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The Effect of Augmented Reality and Virtual Reality Media on Affective Characteristics (Interest, Motivation, and Attitude) in Chemistry Learning: *A Literature Review*

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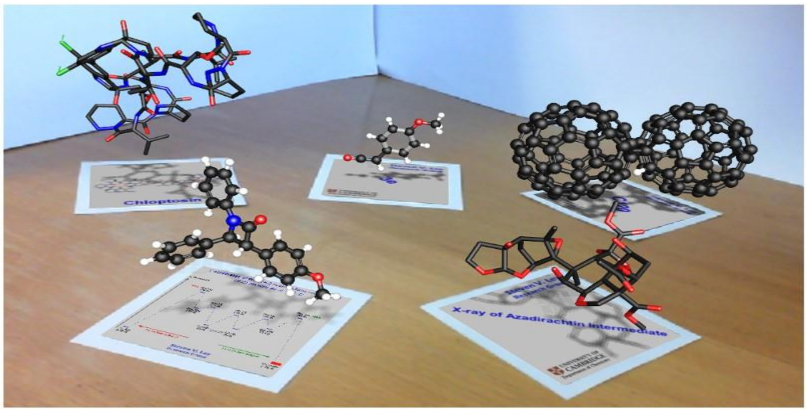
This study aims to analyze the effect of Augmented Reality (AR) and Virtual Reality (VR) media on motivation, interest, and attitude in chemistry learning. Sampling was selected by searching the ERIC database (eric.ed.gov) covering the last five years. Articles were sourced from journals ranging from quartile 1 to quartile 4, resulting in a total of 20 collected articles. Analyses were carried out based on affective characteristics, specifically motivation, interest, and attitude, within the context of chemistry learning using AR and VR media. The study's findings indicate that AR and VR media significantly impact these affective factors, revealing an interrelationship between motivation, interest, and attitude in the learning process.

Graphical abstract



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1. Introduction

The solution to depicting microscopic and submicroscopic structures and processes in chemistry subjects currently involves digital media such as Augmented Reality and Virtual Reality. The involvement of Augmented Reality can affect cognitive aspects because Augmented Reality is an application designed to display images, animations and audio and video files, or other interactive media to real-world objects through smartphone devices [1]. Augmented reality even managed to help represent the more complicated structures and motifs of complex inorganic

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compounds [2]. In learning chemistry, molecular structures are often depicted with two-dimensional media which results in missing information in the learning. Two-dimensional depictions are considered unsuitable for describing visualization interactions, Augmented Reality (AR) helps provide solutions with its ability to visualize three-dimensionally which of course will affect the development of students' cognitive abilities [3, 4].

AR also helps in visualizing the molecular orbitals of biomacromolecular compounds [5]. For more complex biochemical research such as explaining the molecular mechanism of selective ions in potassium channels, AR applications can be helpful [6]. AR in the form of *Palantir* device was successfully developed to help visualize protein complex compounds [7]. 3D visual depiction of protein complex compounds and membranes can be studied easily through AR BIOSIM media [8]. Several other studies have also involved Augmented Reality in solving chemical problems such as those related to the concept of hybridization, molecular geometry, chemical bonding, redox, and electrochemistry [9], as well as about the molecular structure of chemical compounds [10].

Not only problems in the classroom but also problems in chemistry laboratories have been successfully solved by augmented reality, for example by providing virtual titration devices for practical needs, which enable students to perform coulometric titrations via their respective smartphones [11]. AR can also be made in the form of AR video projection so that it is possible to display virtually how to use laboratory instruments and how to operate these instruments [12]. The limitations of laboratory instruments such as spectrophotometers, gas chromatography, and liquid chromatography can be displayed with augmented reality applications by simply scanning through a digital camera available on a smartphone. A study reported the use of augmented reality combined with several other software so that it is possible to do the practicum automatically only by utilizing the buttons provided for the titration practicum [13].

Digital developments then lead to solving chemical learning problems in the context of chemical practicum through virtual reality applications [14, 15]. Virtual reality is the involvement of "users" in the virtual world without seeing the real world. Dai *et al* reported that virtual reality media can be used to help learn coordination chemistry and molecular orbital theory with the advantage that the media created can display objects simultaneously in large numbers [16]. Virtual applications are a response to the importance of efforts to train psychomotor aspects on a laboratory scale.

The limited availability of laboratory equipment and chemicals encourages the birth of a virtual laboratory with an application system based on the concept of virtual reality [17, 18]. The virtual laboratory is a medium that can be used to assist students in providing interactive experiences to observe, manipulate objects and engage in systems and phenomena of the practicum [19]. Virtual laboratory provides advantages because the implementation of the practicum is cheaper and can be carried out anywhere [20]. In its implementation, the virtual laboratory was also able to improve students' concept of understanding the practicum material as well as being able to eliminate students' anxiety about the use of hazardous chemicals [21]. Another study even reported that the virtual reality laboratory could be used to explain the operation of the IR spectrometer and analyze the spectral results to know the structure of chemical compounds based on the spectrum [22].

The average research on Augmented Reality and Virtual Reality is focused on improving cognitive aspects, although Paembonan and Ikhsan (2021) reported that AR and VR can improve students' science process skills. Students with good scientific process skills also tend to demonstrate good cognitive skills because students' science skills are linked to the framework in which a scientist acts, thinks, and delves into problems to find scientific solutions [23]. However, improvement in scientific process skills can only occur when augmented reality media is used in the learning process using guided inquiry strategies. This means that an active learning process is required to support the use of AR and VR media so that it can impact students' science process skills. Devon Alcot, *et al* (2021) stated that AR and VR media should only complement the classroom and not replace the teaching process, because active learning assisted by AR or VR will further improve learning outcomes compared to passive learning.

In chemistry learning, cognitive aspects are not enough. Affective and psychomotor aspects play an important role in learning. Some studies looked at at the affective aspects of using both AR and VR applications [24]. The constructivist basis of science education places affective aspects as an integral part of the learning process. Affective aspects such as motivation, interest, and attitude can be seen in the context of the learning process and play an important role in developing a meaningful understanding of scientific concepts [25]. Chemistry, as a discipline within the scientific realm, involves not only cognitive but also affective processes that require development. In principle, the aspects of motivation, interest, and attitude are interconnected, each influencing the other. A student who feels motivated is likely to demonstrate increased interest, which, in turn, manifests as a positive attitude change.

Several studies using AR and VR media were able to improve the three affective aspects [26]. Sudarwo (2020) said that interest will affect motivation in learning. Motivation by itself will affect attitudes. Increased interest and motivation to learn by using AR and VR media will lead students to the formation of positive attitudes such as a confident attitude in dealing with all chemistry learning problems or an effort to find answers to conjectures that lead to the refraction of critical thinking [21]. The positive influence of AR and VR media integration in chemistry education should focus on enhancing additional emotive dimensions, enabling students to not only comprehend theoretical and conceptual but also to function as individuals with sound mental health. This good mental entity will encourage students to apply chemistry learning in everyday life and find solutions to life problems using the chemical theory that has been learned. Trained affective aspects should also be the basic capital of students in developing other competencies. Seeing the importance of affective aspects in the form of motivation, interest, and attitude towards learning chemistry after intervention with the use of augmented reality and virtual reality media, the review analysis is focused on the effect of augmented reality and virtual reality applications on motivation, interest, and attitude which are part of affective characteristics.

2. Material and Methods

This research is a literature review. The purpose of this study is to review the affective aspects of augmented reality and virtual reality research in the context of chemistry learning. Firstly, we show the results of the extraction and classification of research articles that discuss augmented reality and virtual reality in chemistry learning. In this research, the narrative review allows researchers to combine augmented reality and virtual reality research studies to see the differences between the two in chemistry learning. The data analysis technique was adapted from Rame and Rao (2011) in Melani J (2020) as shown in Figure 1 [27].

Based on Figure 1, the ***search*** step begins with searching for articles related to augmented reality and virtual reality on *eric.ed.gov* software. The search is focused on eric.*ed.gov* software to reduce the mixing of meanings in augmented reality research in the field of computerization and educational technology. The next step is the ***selection*** process. In the selection process, journal findings were eliminated. The selection is focused on the last 5 years because it considers the rapid technological developments in metaverse media for education that have occurred in the last 5 years. The selection process is carried out in the form of the following scheme.

From the data on the results of the article selection, 20 articles were sampled. The sampled articles were then analyzed using the analysis indicators: data collection methods in the article, population characterization, type of technology used, and affective aspects analyzed can be seen in the supporting information. Based on the data, the classification of research related to AR and VR can be described in Figure 3.

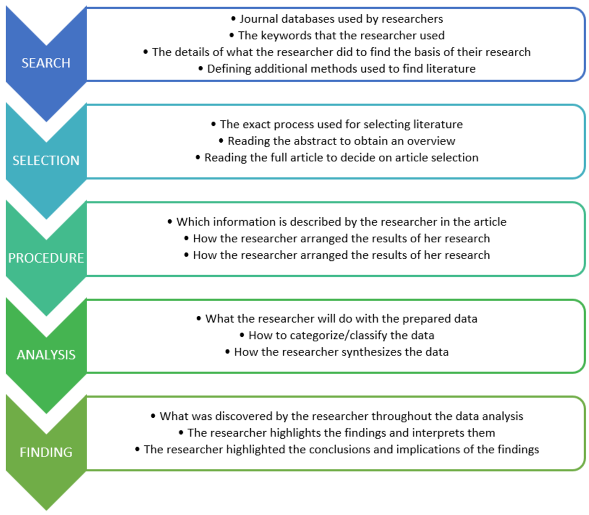

Fig. 1. Flow of Article Review Procedure.

From the data on the results of the article selection, 20 articles were sampled. The sampled articles were then analyzed using the analysis indicators: data collection methods in the article, population characterization, type of technology used, and affective aspects analyzed can be seen in the supporting information. Based on the data, the classification of research related to AR and VR can be described in Figure 3.

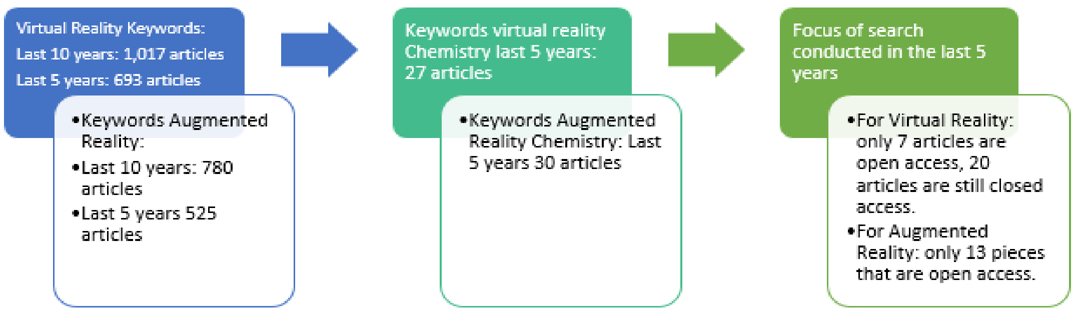

Fig. 2. Schematic of the Search and Selection Process of research articles related to Augmented Reality and Virtual Reality.

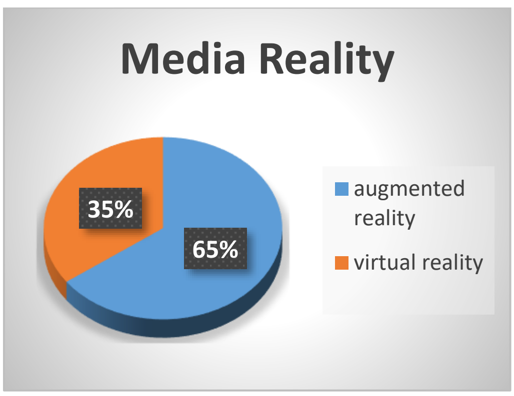

Fig. 3. Percentage of Augmented Reality and Virtual Reality Research.

Figure 3 depicts the percentage of research results related to the use of AR and VR media. From diagram 1, it can be obtained that there are already 65% (13 articles) related to AR and 35% (7 articles) related to VR. This provides information that the opportunity to research the use and development of virtual reality media is still very large compared to augmented reality. This is presumably because the development of AR media is much simpler in terms of supporting media and its use as well as much cheaper financing compared to VR.

3. Results and Discussion

The articles analyzed in Figure 3 are Scopus-indexed journal articles with a quartile range of Q1 to Q4 which can be described as follows in Figure 4.

From the articles listed in Figure 4, several indicators were analyzed. One of them is about the data collection method used in the article as shown in Figure 5. Figure 5 explains that on average, research related to augmented reality and virtual reality uses survey techniques as its data collection method. This survey technique is carried out to see the effectiveness of augmented reality or virtual reality media development. However, some studies have used test sheets to directly test aspects such as attitude, interest, and motivation. From the analysis article, there are other indicators analyzed in the article about the population taken in the study as shown in Figure 6.

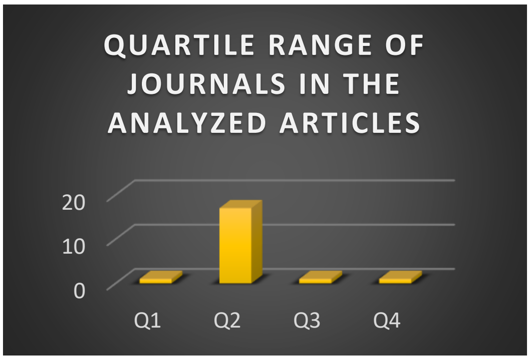

Fig. 4. Quartile Range of Journal Articles Analyzed.

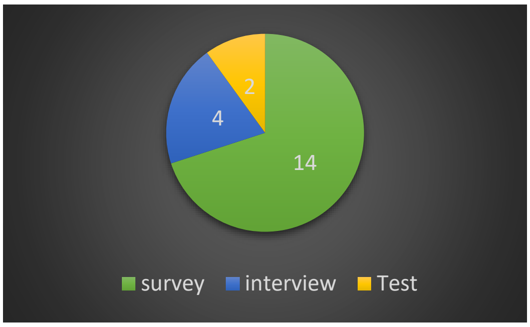

Fig. 5. Article data collection method.

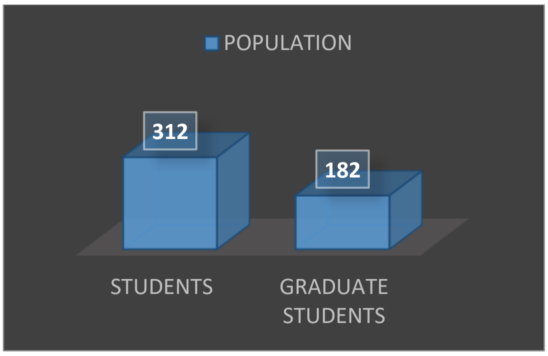

Fig. 6. Population involved in the review.

Figure 6 demonstrates that the research is dominated by the population of students. This indicates that research related to AR and VR is mostly applied at the high school level related to chemistry learning even though some research related to this media has been used at the university level to solve problems in chemistry lectures. This also provides an opportunity that there are still many unsolved chemistry problems at the higher education level. The data in Figure 5 is supported by the findings on the involvement of high school lecturers and teachers as mentors in the use of augmented reality and virtual reality media as shown in Figure 7.

The use of supporting media was also analyzed. The results of the analysis can be seen in Figure 8, which demonstrates that android media dominates in research. This happens because the number of studies that develop AR is much more than VR which takes Android as its media base. VR in its development requires tablet or desktop PC media supported by *occulus* lenses. There is only 1 study that uses IPHONE as its supporting media because the complexity of the AR developed is only compatible for IOS on IPHONE. Analysis of affective characteristics such as attitude, interest and motivation were conducted on research articles with a review pattern as shown in Figure 9.

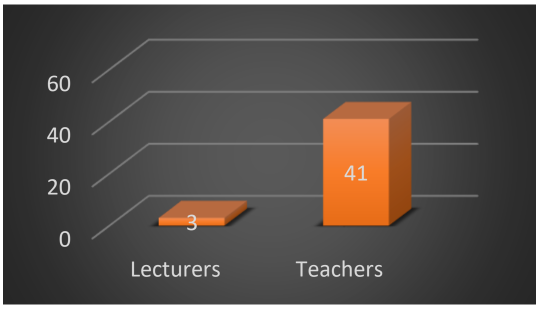

Fig. 7. Mentor Involvement in Research

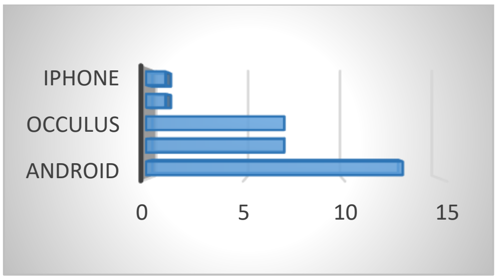

Fig. 8. Analysis of Supporting Media for AR/VR Usage.

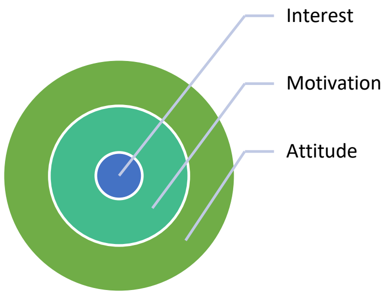

Fig 9. Pattern of Literature Review on Affective Characteristics.

Based on the pattern contained in Figure 9 it is informed that the review is carried out on aspects of motivation, attitude and interest which are part of affective characteristics by comparing these three aspects in the use of media and without the use of AR and VR media and then looking at the attachment between each affective aspect (motivation, interest, and attitude). The results of the literature review can be explained in detail below.

Interest

Interest can be interpreted as an interest in something that develops from a person as a form of psychological display. A person's interest tends to develop slowly but can last a long time and is usually connected to increased knowledge and values [28]. Interest is connected with other concepts such as motivation and attitude [25]. Interest in chemistry is defined as a phenomenon that has similar characteristics to motivation and attitudes but is still considered separate [29]. One of the distinguishing things is that interest is related to the interaction between individuals and their environment [30].

Interest into two namely; situational and individual interests. Situational interests usually last for a short period and tend to be unstable compared to individual interests which can last a long time and are stable. This individual interest involves cognitive aspects and affective aspects. Affective aspects in the form of values and feelings are incorporated into the individual interest component itself.

It was research that investigated the effect of interest in learning by using virtual reality media [21]. Table 1 below describes the results of descriptive analysis of pre-test and post-test scores. Quantitative experiments are measured using a questionnaire instrument containing statements about the affective characteristics scale. Figure10 shows a comparison of the subscales of the pre-test and post-test questionnaire results:

Table 1. Descriptive Analysis Results Of Pre-Test And Post-Test Scores On Interest Measurement.

	Pre-Test	Post - Test
N	17	14
Min	2.75	3.25
Max	5	5
Mean	3.74	4.09
SD	0.56	0.62

From the data in Table 1 and Figure 10, it can be concluded that there is a positive influence on student interest in learning using virtual reality media. This is evidenced by the increase in post-test scores compared to pre-test scores. These results are reinforced by qualitative data obtained from interviews in which almost all participants issued statements of "nice" and "interesting" towards using virtual reality media. This pleasant and interesting feeling is quite representative of depicting of interest as stated by Krapp, that the value and feeling components are depictions of interest.

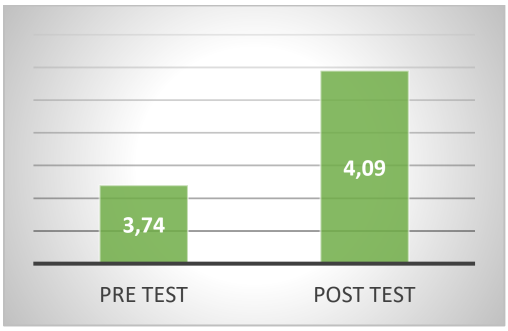

Fig. 10. Subscale Comparison of Pre-Test and Post-Test Questionnaire Results

Several other studies report that there is positive “feedback” on the use of virtual reality and augmented reality in learning chemistry. There was a “wonderful” or pleasant feeling in the survey results on the use of virtual reality in learning coordination chemistry and molecular orbitals [16]. Another explained about the sense of satisfaction in the survey results on the use of virtual laboratories in organic chemistry courses [31]. Jonas, who conducted a survey on the use of augmented reality in inorganic courses for depicting the molecular structure of inorganic compounds, also reported very strong "enjoyable" results[2]. Henrique who developed augmented reality for chemical structure lectures obtained survey results about the feeling of "enjoyed" [8]. Thus, it can be concluded that the use of virtual reality and augmented reality media can generally increase interest in learning chemistry. This conclusion is supported by studies both conducting whole experiments to obtain information about interest in the use of this reality media and the results implicitly obtained from surveys conducted on the development of virtual reality and augmented reality media.

Motivation

Motivation is an internal state that can arouse, direct, and sustain student behavior [28]. Motivation can also be defined as the desire to act [32] . Motivation is very closely connected to the social environment. Motivation is a complex, multidimensional construct with a range: "Unmotivated - Extrinsic Motivation - Intrinsic Motivation" [33]. If a student is unmotivated, then there is a tendency not to perform activities. In contrast, extrinsic motivation means that people perform activities because there are consequences such as rewards or punishments. Intrinsic motivation means when students enjoy the activity and feel satisfied in the activity.

In the reference list, there are no quantitative and qualitative studies that specifically aim to measure student motivation towards the use of virtual reality and augmented reality media. However, some research results implicitly explain student motivation after using the two-reality media. Fan Yang reported the results of their interviews that students feel motivated towards the use of augmented reality as a future teaching laboratory that can help deal with problems in the laboratory [13]. Rou Jia Sang informed about the results of the "useable in the future" interview on the trial of augmented reality media for learning the structure and function of macromolecules [6]. Rebecca also informed that students felt enthusiastic after testing the use of virtual reality laboratory on the introduction of chemistry practicum [20]. From some of the research results described above, it is concluded that there are changes in motivation in chemistry learning after the use of reality media (augmented and virtual).

Changes in learning motivation due to the influence of using AR and VR media cannot be separated from the role of the media itself as a stimulus. When a task looks uninteresting and unsatisfying in learning which is even accompanied by the need for repeated practice, students usually need extrinsic stimulus to increase their motivation [32]. AR and VR are one of media stimuli that are presented from outside the student so that there can be an increase in motivation.

Attitude

Attitude is the tendency to think, feel or act positively or negatively according to objects in the environment. Attitude consists of three components: cognitive, affective, and behavioral [34]. These components can be assessed by researchers. The cognitive component refers to a set of beliefs related to the attributes associated with the attitude object and can be measured through learning outcome reports, tests, or questionnaires. The affective component encompasses feelings toward the object, which can be assessed through physiological measurements, such as heart rate or dry mouth, as well as through the emotional experiences that emerge during the study. The behavioral component is the way people behave towards objects; this can be measured by direct observation of a person's behavior. Therefore, in learning chemistry, a teacher can observe the behavior of his students from the attitude displayed during learning. A positive attitude of students is reflected through their efforts in following the entire learning process, their enthusiasm for learning, and their willingness to read subject-related books to solve conjectures they encounter [28].

Similarly, Perloff explains attitude as a psychological construct, a mental entity embedded in the emotional aspects of a person's character. This construct, referred to as a "hypothetical construct", cannot be directly observed but can be inferred from an individual's actions [35].

Mafor Penn reported on changes in attitudinal aspects towards the introduction of virtual reality media in chemistry learning [26]. Mafor et al. used the ATC (*attitude toward science*) questionnaire to measure student attitudes in the chemistry learning process. The questionnaire consists of 30 questions with four attitude construct questions as shown in Table 2.

Table 2. Sample Questions Based n Attitude Construct.

No.	Attitude construct	Sample question
1	The importance of learning chemistry	How chemical development affects the quality of life
2	Chemistry learning difficulties	I find the use of chemical symbols easy to use
3	Interest in learning chemistry	I find learning chemistry very interesting
4	Chemistry usefulness for future career	My career depends on my knowledge of chemistry

Measurement uses a Likert scale with a range: strongly disagree, strongly agree, disagree, agree, and undecided. Table 3 describes the differences in pre-test and post-test scores on the measurement of attitudinal aspects.

Table 3. Results Of Analysis of Pre-Test And Post-Test Values on Attitude Measurement.

	Median	Standard Deviation	Standard Error
Pre-test	58.92	11.65	1.65
Post-test	82.58	6.17	0.87

Table 3 explains that the test score on attitude looks different in the aspects of "difficulty the subject" and interest in the subject". This indicates that during learning using virtual reality, participants think that learning chemistry is difficult and are not so interested in this.

Mafor also collected qualitative data on the attitudinal aspects of 10 participants [26]. This proved that: (1) eight people stated that learning with virtual reality was more fun while the other two participants felt like playing "games"; (2) seven participants felt more independent in learning while the other three still needed assistants to help solve chemistry problems; (3) all participants considered that virtual media to be more effective in supporting learning, particularly for practical activities, as it allowed for access at any time; (4) all participants agreed that virtual reality enhanced their understanding of concepts related to chemical reactions and spectrophotometry; (5) all participants considered that virtual reality could eliminate togetherness, highlighting this as a potential drawback. Another researcher, Nicholas Yee Kwang Tee, also reported increased student confidence in handling chemical compounds after using augmented reality media as a coulometric titration device [11].

In general, it can be concluded that using virtual reality media in learning has led to positive behavioral changes, including increased self-confidence in dealing with chemical problems and reduction of fear associated with hazardous chemical experiments. Additionally, virtual reality fosters a more enjoyable learning experience, promoting greater independence in solving chemical problems. A positive attitude is often reflected in positive behaviors, and thus, the influence of virtual reality has a beneficial impact on students' attitudes toward learning chemistry. Similar findings have been reported, showing that virtual reality media generates a positive attitude toward learning [36]. This effect is evident through changes in students' positive actions after being exposed to virtual reality media, supporting the notion that attitudes, while not directly observable, can be inferred from behavioral changes [35].

The relationship between interest, motivation and attitude towards the use of ar and vr media

As previously discussed, interest, motivation and attitude are interrelated. Interest influences motivation in learning and motivation, in turn, affects attitude [25]. When using AR and VR media, students first respond to the interesting aspect. Although interest and motivation are closely linked, they can be differentiated through individual and situational involvement [30]. In developing interest and motivation, AR and VR media serve as extrinsic factors influencing both. This extrinsic response positively impacts attitudes due to AR and VR's ability to visualize submicroscopic forms, making them appear real [1]. Within the scope of using VR within a Virtual lab setting, this application enhances extrinsic responses by presenting chemical instruments or chemicals that students only encounter in textbooks, thus brining them into a virtual environment. This extrinsic influence fosters a positive attitude, improving students' understanding of concepts, and also affects their attitudes towards the overall learning process in the lab [32]. It also contributes to increased confidence and a heightened awareness of safety when dealing with dangerous tools and chemicals [26].

4. Conclusions

Digital augmented reality (AR) and virtual reality (VR) media have been widely applied to address challenges in solving chemistry learning. A total of 20 articles were analyzed concerning the involvement of AR and VR media in chemistry learning, with 13 focused on AR and 7 on VR. Most of these studies center on the development of AR or VR platforms, followed by surveys assessing their use. The survey results implicitly highlight the motivational and interest-related aspects of AR or VR applications. The analysis reveals a positive influence on affective characteristics (motivation, interest, and attitude) following the incorporation of Ar and VR media in chemistry learning. These findings suggest that AR and VR can serve as basic data for further media development aimed at enhancing learning competencies, particularly in other affective domains and psychomotor aspects, áreas which have been scarcely studied.

Author Contributions

Muntholib, Maya Sari and Habiddin contributed with conceptualization, format analysis, investigation, methodology and writing original draft. I Wayan Dasna and Sumari contributed with investigation, visualization, writing review, and editing.

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