemistry education.

Motivation, has been described as the desire to act, plays significant role in learning as students often refer to chemistry as a subject full of abstract reasoning and thereby being difficult to study [24]. Studies carried out on enhancing students motivation deployed various technologies such as game-based learning and the use of computer simulations; their findings reveal a significant improvement in students' learning achievement after being subjected to pre-test and post-test[25]–[27] .The introduction and implementation of VR and AR into chemistry education enhances students' motivation for the subject. In a study done by [2], students were subjected to virtual reality learning based on interactive molecular dynamics (iMD-VR) in organic chemistry class. The findings show great motivation in students and its impact on students learning outcomes was also commendable. Beside students' interest which determines a student's decision to either choose chemistry or remain in chemistry class, motivation is very important in determining the sustainability of students' participation and learning in chemistry [26]. The provision of virtual chemistry laboratories in schools, universities or colleges where variety of learning models are displayed would not only enhance conceptual understanding and skill development of participating students but also motivating prospective students who might have read about virtual laboratories but have not experienced learning directly through it [15], [28]. That would instil more curiosity in the students [15].

The inability of chemistry students to form mental image of the sub-microscopic level of chemical substances is a factor to point in which VR and AR gave huge sigh of relief in this regard as they enhance visualization of abstract content [8], [29]–[33] and sophisticated instruments used in analytical chemistry[34]. This clear visualization lead to better learning achievement as students understand the intricacies in chemistry[10], [35]–[39] and also develop better experimental skills [40], [41]. Most of these studies were done in comparison with the traditional teaching technique and more understanding of chemistry content was observed in their findings [42].

Students attitude towards chemistry is an area that attracted many studies many years ago till date [39]. There had been appreciable number of students whose attitude towards learning chemistry improved using VR and AR systems in teaching specific areas in chemistry [38], [43]–[45]

The primary aim of every educational system or curriculum is to develop students' knowledge, skills and values in order to enable them become relevant to themselves, society and the world at large [46], [47]. Since the advent of VR and AR into educational technology, many researchers have assessed the effectiveness of this technology towards students' learning outcomes. Findings from such studies revealed a significant increase in learning outcome of students who participated in learning through virtual science laboratories as well as through augmented reality [26], [37], [48].

The current technology era of the 21st century has transformed almost every aspect of our lives in that, computers and its applications are used immensely to enhance effectiveness and better the quality of life [49]. Gone are the days when students engage in manual experiments without or little intervention of computerized practical equipment. Results obtained had inconsistencies in values due to human and mechanical errors and hence affect students' overall learning outcome. The use of virtual and augmented reality in learning chemistry

most especially in the aspect of organic molecular structures and its stereochemistry, has cleared misconception of students about different kind of spatial arrangement of atoms within a given molecule and students have recorded significant increase in their academic achievement [11], [50].

In a study where students were exposed to interactive molecular dynamics, students expressed satisfaction based on their experience with this VR technology. The interactive, realistic experience of interactive molecular dynamics iMD-VR allowed students to better observe molecular movements within a particular medium, promote understanding of molecular interactions and aid in linking molecular views with macroscopic properties compared with conventional modelling kits and 2D computer models; Students can also study simple molecules, as well as complex structures, biological macromolecules, which significantly widens the scope of chemical comprehension for students with different interests at different memory capacity[2]. Learning chemical concept has been greatly optimized where virtual chemistry laboratory is augmented with physical interactions. Research on exploring how augmenting virtual labs with physical interactions affects students' learning of complex science concepts such as gas laws and kinetic molecular theory shows that, the virtual augmented laboratory helped students develop understanding of most targeted concepts, with significant improvement on understanding of gas pressure and Gay-Lussac's Law, and moderate improvement on gas temperature, Avogadro's law, and the relationship between molecular mass and gas pressure [51].

The use of VR and AR technologies as a technique to get enable students understand and master the techniques involved in and prior to performing experiments in the physical hands-on chemistry laboratory has been highlighted and suggested to be effective by a number of findings [6], [7], [9], [52]. A typical example is a studies done by [5] in which, students were taught the safety and hygienic use of hand gloves using virtual reality systems.

Critical thinking can be seen as a thinking strategy which deals with systematic and logical reasoning towards making inquiry or finding solutions to a problem [53]. In the articles reviewed, there is a relationship between critical thinking and students learning outcomes. In a study done by [54], there was increase in students' learning outcomes and critical thinking after they were subjected to problem solving with concept map. The use of VR and AR in combination with other learning techniques is cardinal in developing students' critical thinking. In a research done on integrating peer assessment with a virtual reality design system, results presented that students who performed the VR design activity with the peer assessment learning approach had higher learning effectiveness, self-efficacy and critical thinking tendencies than those using the VR design system with conventional teacher feedback [37]. In a research performed on the effect of 3D visualization on students' critical thinking and scientific attitude, it was found that students who used 3D visualization had better outcome in critical thinking skills [45]. 3D offers students to view parameters in three dimensions thereby developing better critical thinking since objects, processes and interaction between objects can be well explain by the 3D simulations, the development of more advanced thinking about the parameters may evolve thereby leading to critical thinking and higher order thinking skills.

The natural sciences and particularly chemistry learned at early teenage age is always present throughout the educational moments of students, who seem to show much curiosity and motivation for these disciplines during the early years of learning chemistry. However, these favourable attitudes that arise at an early years do not remain the same throughout a student's learning time at school due to increasing demand of the subject from the students [55] . Effective learning of any subject or course is most often attributed to learners' attitude towards the subject; positive attitude tends to promote better learning achievement of a student compared with that whose attitude is negative [44], [55]. The use of AR and VR technology in learning of scientific facts has proven significant increase in students' general attitude towards learning science and particularly chemistry [16].

From a study where AR was used to determine its effect on students' learning achievement and attitude towards science education, results indicate that students were pleased and eager to use AR applications, thereby

not showing any signs of anxiety while using AR applications [38]. An indicator that shows students' attitude towards learning is ultimately their academic achievement in a determined subject of studies. Furthermore, students' efforts in obtaining a quality scientific study to sharpen their scientific knowledge and skills is an activity that represents a positive attitude towards science [45]. From similar studies done to determine the impact of AR on students' attitude towards learning science, findings show that students did not face serious difficulties while using AR technology. This was true for the students who were able to use AR technology and wanted to use it again in the future. Perhaps, they did not have any concern about its use. Chemistry is often closely related to the discipline that involves students' scientific attitude; In order to help students, improve their imagination in thinking critically and getting used to being scientific, media is required to facilitate the learning process [38].

The ability for the teacher to present learning experiences through AR and VR such that students can have thorough observation of the facts within many time periods over again makes it flexible towards learning regarding time. To present learning experiences the AR applications allows that in certain teaching/learning contexts, they can be performed by the student on his own, thus saving teacher's time spent on repeating explanations. The students gladly welcome this technology, so a well-planned AR application will allow them to successfully perform any learning processes [16]. The technology accommodates both individual and collaborative learning processes, through the wide range of its view in the virtual laboratory and the ability for individuals to observe through the AR system. Collaborative observation through the VR and AR 3D systems is more effective in knowledge gains than collaborative problem solving in a virtual world [56].

*B. Disadvantages of VR and AR in Teaching and Learning Chemistry*

From the report of findings recorded in figure 2 above, it can be observed that the disadvantage associated with learning via VR and AR most reported by the articles under study is the cause of fatigue/nausea for head and hand-mounted devices [5], [33]. Another disadvantage liken to health concerns is that VR and AR systems causes motion sickness [5], [57]. This is an area of much concern for research on the health concerns associated with the use head and hand mounted VR and AR devices. Other disadvantages such as distraction and noise, increase of workload, systems' delay, less interaction, difficult to use, time wastage, lack of assessment feedback, less support for collaborative learning, ineffective for SPS mastery are threat to the effectiveness of these technology systems and potential exclusive adoption in schools and universities for effective learning. Therefore, it is easier to capitalize on the advantages but notwithstanding, conscious effort needs to be employed in tackling these challenges to ensure the full potential of VR and AR technology systems are utilized effectively.

The disadvantage associated with the use of VR and AR in teaching and learning have which indicate that students may be distracted in the process of learning using VR and AR and unsuccessful integrating of these tools in education system can leave many students without realising the learning objectives. In a work done by [58], integrating immersive virtual reality into science laboratory simulations had significant effect on students presence in the laboratory in terms of motivation but offers less understanding and assimilation. This is because learning science in virtual reality laboratory may put in too much load and distract the learner, thereby resulting in less opportunity to develop good learning outcomes. To argue this fact of overloading students with immersive virtual reality into science laboratory, [59], in their work described the feasibility of replacing an instrumentation-based organic chemistry lab with a VR experience; from their findings, results indicate that there are no significant differences in learning outcomes between students who did their experiments traditionally in the chemical laboratory and those who did theirs through the use of VR, and thereby indicates the possibility of using VR tool to offer organic chemistry lab experiment via distance education [32], [60], [61]. Students that tried the VR experience reported a high degree of satisfaction with the product and no significant usability barriers interface.

Furthermore, we cannot neglect the unsuccessful integration of VR and AR in teaching process , so can affect negatively the educational system.[62]. Digital reality technology appears to be a disconnected approach

because it is likely to be too costly to turn all organizational learning through a 3D environment [5], [36], [52], [63]. It would also be important to take due consideration to incorporate virtual reality with the other learning the company provides – whether it is eLearning on computers and mobile devices or offline training such as classroom activities. This is not difficult, but to ensure that the excitement of virtual reality does not distract from the value of other learning opportunities, strategic thinking is needed. It is fair to assume that you do not want to complete your learning in virtual reality at your desk because of the possibility of bumping into colleagues and falling over office chairs. Employers would also need to find a suitable room at the premises to allow users to have personal space to complete learning comfortably. This brings Learning and Growth back to conventional classroom training designed to move away from eLearning in the first place and limits the learner's independence. Moreover, while most of the primary learning style in the UK is said to be kinaesthetic, this is not shared by all learners and so other learning styles may be more successful. [64]

*C. Challenges of VR and AR in Teaching and Learning Chemistry*

The challenges associated with implementation of VR and AR in schools as shown in figure 3 that is mostly reported by the research articles under study, is issues related to the learners which records 30% of all articles. This could be because learners' mode of learning has been conditioned to other learning methods which makes it difficult to embrace learning via AR and VR. The next most reported challenges by the articles under study is the lack of operational and professional skills by teachers which affects the learning process. Proper training of teachers would be needed for teacher effectiveness in using this learning methods. Other challenges such as high cost which records third most reported challenge could result to inability of schools to purchase or replace these systems or its components with new ones. The least reported challenge is the technical problems associated with the VR and AR systems. This would be because professionals are involved in the manufacturing industries where the VR and AR systems are made which may ultimately result to its high cost. These issues generally effected the integration of VR and AR successfully. Researchers mentioned that majority of schools, universities and institutes are using AR and VR traditionally because the teachers have no enough knowledge and skill to use these tools perfectly ore they high cost of these tools is a big barrier against utilizing of VR and AR in the education system.[16], [45], [55], [62], [64]–[67]. The first issue toward using VR and AR in teaching and learning is technical supports. Lack of technical supports caused to degrease the rate of using these technologies in the schools. Teachers are usually afraid to use these technologies. For instance, one type of AR technology includes a head-mounted display and/or additional computer fitted backpack. The bulky and costly design could cause problems like discomfort and poor perception of depth [45]. Additionally, the greater the chance of system failure, the more devices used. How to keep multiple devices highly stable is becoming critical [66] which caused frustration amongst students as they were identified as a highly problematic issue by teachers. Thankfully, the problems of system integration and reliability may be solved by the recent rapid development in portal and wireless technology. A tablet PC or smartphone may include an integrated video camera, GPS, wireless router, faster processor, and large hard-drive memory, in addition to more than a dozen mobile applications. The portable devices in AR systems can be expected to become increasingly integrated and robust when running simulations, games, videos, and GPS applications.

Moreover, the other common issue toward using VR and AR in education system is high cost of VR and AR tools. This is a big issue against integrating these technologies in education system. While there are a range of headsets and phones available to meet various budgets, there is no denying that investing in virtual reality technology would be a costly choice, particularly organizations with many employees. This is likely to mean that organizations are going to continue to invest in small amounts of devices to share among employees. While a relatively cost-effective tactic, limiting resource availability restricts employee flexibility in accessing learning through mobile and tablet devices anytime, anywhere. As stated earlier, one form of AR technology involves a head-mounted display and/or external computer fitted backpack. The bulky and costly design could cause issues such as discomfort and poor perception of depth [64], [66]. Current production of AR systems adopts portable devices that are less obtrusive and improve a sense of immersion and presence to prevent these problems. Furthermore, lack of knowledge and skill and pedagogy issue is the other common factor that affect negatively

implementing VR and AR in Education system. Researchers highlighted, lack of appropriate knowledge and skill is the main cause of why teachers are not interested to use new technology in the class like VR and AR. Indeed, they are not interested to utilize these technologies or can use effectively. According to [62],there are also pedagogical problems which need to be taken into account when implementing AR systems in classrooms. First, as with many educational developments in the past, the use of AR in classrooms could encounter school restrictions and teacher resistance. AR-related learning programs typically include creative methods such as participatory games and the workshop based on pedagogy. In modern teaching methods [65], however, the essence of these instructional strategies is somewhat different from the teacher-centred, delivery-based emphasis. Institutional limitations such as covering a certain amount of content within a given timeline often cause the introduction of technologies to be difficult [55], [66]. Thus, there may be a gap between the methods of teaching and learning currently employed in classrooms and the student-centred and exploratory nature of learning created by AR systems. AR learning environments designers need to recognize the divide and provide resources to help teachers and students cross it

Finally, there is issues related to the learners toward using VR and AR in teaching and learning chemistry. In an AR learning environment, the large amount of information they experience, the various technical tools they are expected to use, and the complex tasks they have to accomplish may cognitively overwhelm students. That is, in AR environments, the students need to be multitasking. [55], [66] stated that when they were participating in a multi-user AR simulation, students frequently felt frustrated and confused, as they had to deal with new technology and complex tasks. In addition, the tasks in AR environments that require students to apply and synthesize multiple complex competencies in spatial navigation, teamwork, problem solving, manipulation of technology, and mathematical estimation [16]. Previous studies suggested that one explanation for learning difficulties for students in AR environments is the lack of such basic competencies [65]. For younger learners and novices in conducting open-ended investigations in particular, additional scaffolding and guidance will be required to help them develop an appropriate action plan, look for potential solutions to their problem, and interpret the clues given by technical tools and embedded in the real-world environment [65]. Additionally, AR offers a situation where reality and fantasy are mixed, but this mixed reality may cause confusions among students. In study by [45], [66], some students "lose sight of where the game ends and where reality starts". Although such uncertainty indicates the validity of an AR program, losing track of the real environment may not be beneficial for learning, and may threaten the physical safety of students [64]

## VI. CONCLUSION

Learning through Virtual and augmented reality for the past five years as reported by the 46 articles in this study have suggests high chances of being well-absorbed into teaching and learning of chemistry in schools. The reported advantages considerably outweighed the disadvantages. Most of the reviewed articles have revealed more advantages of VR and AR as compared with disadvantages and challenges.

## VII. IMPLICATIONS FOR RESEARCH AND PRACTICE

The findings from this study has provided information about the basic issues associated with the use of VR and AR in teaching chemistry based on the outcomes of research done in the past five years about the effect on students affective domain, teaching and learning factors, technicality of the VR and AR systems and cost of affording them by schools. Schools and curriculum planners can find this study relevant in making efforts to enhance the teaching and learning of chemistry towards meeting the educational goals. In the field of research, this study would give basis for review to future researchers in seeking information during any review or meta-analysis within this context.

## VIII. LIMITATION

This study is limited to the study of advantages, disadvantages and challenges of teaching and learning using VR and AR in chemical context from 2015 through 2020. More so, only 46 articles were considered relevant for

this study. Further research under effect of learning chemistry through VR and AR may extend to a greater number of articles to give a wider report of findings about these technologies in chemistry education.

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