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EMPIRICAL INSIGHTS INTO VR IMPLEMENTATION CHALLENGES AND PRACTICES FOR CHEMISTRY EDUCATION

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Abstract

Context

Virtual Reality (VR) has evolved into a vital tool in education and may make teaching science, particularly Chemistry education, much better. In a computer simulated environment, students can safely perform risky experiments, watch chemical reactions in detail, and learn about challenging chemical reactions. This interactive task assists students to learn more about fundamental concepts and lets the students to perform experiments that may not be feasible in a traditional lab. But even with these advantages, there are still a lot of challenges with using VR in labs and classrooms. These consist of the expensive prices of VR equipment's, the challenge of blending VR into current educational environment's, the fact that many teachers lack the technical know-how to use it, the software's constraints, and the unwillingness of schools to accept new technology.

Objectives

The aim of this study is to find out implementation challenges and strategies related with the use of Virtual Reality in Chemistry Education via Systematic Literature Review (SLR) and questionnaire survey. The process will explain how research studies find challenges to Virtual Reality adoption and what methods have worked well to overcome these challenges.

Anticipated Results

The anticipated outcomes include:
(1) A structured list of the challenges in implementation of virtual reality into practice.
(2) A Combination of mitigation strategies.
(3) A conceptual evaluation of the challenges and their solutions.
(4) Data that will help organizations, educators, and students in creating plans for the future use of Virtual Reality.

1. INRODUCATION

Virtual Reality is speedily growing within Learning environments because of its ability to immerse users in interactive, immersive environments [2]. Chemistry education, which requires complicated visualizations and dangerous experiments, presents a strong use case for virtual reality [5]. Conventional materials like textbooks, static pictures, and physical labs restrict students' understanding, particularly when it comes to molecular-level problems.

Research shows that virtual reality (VR) improves motivation, engagement, and conceptual understanding while providing reasonable replacements for laboratory work that requires a lot of resources [9]. Virtual reality (VR) promotes experiments in risk-free environments, allowing for repetition and immediate feedback, elements that are difficult to execute in traditional environments [8].

However, there are a number of challenges that prevent potential from becoming practice, such as: Technical challenges (motion sickness, hardware limitations), Pedagogical limitations (lack of guidance for VR instructional design), Financial challenges (maintenance and infrastructure costs), Low institutional support due to institutional inactivity, User-centered problems such as learner overload and teacher preparation [9].

While different investigations investigate the usefulness of Virtual Reality, there is currently no systematic analysis that focuses on Chemistry-specific implementation challenges. This protocol fills this gap through the development of an organized plan for an investigation.

2. BACKGROUND

According to recent studies on educational technologies VR is becoming more and more integrated into STEM fields [13]. Virtual reality technology allows students to see atomic interactions, manipulate molecules in three dimensions, and replicate procedures that are too costly or dangerous for real labs [2].

Virtual Reality's benefits for teaching Chemistry: Some Notable advantages include: Enhanced comprehension of complex chemical reactions [7], increased interest-driven study motivation [8], access to experiments that are not permitted in physical laboratories, and flexibility for institutions which don't have complete equipment's for performing reactions in labs [9].

Challenges to Virtual Reality Adaptations:

Since the use of Virtual Reality have many advantages but it still has many challenges. Research's finds difficulties that grouped into the following broad categories:

1. Technical issues like motion sickness, software reliability, H/W instability, and upgrading cycles [3].
2. Financial: Poor budgeting, high registration costs, and costly maintenance [9].
3. Educational issues: Poor attention to necessary requirements, weak teacher preparation, and inappropriate VR lesson design [10].
4. User-Related: New users of the Virtual Reality systems' mental strain, usability problems, and accessibility constraints [6].
5. Institutional issues like instructors' hatred for technology, poor IT assistance, and unclear rules [11].

This research goal is to integrate these issues into a logical framework based on methodical systematic research.

3. RESEARCH QUESTIONS

RQ1: What kind of Challenges have been stated in the current studies associated to the use of Virtual Reality (VR) in Chemistry education?

RQ2: What challenges do users presently face when using Virtual Reality (VR) to teach Chemistry in real-world educational and industrial environments?

RQ3: What strategies and procedures have been proposed in previous studies to overcome the challenges of using Virtual Reality in Chemistry education?

RQ4: What practices and strategies are currently used by practitioners to address the challenges of implementing VR in Chemistry education?

RQ5: How do the problems found in the Systematic Literature Review (SLR) compare up with those found in the questionnaire survey?
RQ6: How consistent are the practices identified in the literature with those reported through the questionnaire survey?

4. PROTOCOL FOR SYSTEMATIC REVIEWS:

4.1 Method of Searching

To find findings from reputable digital libraries, an organized search approach will be employed, including:
ScienceDirect, Google Scholar, IEEE Xplore, ACM Digital Library, SpringerLink, and search terms.

Basic concepts:
"Virtual Reality" OR immersive Virtual Reality OR virtual lab
"Chemical Science Learning" OR "Chemistry Education"
"Challenges to" OR barriers OR limitations
"Practices" OR policies OR employment OR adoption

Boolean sample:
String-1: ("Virtual Reality" OR "VR Chemistry Education" OR "Virtual lab") AND (challenges OR barriers OR "limitations") AND (solutions OR "practices" OR "policies")
Earlier VR literature will offer historic context, so there won't be any time constraints.

4.2 Selection/Exclusion Standard

4.2.1 Criteria for Inclusion

- ❖ Research papers that are relevant to our research questions.
- ❖ Research work that describes Virtual Reality used exactly within Chemistry education
- ❖ Research examines expected or actual implementation Challenges.
- ❖ Articles suggest, examine, or asses' practical solutions.
- ❖ The research papers/ articles /books/review paper is in English Language.
- ❖ The article/papers which is available in full text.

4.2.2 Exclusion Criteria

- ❖ Article/papers/books etc. that do not fulfil inclusion criteria as mentioned above will be excluded
- ❖ Virtual Reality irrelevant to Education
- ❖ Science and Technology subjects not having Chemistry topics which is irrelevant.
- ❖ Opinion articles that don't donate anything theoretically or analytically

4.3 Evaluation of Quality

- ❖ Studies will be evaluated using criteria adapted from such as:
- ❖ Transparency in unfolding barriers faced.
- ❖ Clear debate of instructional plan or implementation.
- ❖ Evidence of assessment or Verification.
- ❖ Relation to learning purposes associated to Chemistry.
- ❖ Every paper will receive *Yes / No / Fractional / Not Valid*, and scoring examples may be tested by a second reviewer.

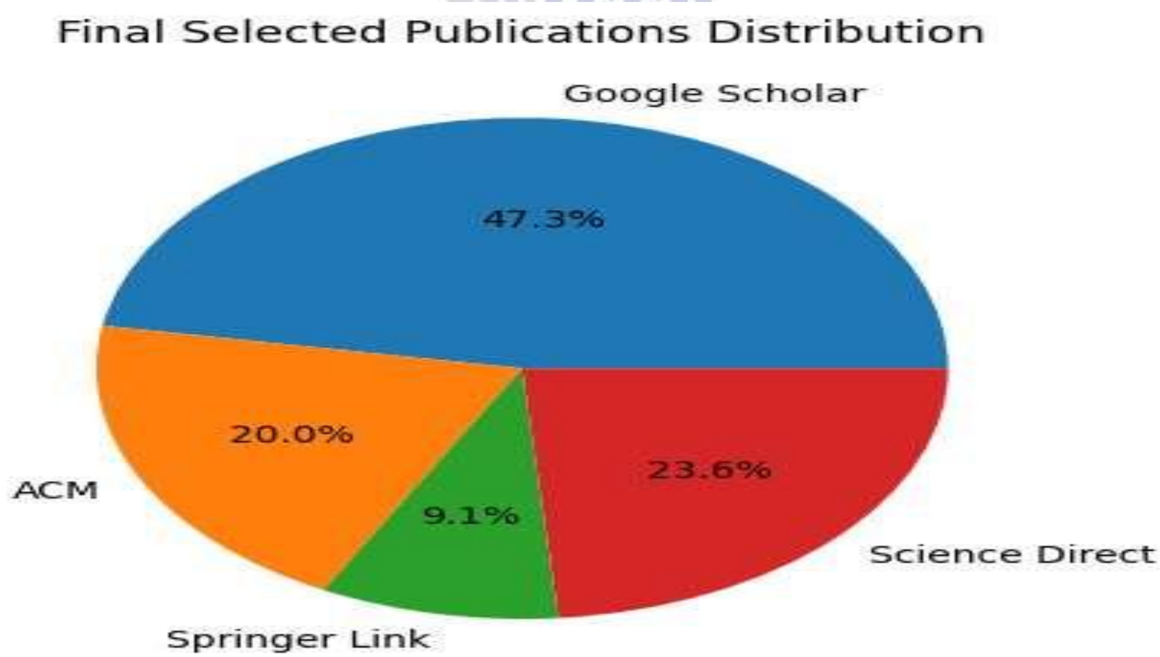
Publication Quality Assessment
The main drive of quality valuation is to check and assess the quality of finally selected papers. The quality checklist contains the following questions:
a. Is the objective of the research is clearly defined?
b. Is the outcomes of the research is connected to the objective of the research?
c. Whether the term Empirical Insights into VR implementation challenges and practices for chemistry education is discussed clearly?
d. Is it clear how the factor/practice was identified?
e. Each of the above interrogations will be marked as 'YES', 'NO', or 'N.A'.

Primary Selection of Relevant Literature
The abstract, title, and keywords of the papers were examined in order to perform the primary selection of gathered data. Removing results that have no relevancy to our research questions is the goal of primary selection. The full texts of the selected research papers have been checked in order to asses them to the prior indicated publishing selection criteria.

SLR Protocol Primary Findings.

S. No	Digital library	Search String Used	Date Constriction	Over-all Publications Found	Initial Selection	Final Selection
1	**Google Scholar**	String 1	All Years	19600	51	26
2	**ACM**	String 1	All Years	24617	60	11
3	**Springer Link**	String 1	All Years	32308	35	5
4	**Science Direct**	String 1	All Years	48066	40	12
5	**Total**			124591	186	54

Total Publications through SLR: 124591
Total Finally Selected Publications: (N=54)
The list of finally selected 54 publications is attached in Appendix-I.



4.4 Generating Data
What data will be taken from each study and why it is important are explained in this section.

• Examine the context: To understand how VR is used in Chemistry education at different levels, one must determine where it is used (K–12, higher education, or informal learning situations).

Technologies used: Since different technologies offer different features and restrictions, this indicates the type of VR technology used (e.g., head-mounted displays, desktop-based VR, or custom-built systems).

Challenges Reported: Highlights the difficulties or problems observed in each study. These challenges will be systematically classified (e.g., technological, pedagogical, cognitive) to promote cross-study comparison.

Design concepts and strategies for mitigation: documents the approaches used to deal with problems that have been stated, such as instructional design selections, technological solutions, and pedagogical changes. Design guidelines are general ideas or recommendations made by writers to direct the development of VR-based Chemistry teaching in the future.

Conclusion and Recommendations: summarize the authors' insightful findings and practical suggestions, especially those that are associated for improving Virtual Reality applications in Chemistry teaching in future.

4.5 Data Extraction and Synthesis Process:

Data extraction is the method of collecting information from research articles that have been finally selected [14]. Our SLR protocol's main objectives is to extract data that answers our stated research questions, which range from RQ1 to RQ6. Data from 54 research papers has been carefully extracted by us. One researcher (the lead author) performed most of the review; if there were any issue with the data collection, research supervisor was approached.

We have used a data extraction form to extract data from the 54 papers that were finally selected. We will adopt the data synthesis approach to properly summarize the gathered data by providing the required data in accordance with the established research questions, which is RQ1, RQ2, RQ3, RQ4, RQ5, and RQ6.

5. EXPECTED RESULTS

The outcomes of this research are:

- ❖ Present a comprehensive Summery of the challenges that prevent Virtual Reality from being mostly used in Chemistry education.
- ❖ Give proven methods to support long-term usage.
- ❖ Help administrators in identifying training requirements, gaps in skills, and resource needs.
- ❖ Help teachers develop virtual reality (VR) lessons that are integrated into the curriculum.
- ❖ Help in finding new research areas, such as evaluating long lasting knowledge retention along with cost effectiveness.
- ❖ In conclusion, the systematic literature review (SLR) will present a systematic approach to guide and inform the successful adaptation of Virtual Reality into Chemistry education.

6. CONCLUSION

By improving accessibility to laboratory experiences, enhancing conceptual understanding, and promoting immersive, experiential learning, Virtual Reality gives significant opportunities to reform Chemistry Education. Still, its implementation is challenging, requiring careful review of instructional design, human factors, resource limitations, and technology capability.

This Systematic Literature Review (SLR) Protocol gives an organized plan to gather and prepare existing evidence on Virtual Reality implementation challenges and solutions [12]. The study will give useful findings that may promote the implementation of Virtual Reality in Chemistry classrooms, labs, and learning environments by classifying challenges and identifying mitigation approaches.

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