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Effects of Context-Based Teaching Chemistry on Students' Achievement: A Systematic Review

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Abstract: This systematic review aims to comprehensively analyze the effect of contextual-based teaching of Chemistry on students' academic achievement. The review includes an analysis of various scholarly articles that have examined the impact of integrating real-world contexts and applications into Chemistry instruction. A total of 10 study articles were selected for further analysis from databases such as ERIC, Scopus, and Google Scholar using a systematic literature review (SLR) method. These studies were thematically organized and reviewed. The interventional context-based (ICB) chemistry study articles employed a range of research designs, including Experimental research method with pre-test-posttest control group design, Experimental research with post-test only design, Quasi-experimental design, and Mixed-method research design, providing a comprehensive examination of the effect of the contextual-based teaching of Chemistry on students' academic achievement. Data analysis methods were utilized, including the independent t-test, one-way t-test, one-way ANOVA or ANOCOA, and MANOVA, to compare means between groups or against specified values. The results of the analysis indicate that context-based chemistry teaching has a positive effect on students' academic achievement. This finding has significant implications for educators, curriculum developers, and policymakers, as it can inform the design of effective Chemistry instruction that enhances students' academic performance. In conclusion, this review highlights the positive impact of contextual-based teaching of Chemistry on student achievement. The findings underscore the importance of integrating real-world contexts and applications into Chemistry instruction. This has implications for educators and policymakers in designing effective teaching strategies to improve students' academic performance in Chemistry. Additionally, the review suggests avenues for future research in this area.

Keywords: Context-Based Approach in Chemistry; Context-Based Learning; Context-Based Learning Chemistry; Effect of Context-Based Learning; Achievement.

Introduction

The context-based approach in chemistry teaching has come into wide use recently, especially in other countries like the United States of America, the United Kingdom, the Netherlands, and Canada, aiming to bridge the gap between students" daily life experiences and the chemistry course content [1]. A contextual approach to chemistry education has been developed to tackle the challenges of teaching chemistry [2]. This approach aims to foster and maintain a sense of awe and inquisitiveness in young individuals towards the natural world [3]. Context-based learning seeks to connect the students' daily knowledge with the content they learn in school. The primary purpose of retaining based on context is to present scientific concepts to students through selected activities in everyday life, which can increase their motivation so that they are interested in learning science [4]. One further definition is given by [5], which focuses on how the existing context should tell students to appreciate and understand the chemical contribution to their lives and provide a way to gain a better understanding of the world, thereby specified explicitly as following: the lesson units should begin with the aspects of student life, which they experience either personally or through the media, and should introduce ideas and concepts only to the needs of students. Difficulties in applying acquired knowledge and little interest in scientific studies have been quoted as one of the leading challenges in science (chemistry) teaching [6,7,8].

Further, many teachers have pointed out the low interest of their students in chemistry. Students also enjoyed linking the topics they studied in chemistry with everyday life. However, the difficulty here is that many students lack sufficient knowledge about setting up appropriate connections (Bennet & Holman, 2002 [9,10]. Many research results explain that context-based learning can help students improve the quality of chemistry learning. For example, [11] demonstrated that context-based learning can facilitate students to increase their understanding of the concepts of the properties of matter, heat, and temperature. A Reference [12] conducted a study on context-based learning. It concluded that students who adopted contextual learning improved their understanding of chemical ideas and gained higher scores than those who embraced the traditional way of learning.

In a study conducted by Reference [13] over the past two decades, context-based chemistry learning programs have been developed and implemented in international schools to improve the linkage of chemical concepts that are integrated into the real lives of students. By linking chemistry principles to everyday experiences or practical situations, contextual teaching aims to enhance students'

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understanding and engagement in learning chemistry. Contextual Teaching and Learning teaching emphasizes the full student's physical and mental activity [14]. The primary purpose of learning based on context is to present scientific concepts to students through selected activities in daily life, which can increase their motivation so that they are interested in learning science [15].

If students can see the relevance of science in their lives and perceive that it is meaningful to learn, they can expect that the knowledge they learn during their teaching practices will be more effective and essential for students [16]. Although there is increasing research on the impact of context-based teaching chemistry on student achievement, there is a lack of comprehensive systematic review studies that specifically analyze the overall effects of context-based teaching chemistry on students' achievement.

By identifying the research gap in this area, this review aims to contribute to the existing literature and provide valuable insights into the effectiveness of contextual teaching Chemistry in enhancing students' achievement in chemistry.

Furthermore, research results report that context-based chemistry learning can significantly improve student learning achievement [17]. Reference [18] said CBT is more effective in students with low cognitive levels. Examining the change in students' accomplishments in different chemistry subjects with context-based teaching reveals the importance of the study.

A study by Reference [19] shows that CBT contributes to students' motivation, achievement, interest, and attitude toward chemistry courses.

Review Questions

In this review, the following review questions were addressed.

1. What research designs are employed in interventional context-based (ICB) chemistry studies?
2. What data analysis methods have been adopted in the ICB chemistry studies?
3. In what topics of chemistry is the context-based approach used?
4. What are the research variables investigated in ICB chemistry studies?
5. What are the teaching methods or instructional strategies adopted in the ICB approach to chemistry studies?
6. What are the effects of context-based teaching of Chemistry on students' achievement, as revealed by the analysis?
7. How do the results of the reviewed articles contribute to our understanding of the relationship between context-based teaching and students' academic achievement in Chemistry?
8. What are the implications of the findings for educators and policymakers to enhance students' academic achievement in the subject?

Significance of the Review Study

This review study article holds significant value for educators, policymakers, and researchers as it provides evidence-based insights into the effects of contextual teaching in chemistry education. By understanding the impact of this instructional approach on students' achievement, stakeholders can work towards enhancing teaching practices and improving learning outcomes in chemistry.

Limitation of the Review

The review study article's findings may be limited to a specific population or context, such as a particular grade level or type of school, which could restrict the applicability of the results to other settings or student populations. Additionally, due to time and resource constraints, the review study articles may not encompass all relevant studies or conduct a comprehensive analysis of contextual teaching approaches and their effects on students' chemistry achievement, limiting the findings' comprehensiveness and generalizability.

Review Methods

This review employs a systematic literature review approach known as Systematic Literature Review (SLR). SLR is a methodical literature review that adheres to established guidelines to identify and consolidate all pertinent research findings, evaluating the existing knowledge on the investigated subject [20].

Search Sources and Methodology

This study's systematic literature review (SLR) involved searching for scientific research publications using online article databases such as Google Scholar, Scopus, and Eric. The search utilized keywords such as "Context-based approach in chemistry," "Context-based learning," "Context-based learning chemistry," 'effect of Context-based learning,' "achievement' and 'The effect of or impact of or influence of' [21]. When searching for relevant study articles, the researcher adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. PRISMA is a widely used reporting guidance for systematic reviews covering the literature search component [22].

Exclusion/Inclusion Criteria

The inclusion criteria employed for the reviewing studies are as follows: only study articles that focus on context-based chemistry learning issues and their effect on students' achievement, experimental or interventional study designs, student participants at secondary or tertiary levels, empirical studies (excluding unpublished theses, government reports, policy documents), availability of full-text, studies written in English, and publication within the period of 2016–2023. Study articles not meeting these criteria were excluded from the review. Similar criteria were employed in previously conducted reviews [23].

Procedure

The review was conducted between September and December 2023. Initially, selection criteria for study articles were established, along with the choice of databases for the bibliographic search. Three digital databases were chosen based on their online accessibility and comprehensive coverage of scholarly literature relevant to education. These databases are highly regarded in the scientific community and were considered essential for inclusion in the review.

All study articles were identified from the three databases using the following search strings [24]
1. "context-based teaching" AND "chemistry" AND "students' achievement"
2. ("context-based teaching" OR "contextual teaching") AND "chemistry" AND ("student performance" OR "academic achievement")
3. ("systematic review" OR meta-analysis) AND "context-based teaching" AND "chemistry" AND ("student outcomes" OR "academic success")
4. "effectiveness of context-based teaching in chemistry" AND "student achievement."
5. ("context-based learning" OR "contextualized instruction") AND "chemistry education" AND ("academic performance" OR "learning outcomes")
Based on inclusion and exclusion criteria, 25 study articles were primarily obtained. Amongst these, 16 study articles were from Google Scholar, five from Scopus, and four from ERIC. Three researchers analyzed the studies. They worked independently and shared the results at the end of the work.
After reading the abstract and full text of the study articles step by step based on the inclusion /exclusion criteria in the first and second levels of exclusion, 15 study articles were excluded based on the inclusion /exclusion criteria employed. Finally, 10 study articles were accepted, as shown in Figure 1 below.

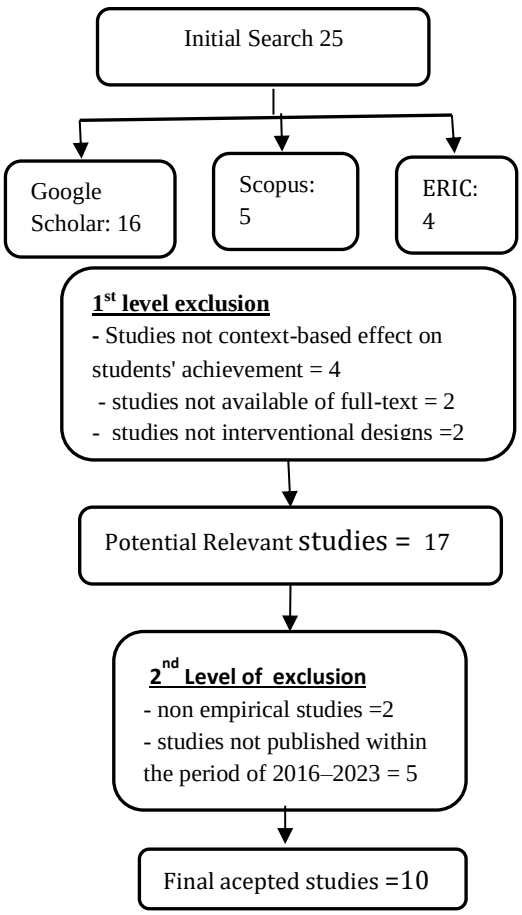

Figure 1. Flow chart depicting the Selection Process of Study Articles

Each study article was categorized based on participant type, with 80% (8 out of 10) of the study articles involving high school students, 10% (1 out of 10) involving college-level students, and another 10% (1 out of 10) involving university-level students. From this, it can be inferred that most of the study articles (80%) focused on high school students. However, the relatively lower percentage of study articles involving college and university-level students may indicate a gap in research focusing on these populations, potentially highlighting an area for further investigation.

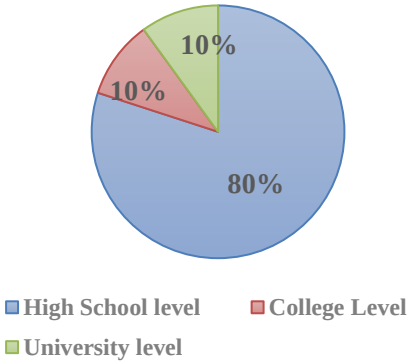

Figure 2. Percentage of ICB Chemistry Studies Conducted in Student Participants Leve

Quality Assurance Process

To maintain review quality, we identified reputable journals and implemented quality assurance processes such as keyword selection, title screening, abstract review, full-text examination, and detailed data extraction. We also followed the PRISMA guidelines, which offer an evidence-based framework for assessing the quality of systematic reviews and meta-analyses [22].

Results and Discussions

Regional Disparities in Chemistry ICB Study Articles

The systematic review of 10 study articles identified a notable concentration of chemistry ICB studies in specific regions. Studies Ar 2, Ar 6, Ar 7, and Ar 10 were predominantly conducted in Indonesia. Ar 3 and Ar 4 were carried out in Turkey, indicating a significant presence of such studies in these areas. However, the distribution of studies was more diverse, with Ar 5 and Ar 9 originating from Nigeria, Ar 1 from the Philippines, and Ar 8 from the Netherlands, reflecting a broader global presence in this research domain. These regional disparities in the geographical distribution of chemistry ICB studies have important implications for understanding the global landscape of interdisciplinary and cross-border research efforts in chemistry. It is crucial to investigate further the factors influencing the concentration of such studies in specific regions and their potential impact on advancing knowledge and collaboration in the field.

It's important to note that these regional disparities in chemistry ICB studies may have different implications and interpretations within the context of students' achievement in chemistry education. Understanding these regional disparities can provide insights into the distribution of context-based teaching interventions and the effectiveness of different teaching approaches in diverse contexts. This underscores the significance of further exploring the factors

driving the regional concentration of context-based teaching studies and their impact on student achievement in different parts of the world.

Research Methodologies Employed in the ICB Approach of Study Articles

Research Design Adopted in the ICB Approach of Chemistry Studies

The nature of the research design adopted by each ICB Chemistry study article (Ar) is presented below in Table 1. The ten study articles (Ar) were categorized based on the type of research design employed.

Table 1. The type of research design employed in the ICB chemistry study articles.

Types of Research Design	Total N (%)	CB Study Articles
Experimental research method with pre-test post-test control group design	4(40)	[25], [31], [32] & [34]
Experimental research with posttest-only design	1(10)	[26]
Quasi-experimental design	3(30)	[27], [29] & [33]
Mixed-method research design	2(20)	[28] & [30]

Note: N- number, CB - Context-based, Ar-study article

As the table indicated, 40% (4 out of 10) of the study articles used an experimental research method with a pre-test-posttest control group design. In comparison, 10% (1 out of 10) of study articles utilized an experimental research design with a post-test only. Additionally, 30% (3 out of 10) of articles employed a quasi-experimental design, and another 20% (2 out of 10) of study articles utilized a mixed-method research design. These findings suggest that various research designs were employed in the ICB chemistry study articles, allowing for a comprehensive examination of the effectiveness of the CB teaching aspects of the subject matter.

Sampling Techniques Employed in the ICB Study Articles

In the reviewed ten study articles, various sampling techniques were employed to select research participants.

As shown in Figure 3, except for one of the study articles, the authors state the sampling of each study. Three (30 percent) of the study articles utilized convenience sampling. Two (20 percent) study articles employed cluster random sampling, and one (10 percent) study article used stratified random sampling. Another study article (10 percent) used purposive sampling. One (10 percent) study article employed a randomly chosen sampling technique. One (10 percent) study article utilized a combination of purposive and convenience sampling. Lastly, one (10 percent) study article did not explicitly state the sampling technique used.

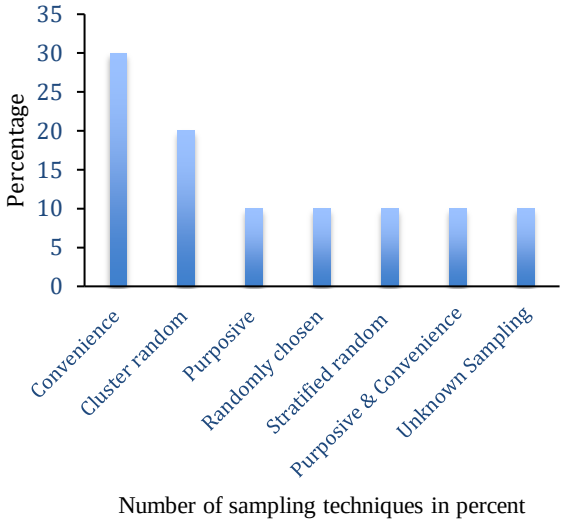

Figure 3. Percentage of Chemistry Study articles employed sampling techniques

From this, we can suggest that the nature of sampling in this case was that various sampling techniques were employed. Convenience sampling dominates the interventional context-based chemistry studies in terms of the number of sampling methods. These different techniques emphasize the importance of selecting an appropriate method to ensure the representativeness and generalizability of the research findings. Additionally, it is noted that one study article did not explicitly state the sampling technique used, which may limit the ability to assess the validity of its findings. The data collection methods used in the reviewed study include questionnaires, achievement tests, structured grids, Likert-type scales, and qualitative instruments such as interviews and open-ended questionnaires. These methods were used to collect quantitative and qualitative data on students' achievement in chemistry. The study articles employed a combination of test and non-test instruments to gather data from treatment and control groups. Overall, various tools were used to measure and assess the effect of contextual-based teaching chemistry on students' achievement.

Data Analysis Methods Adopted in ICB Studies

In the data analysis section of reviewing, Table 2 below shows an overview of the types and number of analysis methods adopted by the study articles. Among the study articles, three article [26,30,34] utilized the independent t-test as their data analysis method. Additionally, three study articles [25,27,33] used the one-way t-test. Furthermore, five study articles [25,28,30,31,32] employed the one-way ANOVA/ANOCOA as their data analysis method. Lastly, one study article [25] utilized the MANOVA method, which stands for multivariate analysis of variance.

From this (Table 2), we can conclude that three study articles [26,30,34] utilized the independent t-test as their data analysis method. The independent t-test was employed in these studies to compare the means of two separate groups. Additionally, three study articles [25,27,33] used the one-way t-test, also known as a single-sample t-test. This test was used to compare the mean of a single group to a known or

hypothesized value. Furthermore, five study articles [25,28,30,31,32] employed the one-way ANOVA or ANOCOA as their data analysis method. This statistical test allowed for the comparison of means across multiple groups within a single factor. Lastly, the study article [25] utilized the MANOVA method, the One-way t-test, and one-way ANOVA or ANOCOA, which stands for multivariate analysis of variance. This technique enabled the assessment of differences in means across multiple dependent variables. Overall, the data analysis methods employed in these articles varied, with the independent t-test, one-way t-test, one-way ANOVA or ANOCOA, and MANOVA being utilized to compare means between groups or against specified values.

Table 2. Data Analysis Methods of ICB

Data Analysis Method	Specific DAM	CB Study Articles	N
t-test	independent t-test	[26,30,34]	3
	One-way t-test	[25,27,33]	3
ANOVA or ANCOVA	One –way	[25,28,30,31,32]	5
MANOVA		[25]	1

Note: DAM- Data Analysis Method

Chemistry Topics Used in ICB Chemistry Study Articles

As can be seen from Table 3 below, Chemistry topics are identified in the ten ICB study articles. Matter & chemical reaction [25], Acid-base chemistry [26], Chemical changes [27], Physical and chemical changes [28], chemical reaction [29], Chemical equilibrium [30] and Electrolyte solution and redox reaction [31], Green chemistry principle (8), Hydrocarbon concept (9) and Chemistry literacy ability (10) are the ten chemistry topics applied for teaching and learning by ten study articles.

Table 3. Chemistry Topics Investigated by ICB Chemistry Study Articles (N = 10)

CB Study Articles	Chemistry Topic	Total N (%)
[25]	Matter & chemical reaction	1(10)
[26]	Acid-base chemistry	1(10)
[27]	Chemical Change	1(10)
[28]	Physical and chemical changes	1(10)
[29]	Chemical reaction	1(10)
[30]	Chemical equilibrium	1(10)
[31]	Electrolyte solution and redox reaction	1(10)
[32]	Green chemistry principle	1(10)
[33]	Hydrocarbon concept	1(10)
[34]	Chemistry literacy ability	1(10)

Note: N: number; CB: context-based

Each chemistry topic was investigated in one study article, representing 10% of the total study articles. Generally, 100 percent (10 out of 10) of ICB chemistry study articles reported the topics investigated for teaching-learning intervention.

Research Variables Investigated by ICB Chemistry Study Articles

While the ten ICB chemistry study articles examined a range of learning variables, this review study focuses solely on the student's academic achievement. 100 percent of the selected study articles [25-34] investigated the students' achievement variable.

Teaching methods or strategies Adopted in ICB Chemistry Study Articles

Table 4 presents the various teaching methods (instructional strategies) within the context of the CB approach conducted in 10 ICB chemistry studies. Context-based teaching aims to make learning more meaningful and relevant by connecting concepts and skills to real-life situations. It emphasizes applying knowledge in practical contexts, allowing students to see the value and relevance of their learning. This approach encourages active engagement, critical thinking, problem-solving, and the development of transferable skills.

Table 4. Types of Teaching methods or strategies applied in the study articles

CB Study Articles	Teaching methods or strategies
[25]	Experiments
[26]	Teaching with 4Ex2 Model
[27]	Worksheet
[28]	Virtual experiment
[29]	Not stated
[30]	Taking notes, solving problem
[31]	POGIL model
[32]	Scrum methodology
[33]	Lecture method
[34]	Guided inquiry learning

According to the table, various context-based teaching methods or strategies were utilized in the ICB chemistry studies. For instance, one study article [26] employed an experiment-based teaching method, likely integrating real-world scenarios and practical applications into the learning process. Another study article [27] utilized the 4Ex2 Model to provide students with multiple examples, explanations, and exercises to enhance their understanding. In addition, a third study article [25] employed a Worksheet approach, likely involving structured worksheets to guide student learning and practice. Furthermore, one study article [28] used virtual experiments, providing students with simulated laboratory experiences. Another study article [30] focused on note-taking and problem-solving, representing a more traditional instructional approach.

Moreover, one study article [31] used the POGIL teaching mode, involving collaborative and inquiry-based learning activities. Additionally, one study article [32] employed Scrum methodology, another study article [33] used the Lecture method, and one more study article [34] employed Guided inquiry learning. Finally, one study article [29] did not specify the teaching method or strategy used in its context-based approach. In general, the analysis of teaching methods in the reviewed study article indicates a diverse range of instructional strategies employed to support students' achievement in chemistry within a context-based framework. This diversity highlights the complexity of designing effective pedagogical interventions in context-

based chemistry education. It suggests further research to evaluate the comparative effectiveness of these varied teaching methods.

The Specific Effects of Context-Based Teaching Approach of Chemistry on Students' Achievement

Table 5 presents the effectiveness of the context-based instructional approach per specific Chemistry topics used and research Variables measured in the study articles. It demonstrates that to investigate the measured dependent variable, different instructional methods/ strategies were applied to teach various chemistry topics.

The table indicates that 90% of the study articles (9 out of 10) reported a significant positive impact on students' learning outcomes when employing context-based instructional methods for teaching chemistry topics.

Table 5. The Effectiveness of CB Teaching Methods or Strategies per Chemistry Topics and Measured Variable in ICB Study Articles

Studies Articles	CB Teaching Methods or Strategies Employed	Chemistry Topics Studied	Dependent Variable	Effectiveness on the dependent variable
[26]	Experiment	Acid-base reaction	Achievement	Significant
[27]	4Ex2 Model	Chemical change	Achievement	Significant
[25]	worksheet	Matter & chemical reaction	Achievement	Significant
[28]	Virtual experiment	Physical & chemical changes	Achievement	Not Significant
[29]	Not stated	Chemical reaction	Achievement	Significant
[30]	Taking notes, solving problems	Chemical equilibrium	Achievement	Significant
[31]	POGIL Model	Electrolyte solution Redox reaction	Achievement	Significant
[32]	Scrum methodology	Green chemistry principle	Achievement	Significant
[33]	Lecture method	Hydrocarbon concept	Achievement	Significant
[34]	Guided inquiry learning	Chemistry literacy ability	Achievement	Significant

Based on the data analysis of the study articles [25-34], it was found that there is a significant mean difference in students' achievement scores across different topics and instructional methods. This means the student's scores varied significantly regardless of the specific topic or instructional method. Specifically, study [26], which used an experimental instructional strategy in acid-base chemistry, reported a significant mean difference in student achievement scores. Study [27], which utilized the 4Ex2 model in teaching chemical reactions, also said a significant mean difference in student scores. Similarly, study [25], which employed worksheets in teaching matter and chemical reactions, found a significant mean difference in achievement scores. However, study [28], which utilized virtual experiments in teaching chemical reactions, did not report a significant mean difference in student scores. No significant difference was found between the experimental group and the control group students. It can be said that the application of virtual experiments as an instructional approach in teaching chemical reactions did not significantly affect student achievement. Study [29], which did not specify the instructional strategy used but focused on chemical reactions, reported a significant mean difference in student achievement scores. Study [30], which involved taking notes and solving problems in teaching chemical equilibrium, found a significant mean difference in achievement scores. Study [31], which utilized the POGIL model in teaching electrolyte solutions and redox reactions, reported a significant mean difference in student achievement scores. Study Ar8 focused on applying the Scrum methodology in teaching green chemistry principles and showed a significant mean difference in student achievement scores.

Study [33] examined the effectiveness of the lecture method in teaching hydrocarbon concepts and revealed a significant mean difference in student achievement scores. Study [34] evaluated the impact of guided inquiry learning on chemistry literacy ability and demonstrated a significant mean difference in students' achievement scores in chemistry literacy ability.

Overall, these findings suggest that the students' mean scores varied significantly regardless of the specific topic or instructional method used.

Contribution of the Reviewed Studies Result to Our Understanding

The reviewed articles comprehensively analyze the relationship between context-based teaching methods and students' academic achievement in chemistry. The results reveal diverse context-based instructional methods employed across different chemistry topics, each yielding a positive significant effect on students' academic achievement. For instance, experiments, models, worksheets, virtual experiments, note-taking, problem-solving, POGIL model, Scrum methodology, lecture method, and guided inquiry learning were examined in relation to topics. Notably, significant positive effects on the dependent variable of achievement were observed in most studies, indicating the potential of context-based teaching methods to enhance students' academic performance in chemistry. These findings contribute valuable insights into the effect of context-based instructional strategies on students' academic achievement in chemistry across various topics.

Implications of the Findings of Reviewed Studies for Educators and Policymakers

The implications of the findings for educators and policymakers regarding enhancing students' academic achievement in chemistry are multifaceted. Firstly, the significant positive impact of context-based instructional methods on students' learning outcomes, as evidenced by 90% of the study articles reporting such effects, highlights the potential of these methods for improving academic achievement. Educators can consider incorporating context-

based teaching approaches into their chemistry curriculum to enhance student performance. Policymakers can use these findings to advocate for professional development opportunities for educators to effectively improve their pedagogical skills in context-based instructional methods. Additionally, policymakers may consider allocating resources to research and develop context-based teaching materials and strategies that align with different chemistry topics. These implications emphasize the importance of a nuanced and strategic approach to implementing context-based instructional methods to improve students' academic achievement in chemistry.

Conclusion

In conclusion, the analysis of these studies on the effects of contextual teaching in chemistry has provided valuable insights into the relationship between instructional methods, specific topics, and students' achievement. Most studies reviewed reported a positive impact and significant mean differences in student scores when using contextual-based instructional strategies. These findings suggest incorporating real-world applications and relevant contexts into chemistry instruction can enhance students' understanding and performance. The instructional strategies conducted in the study articles effectively improved students' achievement scores. However, it is worth noting that the study on virtual experiments in teaching chemical reactions (study Ar4) did not report a significant mean difference in student scores. This suggests that further research is needed to explore the effectiveness of this instructional method in different contexts or with different populations. Based on these findings, it is recommended that educators consider incorporating contextual-based instructional strategies into their chemistry teaching practices. Further research should continue to explore the effectiveness of different contextual-based instructional methods in various chemistry topics and populations to provide more comprehensive guidance for educators. Furthermore, policymakers should consider incorporating contextual teaching into national or state-level curriculum standards for chemistry education. Explicitly recognizing the value of connecting chemistry to real-world contexts can help ensure consistent implementation across schools and provide guidance for educators.

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I want to acknowledge many individuals' invaluable contributions and support in making this review possible. I am grateful to the researchers and authors whose studies were included in this review, as their work has greatly enhanced our understanding of the impact of contextual teaching on chemistry students' achievement. I also extend my thanks to the educators and students who participated in the reviewed studies, as their perspectives and experiences have been essential for this review. Furthermore, I appreciate the guidance and feedback provided by our instructors throughout this process.

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