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Chemistry Taught With Augmented Reality And Learning Outcomes: A Review

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Augmented Reality
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Abstract
The point of this inquiry is to decide the effect of utilizing increased reality within the learning preparation and what materials frequently utilize AR at different levels of instruction and to decide the adequacy of AR in accomplishing learning results and expanding understanding of chemical concepts. The research strategy could be an orderly writing survey of different observational things about and related writing. Utilizing the SCOPUS database, mapping was carried out utilizing PRISMA charting innovation to get 40 articles recorded by Scopus. The inquiry about comes about appears that AR isn't as it was utilized to ponder chemistry subjects in essential and auxiliary instruction, but too to study progressed subjects such as response components and ghastly investigation in higher education. The most important reason for utilizing AR in chemistry learning is its capacity to supply three-dimensional visualization and interactivity to assist understudies in understanding complex and theoretical concepts. AR makes immersive and locks in learning encounters, increments understudy inspiration and engagement, and empowers secure and open virtual tests. The observational proof appears that the utilization of AR moves forward data maintenance, conceptual understanding, and down-to-earth aptitudes, essentially making strides in students' learning results and conceptual understanding. AR innovation has demonstrated success in accomplishing superior learning results and developing students' understanding of chemistry concepts, making it an imaginative and important instrument in chemistry instruction.

1. INTRODUCTION

Expanded reality (AR) could be a field of innovation that's always setting computer-generated virtual pictures into the genuine world, extending access to data and making modern conceivable outcomes for interaction. AR is nonstop scaling from the genuine environment to the virtual environment (Milgram, 2012). Due to its vicinity to the genuine environment, it can be seen as an expanded form of the genuine world by utilizing virtual objects. In later a long time, the instruction segment has appeared intrigued by AR innovation (Kencevski & Zhang, 2019), expanding its nearness at different levels, from preschool to postgraduate instruction. Numerous benefits have appeared when utilizing AR as a device to bolster education methods (Pribeanu et al., 2017). This gives openings for teachers to supply better approaches to displaying learning materials (Zhang et al., 2020). and planning a more intelligent learning environment to fortify students' mental interest (Elford et al., 2022) and bolster modern data to make strides in conceptual information (Irwansyah et al., 2020), theoretical concepts (Hikmah et al., 2017), and learning execution. Essentially, it encourages learning (Olim & Nisi, 2020), energizes the improvement of spatial aptitudes, and bolsters the learning of unique concepts (Virata & Castro, 2019). Investigate too appears that the passionate angle is emphatically impacted by motivation, self-confidence, satisfaction, etc. In times of social limitations such as the COVID-19 widespread, AR apps that permit understudies to work from domestic utilizing common portable gadgets are valuable.

Hence, a few regions of learning are progressively bolstered by AR-powered procedures. In chemistry, it is vital to get it the world of micro/macroscopic chemistry and theoretical concepts, counting complex themes such as atomic structure (Maier & Klinker, 2013), chemical bonds, and chemical responses. Typically exceptionally advantageous for understudies (Cai et al., 2014). Hence, the visualization of three-dimensional (3D) models can play an imperative part in the preparation of understanding this world (Aw et al., 2020). These models are regularly troublesome to get and utilize since they can speak to chemical forms at the nuclear level that are blocked off to tangible encounters and require progressed cognitive, spatial, and deliberation aptitudes (Frevert & Di Fuccia, 2019). For this reason, AR has become a fundamental instrument for the education of chemistry, giving an environment in which genuine and virtual universes coexist, advancing perspectives related to cognition, abstraction, and feelings. The advancement of information and communication innovations within the instruction region gives an alteration within the conventional learning environment(Auliya & Munasiah, 2020).

As of late, a precise writing audit (SLR) exploring the utilization of AR to bolster learning explored the benefits, patterns, benefits, and challenges of AR (Alzahrani, 2020). From a marginally diverse viewpoint, the SLR distributed by (Garzón et al., 2019) analyzed the effect of AR adequacy on learning. SLRs in expansion to having more particular objectives, for illustration, the creators (da Silva et al., 2019), needed to appear how AR can be assessed in instruction (Akçayır & Akçayır, 2017), highlighting which AR innovations are most regularly utilized for instructive purposes. Increased reality learning media makes unused encounters in instruction (Nengsih et al., 2023). All of these efficient surveys address issues related to the utilization of AR in instruction, but none center on particular angles related to chemistry learning and instructing.

In this field of science, most of the components and wonders are imperceptible to the human eye. Hence, the plausibility of depending on innovation to imagine these components is very interesting and this is often the main reason why we propose this specific SLR camera, centering on the utilization of AR in chemistry lessons. When we think about the utilization of innovation to bolster chemistry learning, the potential of AR is clear. Hence, a clearer picture of the current and past utilization of AR in chemistry learning and instructing is required. In this setting, it is vital to distinguish which AR points have been connected in chemistry instruction, what sorts of gadgets are utilized, what benefits have been gotten, and what challenges have been confronted. This data can be utilized to direct the advancement of modern AR instructive ventures in chemistry, give unused bearings for future investigations, and have a coordinated effect on conventional educating and learning designs. The significance of this ponder is that it primarily centers on two fundamental inquire about questions :

RQ-1:What chemistry subjects are instructed utilizing increased reality (AR) in chemistry classes at diverse levels of instruction?

RQ-2:What chemistry themes are instructed utilizing expanded reality (AR) to realize learning results and pick up a more profound understanding of chemistry concepts? Based on past writing audits, AR has appeared to make strides in inspiration, engagement, and conceptual understanding in science and innovation (Langitasari et al., 2022). Be that as it may, particular investigation on the subject of chemistry instructed utilizing AR is still constrained. Distinguishing these topics gives knowledge into where AR is being utilized most successfully and identifies holes that ought to be tended to. Moreover, assessing strategies utilized in chemistry instruction utilizing AR can offer assistance to educators and analysts select and planning the foremost viable educational approaches. This investigation is additionally vital to comprehensively assess the effect of AR on understudy learning results, counting conceptual understanding, down-to-earth aptitudes, and positive demeanors toward chemistry learning. In this manner, this inquiry will not as it were fill the existing writing crevice but also give commonsense direction to teachers and educational module designers to progress the quality of chemistry learning through AR innovation.

The significance of this investigation is how chemistry points instructed utilizing AR can offer assistance to teachers and analysts get it how this innovation is utilized to explore different chemical concepts. This gives you a clear thought of which subjects are best suited to instruct with AR. In expansion, with information on the points being instructed, analysts can utilize AR to recognize holes in writing or themes that have not been broadly examined. This could be the premise for the advanced investigation and development of instructive materials. It is additionally vital to educate educational program designers who utilize AR innovation to plan more compelling and inventive learning materials, particularly in zones that have not utilized it much.

2. METHOD

This ponder employments an efficient writing survey approach. Typically how logical inquiry is analyzed and considered, and conclusions are reached that eventually end up modern hypotheses and concepts. The inquiry displayed in this article is based on the SLR strategy (Mangaroo-Pillay & Coetzee, 2022), which is characterized by exploratory inquiry. The literature used to investigate fabric in this think about is auxiliary information within the shape of scholastic papers and a collection of scholastic diary articles.

The inquiry that was investigated and analyzed was constrained to the distribution period of Scopus-indexed papers, specifically from 2016 to 2024 (the year of cherry blossoms). Logical papers are within the frame of inquiry about works as inquiring about materials, and the information source is obtained from the Scopus database. The number of things utilized is 40 things. The catchphrases utilized to look and distinguish related articles are "learning media, expanded reality, time"

Table. 1 Inclusion criteria

No	Kind	Inclusion
1	Article Type	Research articles
2	Year of Publication	2016-2024 (current year)
3	Origin of the article	Scopus Database
4	Journal status	Indexed Q1-Q4
5	Example	Various levels of education

Search for articles via Scopus with search strategies

Table 2. Search Strategy

Look for	**Search terms in SCOPUS**	**Total Results**
S1	augmented AND reality AND in AND education	2851
S2	augmented AND reality AND education AND technology AND chemistry AND education	156
S3	augmented reality OR AND enhanced learning	708
S4	S1 OR S2 OR S3	604

With catchphrase channels from 604 articles. Within the information distinguishing proof, there were 257 articles issued since they had a tall likeness in substance compared to other articles, did not list the year of inquiry, and did not list the scope of instruction. Subsequently, the channel arrange yields 166 out of 257 papers that can be proceeded to the following extraction organize. The following is the full-text qualification organized. As of now, there are 37 articles looked at and 3 unique looks at chemistry instruction diaries ordered by Scopus Q1, so an add up to 40 articles are accessible as a source of analyst information.

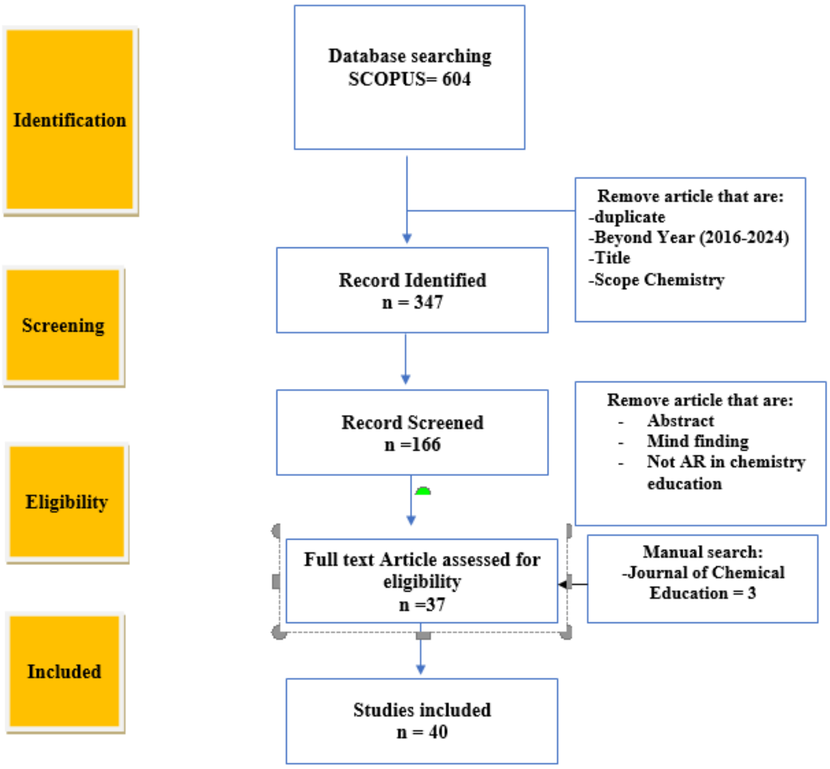

Figure 1. Prism Diagram.

3. RESULTS AND DISCUSSION

Result

The inquiries about discoveries from this precise writing survey were obtained through the method of looking into, analyzing, and summarizing papers through the extraction process. Explanatory themes within the investigation related to the utilization of expanded reality in chemicals, reasons related to the determination of chemicals examined, the investigation comes about, and investigative information is displayed underneath.

Table 3. Article Analysis

No	Article Analysis
1	Paper: Mobile Augmented Reality Assisted Chemistry Education: Insights from 4D Elements (Yang et al., 2018). Topic: Chemical bonding Reason for topic selection: Lack of understanding of chemical content Abstract: This article examines long-standing time discernment of chemistry instruction fueled by portable expanded reality (Damage), highlights their positive states of mind towards immersive learning encounters, and impacts the viability of Damage upgrade in instructing.
2	Paper: App-Free Methods for Polymer Visualization in 3D and Augmented Reality(Roshandel et al., 2023). Topic: Polymer Chemistry Reasons for choosing the topic: The requirement for 3D polymer models, illustrates the ease of making AR and 3D models for brief polymer chains utilizing free assets and highlights the instructive potential of these models. Abstract: This article presents a workflow for creating a 3D polymer show utilizing atomic elements and Blender. The objective is to create a viable and adaptable visualization approach

No	Article Analysis
	for frameworks of the same estimate, with a center on the availability of AR and 3D modeling for brief polymer chains utilizing free assets.
3	Paper: Development of Guided Inquiry-Based Learning Materials Enriched with Augmented Reality on Electrolytic Cell Materials (Pradani et al., 2020). Topic: Electrolysis Reason for topic selection: The requirement for guided inquiry-based instructing materials enhanced with Expanded Reality on electrolytic cell materials approved by master validators with a tall rate of media, materials, and lucidness, showing the reasonableness of educating materials with learning exercises. Abstract: This paper centers on the advancement of upgraded guided inquiry-based learning materials with electrolytic cell increased reality to make strides in students' understanding and engagement in chemistry learning, inquiry-based learning methodologies, and logical prepare expertise improvement, highlighting the significance of utilizing AR innovation. Highlighted.
4	Paper: Teaching and Learning of Chemistry through Augmented and Immersive Virtual Reality (Jiménez, 2019). Topic: General chemistry Reasons for choosing the topic: Most discoveries of the ponder incorporate the positive effect of immersive increased reality and virtual reality advances on chemistry instruction, common chemistry subjects secured utilizing these advances, the developing ubiquity of online instruction, and the benefits of expanded reality and the utilization of such advances. The viability in different zones of instruction and the benefits of IVR innovation in giving a lock-in learning environment Summary: Most discoveries of the ponder incorporate the positive effect of immersive increased reality and virtual reality advances on chemistry instruction, common chemistry subjects secured utilizing these advances, the developing ubiquity of online instruction, and the benefits of expanded reality and the utilization of such advances. The viability in different zones of instruction and the benefits of IVR innovation in giving locks in a learning environment
5	Paper: Usability Testing and Development of Augmented Reality Applications for Lab Learning (An et al., 2020). Topic: Chemical synthesis of compounds Reasons for choosing the topic: The ARiEL app makes a difference decreases uneasiness in utilizing hardware, makes strides in mental openness, and gets positive criticism from understudies. Summary: This article depicts the improvement and usage of ARiEL, an increased reality application outlined to supply understudies with first-hand data and almost logical hardware utilized in chemistry research facilities. This points to progress in the learning experience of understudies within the research facility.
6	Paper: Using augmented reality learning environments to teach electrophilic aromatic substitution mechanisms(Bullock et al., 2024). Topic: Organic Chemistry Reason for topic selection: Understudies altogether make strides in their learning results by a huge degree of impact. Understudies don't involve a tall cognitive stack and appear common acknowledgment of AR-LE. The post-test came about was much way better than the pre-test came about, appearing viable learning with AR-LE. Summary: This article portrays the utilization of expanded reality to educate the instruments of electrophilic fragrant substitution in natural chemistry. Critical learning advancements were seen due to moo cognitive stack and tall understudy acknowledgment.
7	Paper: Design and application of multimodal interactions in augmented reality for chemistry experiments(Xiao et al., 2020). Topic: Chemical reactions Reason for choosing the topic: The need for interaction understanding in expanded reality

tests progresses client encounter and interaction productivity.

No	Article Analysis
	Summary: This article portrays the improvement and execution of ARGEV and VRFITS to progress client interaction and proficiency in virtual tests. It was approved utilizing cases of chemical tests and appeared to expand interactivity and convenience within the genuine world.
8	Paper: Interacting with Three-Dimensional Molecular Structures Using Augmented Reality Mobile Apps (Aw et al., 2020). Topic: Organic Chemistry Reason for choosing a topic: need to learn natural chemistry without extra offer assistance, even though it does not increment intrigued within the course or crave to ponder more themes in natural chemistry Summary: This article portrays the improvement and testing of NuPOV portable apps. The app points to improving chemistry instruction by permitting understudies to associate with 3D atoms in an AR environment, with a center on the expansion of nucleophilic and spatial visualization abilities.
9	Paper: Developing virtual and augmented reality applications for science, technology, engineering, and mathematics education(Hemme et al., 2023). Topic: Pharmacy Reason for choosing a topic: Virtual reality innovation is presently commercially practical and progressively utilized in STEM instruction scholastics and inquire about. - Collaboration between distinctive units comes about within the advancement of a few VR/AR applications that have been coordinated into the educational programs at the College of Rhode Island School of Drug Store. Summary: This article examines the advancement and execution of virtual reality and increased reality applications for the educating of biomedical concepts, their dynamic consolidation and integration into the educational programs at the College of Rhode Island, as well as the authentic foundation of VR innovation and computer program highlighted in the scholarly community
10	Paper: Development of Augmented Reality Games to Teach Abstract Concepts in Food Chemistry (Crandall et al., 2015). Topic: Chemical kinetics Reason for topic selection: The utilization of intelligently expanded reality recreations is more suggested than conventional instructing strategies to educate protein energy in nourishment chemistry. Understudies collectively favor game-based learning over the standard address arrangement. These recreations lock in understudies and give a more pleasant and successful learning involvement in understanding complex concepts such as chemical response energy. Summary: This article presents the improvement and testing of increased reality recreations to educate protein energy in nourishment chemistry. The diversion has been well-received and promising for locks in understudies and giving a wealthy learning involvement, inciting the creators to report advance considerations on the game's refinement and development.
11	Paper: Development and Implementation of Augmented Reality-Based Card Game Learning Media with Environmental Literacy to Improve Students' Understanding of Carbon Compounds(Ardyansyah & Rahayu, 2023). Topic: Carbon Chemistry Reason for choosing the topic: It is troublesome for understudies to understand the concept of carbon chemistry Summary: We executed learning media within the frame of increased reality (AR)-based card recreations that centered on natural proficiency to make strides in students' understanding of carbon compounds. This learning media points to assist understudies in getting complex chemicals more effectively by combining AR innovation and instructive diversion concepts. The conclusion of the ponder appears that the utilization of AR-based learning media can altogether increment students' intrigue in learning, understanding

concepts, and natural concerns.

No	Article Analysis
12	Paper: Mobile augmented reality in chemistry learning: an evaluation of science exploration (Lah et al., 2024). Topic: General chemistry Reasons for choosing a topic: need of understanding of chemical concepts and their viability Summary: Applying learning media within the shape of expanded reality (AR)-based card recreations that center on natural proficiency to move forward students' understanding of carbon compounds. This learning media points to assist understudies in getting complex chemicals more effectively by combining AR innovation and instructive diversion concepts. The conclusion of the ponder appears that the utilization of AR-based learning media can essentially increment students' intrigue in learning, understanding concepts, and natural concerns.
13	Paper: Augmented reality technology as a tool to support chemistry learning: a scoping review (Sari et al., 2021) Topic: Chemistry Reason for topic selection: The application of AR to chemistry learning has appeared to move forward conceptual understanding and increment understudy intrigued engagement, inspiration, and fulfillment. AR innovation has the potential to convert the chemistry learning handle by having a positive effect on different learning results such as conceptual understanding, problem-solving aptitudes, inspiration, and specialized competence. Summary: This article examines the challenges of chemistry learning, the potential of AR innovation to address these challenges, the positive effect of the application of AR on learning results and states of mind, and the integration of AR and academic approaches in chemistry instruction.
14	Paper: Developing a Simple and Cost-Effective Markerless Augmented Reality Tool for Chemistry Education (Abdinejad, Ferrag, et al., 2021). Topic: Molecular chemistry Reason for choosing the topic: AR applications altogether move forward students' understanding of the atomic structure and are considered more viable than other programs, driving the effective improvement of markerless AR applications. Summary: This article portrays the improvement and usage of a markerless AR application called ARchemy for chemistry instruction. This has been demonstrated to be useful in moving forward students' understanding and visualization of chemical concepts compared to conventional atomic material science modeling apparatuses.
15	Paper: How to Evaluate Augmented Reality Embedded in Learning Planning in Teacher Education (Henne et al., 2024). Topic: Computational chemistry Reasons for choosing the topic: Key discoveries incorporate the significance of careful planning and the requirement for an assessment rubric to assess instructive AR and its integration, insufficient basic classification of AR highlights to evaluate the quality of instruction, and predominant execution of Bunch 5 AR in all zones. Summary: This article talks about the significance of AR in instruction, the advancement of a modern assessment rubric (EVAR) to assess AR in instructive settings, its effective execution in assessing AR learning scenarios, and the characteristics of AR for assessing classification instruction. The reason for this think about is to fill the gap in AR assessment within the setting of learning and give an apparatus to survey the quality of AR applications in instructive scenarios. This paper concludes that the EVAR assessment rubric can effectively survey the quality of AR instructional methods within the instructive environment.
16	Paper: Supporting flipped and gamified learning with augmented reality in higher education (Lu et al., 2021).

Topic: Computational chemistry
Reasons for choosing the topic: Key discoveries point to the adequacy and potential of utilizing the AR program to upgrade the learning involvement, as well as positive audits and

No	Article Analysis
	understudy fulfillment with the innovation, hence advertising potential future inquiries about headings. Summary: This article talks about the challenges in chemistry instruction, the positive response to the application of AR, and its potential as a pre-teaching accomplice within the flipped classroom.
17	Paper: Augmented reality for chemistry education to promote the use of chemical terminology in teacher training(Ripsam & Nerdel, 2022). Topic: Computational chemistry Reason for choosing the topic: The AR learning environment points to progress in the utilization of chemical phrasing and moving forward in understanding the concept of matter and particles among chemistry instructors. Diverse elaboration profiles are anticipated based on interaction with the tablet or the extended HoloLens show. Abstract: This article investigates the utilization of expanded reality in chemistry instruction to progress teachers' understanding and utilization of chemical terminology. The center is on the utilization of genuine research facility hardware for redox responses and electrolysis, and the assessment is carried out utilizing pre-tests and post-tests. Subjective substance investigation is utilized to analyze the convention of considering difficulty amid test errands.
18	Paper: Acceptance of technology from collaborative augmented reality systems that can be used in chemistry learning among junior high school students(Du & Dewitt, 2024). Topic: Computational chemistry Reason for topic selection: Collaborative learning, information sharing, and collaborative composing utilizing WcAR are related to diverse levels of innovation acknowledgment structures. Reword Tall school understudies are most likely to utilize WcAR in chemistry courses. Information sharing has the most prominent effect on the discernment of ease of utilization and ease of use of WcAR. Abstract: This article explores the selection of deployable collaborative expanded reality framework innovation in tall school chemistry instruction, centering on the integration of collaborative learning structures into TAM models.
19	Paper: Mobile Augmented Reality Lab for Acid-Base Titration Learning (Domínguez Alfaro et al., 2022). Topic: Acids and bases Reasons for choosing the topic: Despite the specialized issues, we concluded that the convenience of the apparatus is satisfactory understudies can utilize the instrument autonomously and complete the preparation remotely Summary: This article portrays the improvement and positive reaction of the Damage Lab app, an expanded reality apparatus for preparing understudies to conduct easy-to-use titration tests, and traces plans for future advancements.
20	Paper: Augmented Reality as a Sustainable Technology to Improve Academic Achievement in Students with and without Special Educational Needs (Badilla-Quintana et al., 2020). Topic: Special Education Reasons for topic selection: Key discoveries from the consider included noteworthy scholastic pick up and substance maintenance, comparable execution among understudies with and without uncommon instructive needs, and extraordinary instructive needs after AR intercessions. This incorporates made strides in scholastic execution for understudies with extraordinary instructive needs, moved forward behavior, and higher acknowledgment rates for understudies with uncommon instructive needs. Abstract: This article explores the effect of increased reality on scholastic execution in several classes. School execution and information maintenance rates have progressed essentially, illustrating tall levels of inspiration and acknowledgment of increased reality innovation. Encourage research on long-term impacts and social/societal impacts is

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	additionally suggested. Basic aptitudes affect.
21	Paper: Teaching chemistry in the metaverse: the effectiveness of using virtual and augmented reality for visualization(Amirbekova et al., 2023). Topic: Computational chemistry Reason for choosing the topic: The profound integration of VR/AR innovation into chemistry instruction marks the start of the metaverse move. In any case, this preparation is still in its early stages. Chemistry classes within the Metaverse that utilize immersive VR/AR innovation are more curious than conventional courses. Made strides VR/AR learning is more viable than conventional chemistry programs, particularly in progressing students' self-management aptitudes and self-actualization. Summary: This article looks at the in-depth adequacy of VR/AR innovation in chemistry instruction to progress inspiration, expertise advancement, self-actualization, self-management, and communication abilities, with the potential to make prescient models of understudy execution.
22	Paper: Teachers' attitudes and self-efficacy towards augmented reality in chemistry education(Ripsam & Nerdel, 2023). Topic: General chemistry Reason for choosing the topic: The significance of assessment devices in surveying the convenience and acknowledgment of inventive advances such as AR in chemistry instruction. By and large, the comes about of the think about appears that instructors see the advanced learning environment emphatically and highlight the potential benefits of joining AR into chemistry lessons. Summary: This article depicts the positive assessment of computerized media and AR learning situations by chemistry instructors and highlights the potential benefits of utilizing this innovation in chemistry instruction.
23	Paper: Augmented Reality Experiment on Oxygen Gas Generation from Hydrogen Peroxide and Bleach Reaction (Gan et al., 2018). Topic: Chemical bonding Reasons for topic selection: Key discoveries incorporate the advancement and adequacy of increased reality instruments to imagine redox responses between hydrogen peroxide and sodium hypochlorite arrangements, positive criticism from tall school understudies, and teacher's materials and arrangement. Summary: This article presents an increased reality instrument to educate the redox response between hydrogen peroxide and oxygen-producing sodium hypochlorite. The objective is to progress students' understanding and abilities securely and engagingly, as proven by the positive input from our progressed understudies.
24	Paper: Augmented Reality, An Overview of Ways to Represent and Manipulate 3D Chemical Structures (Fombona-Pascual et al., 2022). Topic: Chemical structure Reasons for choosing the topic: Most discoveries of this study highlight the hole within the viability of AR innovation, especially in higher instruction. AR is viable for understudies who are modern to the research facility environment and working on complex forms. AR is prescribed to be included in chemistry preparation. Summary: This paper gives an outline of increased reality innovation and its potential applications to progress human execution by encouraging the understanding and visualization of 3D chemical structures, especially within the field of instruction.
25	Paper: Increasing Enthusiasm and Enhancing Laboratory-Biochemistry Safety Learning with Augmented-Reality Programs (Zhu et al., 2018). Topic: Biochemistry Reason for topic selection: This paper gives an outline of expanded reality innovation and its potential applications to progress human execution by encouraging the understanding and visualization of 3D chemical structures, especially within the field of instruction. Summary: This article presents an expanded reality program planned to educate research

facility security in a more proficient and lock-in way. This permits understudies to memorize more things within the lab compared to conventional strategies.

No	Article Analysis
26	Paper: Student Perception Using Augmented Reality Technology and 3D Visualization in Chemistry Education (Abdinejad, Talaie, et al., 2021). Topic: Molecular Reason for choosing the topic: The most about of this highlights the victory and positive gathering of the improvement of 3D liveliness and ARchemy applications in progressing students' understanding of complex chemistry concepts Summary: This article examines the challenges understudies confront when visualizing atomic structure and chemical changes in 3D, and how the improvement of 3D movement and increased reality apparatuses can progress students' understanding of chemistry instruction. This article highlights the potential effect of actualizing ARchemy within the field. Chemistry lessons and conceivable development into other zones of instruction.
27	Paper: Teaching with Augmented Reality Using Tablets, Both as Tools and Learning Objects(Syskowski et al., 2024). Topic: Reasons for choosing the topic: Need of intrigued by the circumstances and need to learn mindfulness among imminent instructors and high school understudies. Understudies are evaluated as fruitful with the modern AR-LS. Summary: This article presents an inventive approach to the utilization of tablets in chemistry instruction. It'll consolidate augmented reality innovation to form immersive learning scenarios that emphasize supportability and cultivate a comprehensive understanding of the part of ICT in instruction.
28	Paper: Tetrahedral chemical representation-based augmented reality learning media: How effective is it in the learning process?(Yamtinah et al., 2023). Topic: molecular shape Reason for choosing the topic: AR learning media based on tetrahedron chemical representations has been effectively created and demonstrated to be viable in making strides in learning results. AR media is organized and based on four components of tetrahedral chemical representation. The utilization of AR media has been demonstrated to be successful in making strides in learning results. Summary: This article diagrams the victory and adequacy of the improvement of tetrahedral chemical representation-based AR learning media to make strides in chemistry instruction learning results and highlights the benefits of AR innovation in instruction.
29	Paper: Simple and Practical Methods for Incorporating Augmented Reality into Classrooms and Laboratories (Plunkett, 2019). Topic: Organic Chemistry Reason for choosing the topic: Need for a broad learning encounter through an exhibit of response items and response components. The utilization of AR innovation illustrated by HP Uncover is well-known to learners and gives a better approach to conveying substance in instruction. Summary: This article employs the HP Uncover app to form AR note cards for Natural Chemical Responses and Instruments, expanded reality (AR) note cards for classrooms and labs that offer assistance to clients set up and work guided gear) appeared underneath.
30	Paper: The Use of E-Resources and Innovative Technologies in Transforming Traditional Teaching in Chemistry and Its Impact on Chemistry Learning (Hsiung, 2018). Topic: Chemical Bonding Reason for choosing the topic: The utilization of electronic assets and inventive advances features a positive effect on students' chemistry learning and increases their understanding and engagement with the course. Abstract: This article talks about the challenges of conventional chemistry educating strategies and the benefits of combining electronic assets and inventive innovation to convert

the learning involvement for understudies. This article highlights the positive effect of mixed learning, learning administration frameworks (LMS), reenactments, expanded reality, and versatile clickers on understudy engagement and understanding in chemistry.

No	Article Analysis
31	Paper: The use of augmented reality in chromatography learning: How do these dynamic visual artifacts drive the visualization capacity of chemistry undergraduate students? (Merino et al., 2022). Topic: Chromatography Reason for choosing the topic: Need for visualization of the chromatographic preparation, recommended that understudy promotion can end up more complex. Summary: This article investigates undergrad students' visualization aptitudes, especially in clarifying chromatography forms, to assist understudies to get it the discernible world through thinking utilizing and particles at the same time. This highlights the significance of visual artifacts and they have to progress the educating and learning arrangement to make strides in students' visualization capacities.
32	Paper: Effect of using haptic augmented simulation power feedback on the attitude of gifted students toward learning chemical bonds in a virtual reality environment(Ucar et al., 2017). Topic: chemical bonding Reasons for choosing the topic: - There's a positive relationship between the utilization of constrained input haptic apps created in a virtual reality environment and the demeanors of skilled understudies towards instructive programs. Gifted understudies within the considered bunch had more positive convictions around the utilization of the sense of touch compared to the control gathering, which recommends that the application of touch is widely used and favored over conventional strategies to extend instructive efficiency. Summary: This article examines the effect of material fashion criticism applications in virtual reality situations on talented students' states of mind toward chemistry lessons and finds a positive relationship between the utilization of such applications and students' states of mind.
33	Paper: Evaluation of the Usability and Acceptance of the Use of Augmented Reality for Learning Atomic and Molecular Reactions by Elementary School Girls in Palestine (Ewais & Troyer, 2019). Topic: Reasons for choosing the topic: Versatile AR applications have points of interest over conventional learning materials and can offer assistance to understudies getting molecules, particles, and intuition in chemistry courses. Abstract: This paper diagrams an inquiry conducted in a Palestinian basic school concerning female students' states of mind toward the utilization of portable AR apps in chemistry instruction, giving positive comes about and planning suggestions for future applications.
34	Paper: Augmented Reality in the Science Lab: Investigating High School Students' Navigation Patterns and Their Effects on Learning Performance (Jiang et al., 2022). Topic: Laboratory science Reason for choosing the topic: AR has incredible potential to supply students with the opportunity to memorize logical concepts viably. The comes about of Autonomous Tests T-test showed that there was no critical distinction within the execution of the two bunches in clarifying the method, but there was a critical contrast in clarifying the reason. Summary: This article talks about the transformative potential of AR in science instruction, analyzes understudy routes and learning designs utilizing versatile AR innovation, and gives more data on planning different shows and intuitive AR innovation for science labs.
35	Paper: Does Augmented Reality Help Understand Chemical Phenomena during Live Experiments?-Implications for Cognitive and Learning Load(Peeters et al., 2023). Topic: laboratory experiments Reason for choosing the topic: The AR bunch did not appear a critical change in learning compared to other bunches. The AR gather experienced higher inside and outside cognitive stack amid the test. Past considerations have appeared positive impacts on utilizing AR for

No	Article Analysis
	science learning, but this consideration did not discover any noteworthy benefits related to chemistry tests. Summary: This article depicts how the utilization of increased reality in chemistry instruction can visualize submicroscopic substances amid hands-on tests. In any case, this thing did not discover a critical learning advantage within the AR gather compared to other bunches. More investigation is required to test the potential benefits of AR in completely different circumstances.
36	PaperUse augmented reality to experiment with the elements in chemistry courses (Chen & Liu, 2020). Topic: chemistry science Reason for choosing the topic: TLive AR learning exercises increment conceptual information and invigorate intrigue in science way better than exhibit techniques. Coordinate methodologies are exceptionally compelling in progressing the understanding of chemical responses and the significance of circumstances.
37	Paper: MoleculAR: An Augmented Reality App for Understanding 3D Geometry (Levy et al., 2023). Topic: Molecular Reason for choosing the topic: MolecuAR is a compelling and locks-in instrument for understudies to imagine and control atomic structures in 3D, in this manner improving their learning encounter. This app, which is outlined to assist understudies learn approximately the structure and bonds of atoms, has gotten positive input from understudies around its convenience and value. Summary: This article portrays the improvement and usage of the Atomic app, an increased reality app for understanding 3D geometry in chemistry instruction, giving a lock-in and viable learning involvement for understudies.
38	Paper: Fostering Motivation for Chemistry through Augmented Reality Educational Escape Activities. Self-Determination Theory Approach(Elford et al., 2022). Topic: Chemistry Reason for choosing the topic: Competence isn't an indicator of scholarly execution, AR has no noteworthy impact on natural inspiration or test scores, and members discover the movement curiously Summary: This article investigates the utilization of increased reality in instructive elude exercises to extend inspiration and engagement in higher instruction chemistry instruction, with a center on supporting independence, competence, and interconnecting through movement plan.
39	Paper: Model-based learning about the structure and properties of chemical elements through the use of augmented reality (Xu et al., 2019). Topic: Chemical compounds Reasons for choosing the topic: This article highlights the potential of expanded reality in chemistry instruction utilizing illustrations such as natural compounds, intermittent table components, water extremity, and carbon nanotubes. This highlights the significance of watching complex structures in different representations and understanding the intelligence of polar compounds. Summary: This article highlights the significance of imaginative advances such as logical models, visualization, and increased reality to assist understudies learn chemical concepts. Illustrations incorporate natural compounds, chemical components, water extremities, carbon nanotubes, etc.
40	Paper: The Effect of Augmented Reality-Based Chemistry Experience Applications on Student Knowledge Gains, Learning Motivation, and Technology Perception (Liu et al., 2023). Topic: Chemicals Reason for choosing the topic: Need to understand the composition of chemical magnifying instruments

Summary: This article depicts the advancement and assessment of AR applications that educate high school understudies in almost the minuscule composition of chemicals and have a positive impact on information securing, learning inspiration, and mechanical mindfulness.

Discussion

RQ-1: What chemistry topics are taught using augmented reality (AR) in chemistry classes at different levels of education?

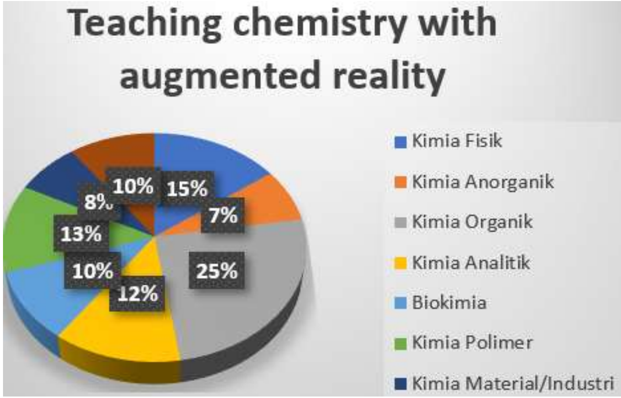

Figure 2. Chemistry learning with augmented reality

From the graphical examination, ready to see that most of the chemicals explored were utilizing increased reality, i.e. 25% of the 40 papers examined were natural chemicals

The utilization of expanded reality (AR) innovation in chemistry learning has different reasons and benefits that make it a successful choice within the world of instruction. The most important reason why chemistry subjects are instructed in AR is:

Visualize unique concepts. Chemistry regularly includes theoretical and slippery concepts such as atomic-level atomic structure, chemical responses, and molecule mechanics. AR permits understudies to see and control three-dimensional representations of these particles and responses, making them simpler to get. Steady with the discoveries of the study(Virata & Castro, 2019), we found that the utilization of AR makes learning subjects more theoretical and simpler to suppose. This increment may also be related to certain chemical bonds. This region features a certain perspective of complexity, related to a unique understanding of concepts that are troublesome to clarifying Interactive and immersive learning. AR creates a more interactive and immersive learning environment. Students can manipulate molecular models, observe chemical reactions in real-time, and conduct virtual experiments similar to those conducted in a real laboratory. This increases students' engagement and interest in the subject matter.

Secure test involvement. A few chemical tests can be unsafe or require costly specialized gear. By utilizing AR, understudies can securely and risk-free reenact tests while completely understanding the method being carried out (Midak et al., 2019).

Increment engagement and understanding. Investigate appears that learning with visual and intelligent components progresses data maintenance and conceptual understanding. AR makes a difference in improving themes through more concrete visualizations. AR innovation makes learning more curious and fun. This progressed innovation makes understudies more effectively included within the learning handle and increases their intrigue in science, especially chemistry. Utilizing AR within the classroom permits collaboration between understudies. Fortify collaboration and communication abilities by working together in virtual tests and talking about perceptions.

RQ-2: Can learning outcomes be achieved by using augmented reality (AR) to gain a deeper understanding of chemical concepts?

Increased reality (AR) can be utilized to ponder chemistry and pick up a more profound understanding of chemical concepts. Here are a few reasons and proof that back this.

Clearer visualization. Utilizing AR, visualize atomic structures and chemical responses in 3D that are troublesome to get in course readings or 2D charts. This permits understudies to get it and keep in mind these concepts more effectively.

Upgraded interactivity. AR permits understudies to associate specifically with chemical models, control particles, and watch responses in genuine time. This interactivity increments understudy engagement and makes learning more locked in and immersive.

An immersive learning involvement. AR makes an immersive learning environment where understudies can "see" and "feel" chemical responses on the off chance that they are in a research facility. This encounter will offer assistance in reinforcing conceptual understanding.

Dynamic and participative.AR learning energizes dynamic learning, where understudies effectively take an interest in the learning preparation instead of latently getting data. This increases students' inspiration and intrigue in learning. Encourage virtual experiments. AR permits understudies to conduct virtual tests which will be unsafe or costly in a genuine research facility. These tests offer assistance to understudies to get chemical forms without harming them. Real-time input. AR gives moment input whereas learning permits you to instantly adjust botches and move forward in understanding.

Reinforce your collaboration aptitudes. The utilization of AR frequently requires gathering work and collaboration, which moves forward students' conceptual understanding as well as social and communication abilities.

In general, the utilization of expanded reality in chemistry learning has been demonstrated to be successful in accomplishing learning results and expanding understanding of chemistry concepts. By coordinating these innovations into conventional educating strategies, able to give understudies a more all-encompassing and immersive learning involvement.

Virtual Reality

Azuma characterizes AR as a sort of virtual reality (VR). Compared to conventional VR, AR has an interface that combines genuine and virtual universes, making an environment where clients can combine genuine scenes and virtual objects, making a normal and practical human-machine involvement. AR characters are a set of advances that can combine genuine and virtual pictures intuitiveness and in real-time, permitting clients to include virtual data to the physical data they see within the genuine world(Maier & Klinker, 2013)

As specified, AR is the portion of a real-to-virtual continuum of extension. At one conclusion the scale could be a genuine environment and "comprises as it were of real objects" and at the other conclusion may be a virtual environment and "comprises as it were of virtual objects". The creator considers blended reality (MR) as an environment comprising a blend of genuine and virtual objects. MR situations that increase the genuine world with virtual substance are called ARs. On the other hand, an environment in which genuine objects are seen or included, indeed although most of their substance is virtual, is called expanded virtuality (AV).

It is vital to note that the proposed definition unequivocally alludes to visual representation as it were. Be that as it may, in this situation, AR may be a complement to VR and can be deciphered as a midpoint between virtual and genuine situations. In this way, AR does not supplant the genuine environment, but or maybe give the client the impression that virtual and genuine objects exist at the same time within the same space. On the other hand, we center on computer frameworks that coordinate AR, and appears that these frameworks require three imperative characteristics. It can be caught in three measurements.

Increased reality can be analyzed by considering different angles such as the stage utilized, the gadget utilized, and the category of the framework. Marker-based AR involves the utilization of fake markers in a real-world environment to discover the area of physical objects inside that environment.

In differentiation, a framework without a marker does not require counterfeit markers in a genuine environment since it is based on following the normal characteristics of physical objects in that environment. Concerning the utilization and application of AR assets, a few ponders have been conducted and different computer arrangements have been presented to misuse AR. Particularly within the field of instruction, the fast headway of AR has extended its utilization in instructing and learning applications (Chen & Liu, 2020). AR has pulled in great interest in chemistry. The most important reason is that understudies can visualize wonders that are as a rule undetectable to the human eye.

4. CONCLUSION

Increased reality (AR) innovation is utilized within the consideration of different chemical subjects at distinctive levels of instruction to move forward viability and understanding. The utilization of AR in chemistry learning is based on its capacity to supply three-dimensional visualization and interactivity so that it permits understudies to pick up a more profound understanding of complex and unique concepts. AR makes immersive and locks in learning encounters, increments understudy inspiration and engagement, and empowers secure and available virtual tests. Observational thinking appears that the utilization of AR altogether moves forward learning results and understanding of chemical concepts, progressing students' data maintenance, conceptual understanding, and viable aptitudes. Subsequently, AR has been demonstrated to be compelling in accomplishing superior learning results and extending students' understanding of chemistry concepts, making it an imaginative and important instrument in chemistry instruction.

Based on (Pradani et al., 2020) center on creating guided inquiry-based learning materials improved with AR for electrolytic cell materials, approved by master validators. This consideration underscores the significance of inquiry-based learning procedures and AR innovation in upgrading students' logical handling abilities and engagement. (Jiménez, 2019) investigates the utilization of immersive increased reality and virtual reality (IVR) advances in common chemistry instruction, emphasizing their positive effect on understudy engagement and learning, particularly for Era Z learners. This ponder highlights the developing notoriety and benefits of coordinating present-day innovation into instruction.

Depend on (An et al., 2020) portray the advancement and ease of use testing of the ARiEL application, outlined to make strides in students' learning encounters in chemistry research facilities by giving first-hand data approximately logical hardware, hence diminishing uneasiness and progressing mental openness. (Bullock et al., 2024) display the utilization of AR learning situations to educate electrophilic fragrant substitution components in natural chemistry. The think about reports critical learning enhancements with cognitive stack and tall understudy acknowledgment, showing the viability of AR in encouraging complex natural chemistry learning.

The consideration highlights that AR media, organized around four components of tetrahedral chemical representation, altogether upgrades students' understanding of atomic shapes. The comes about illustrates that AR learning instruments can effectively bridge theoretical chemical concepts and students' visual and cognitive discernments, subsequently making strides in engagement and comprehension in chemistry instruction. The inquiry underscores the potential of AR innovation to convert conventional instructing strategies by advertising intuitively and immersive learning encounters, eventually driving to way better learning results.

Generally, these things collectively outline that increased reality can essentially upgrade chemistry instruction by making theoretical and complex concepts more unmistakable, progressing understudy engagement, and cultivating more profound understanding. The positive input from understudies and the quantifiable enhancements in learning results encourage the approval of the integration of AR innovation in chemistry educational programs.

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