



EFFECTIVENESS OF DESIGN THINKING-BASED CHEMISTRY INSTRUCTION ON CONCEPT APPLICATION AND PROBLEM-SOLVING SKILLS AMONG SECONDARY SCHOOL STUDENTS

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Abstract

The growing emphasis on 21st-century skills in science education requires teaching approaches that extend beyond traditional lecture-based instruction. Chemistry, often regarded as abstract and challenging, demands strategies that promote meaningful understanding and practical application. This study investigates the effectiveness of integrating design thinking into high school chemistry instruction to enhance students' concept application and problem-solving skills. A quasi-experimental pre-test-post-test control group design was employed with 60 secondary school students divided into experimental and control groups. The experimental group received instruction based on design thinking principles, while the control group followed conventional teaching methods. Data collected through a researcher-developed achievement test revealed a significant improvement in the performance of students exposed to design thinking-based instruction. The findings suggest that integrating design thinking enhances conceptual understanding and strengthens higher-order thinking skills in chemistry education.

Keyword: *Design Thinking, Chemistry Instruction, Concept Application, Problem-Solving Skills, Secondary School Students, Quasi-Experimental Design, 21st-Century Skills*

1.Introduction

The evolving demands of 21st-century education require students to develop higher-order thinking skills beyond factual knowledge. In science education, particularly in chemistry, learners must be able to apply concepts and solve real-world problems effectively. However, conventional teaching methods in secondary schools often emphasize memorization and examination performance, which may limit students' deeper conceptual understanding and analytical abilities.

Chemistry is frequently considered a challenging subject due to its abstract nature and the need for systematic problem-solving. Many students struggle to transfer theoretical



knowledge into practical contexts, creating a gap between learning and application. To address this issue, innovative instructional approaches are necessary.

Design thinking is a student-centered, problem-based approach that encourages creativity, critical thinking, and iterative learning. By engaging students in identifying problems, generating ideas, and testing solutions, design thinking can promote active learning and meaningful understanding. Therefore, this study examines the effectiveness of integrating design thinking into chemistry instruction to enhance concept application and problem-solving skills among secondary school students.

1.1 Statement of the Problem

Many secondary school students struggle to apply chemistry concepts and solve analytical problems effectively. Traditional teaching methods often focus on content delivery rather than developing higher-order thinking skills, leading to limited conceptual understanding and practical application. Although design thinking has been proposed as an innovative instructional approach, its effectiveness in enhancing concept application and problem-solving skills in chemistry classrooms remains underexplored. Therefore, this study seeks to examine the impact of design thinking-based chemistry instruction among secondary school students.

1.2 Need for the Study

The evolving landscape of education emphasizes the development of critical thinking, creativity, and problem-solving skills alongside subject knowledge. In chemistry education, students often struggle to apply theoretical concepts to real-world situations, highlighting a gap between knowledge acquisition and practical application. Traditional instructional approaches may not sufficiently promote analytical and higher-order thinking abilities required in modern science learning.

Design thinking, as a student-centered and problem-based approach, has the potential to foster deeper engagement and meaningful learning experiences. However, limited research has examined its effectiveness within secondary-level chemistry classrooms. Therefore, there is a need to investigate whether integrating design thinking into chemistry instruction can enhance students' concept application and problem-solving skills.

1.3 Scope of the Study

- The study focuses on the integration of design thinking in secondary-level chemistry instruction.
- It examines the impact of design thinking on students' concept application and problem-solving skills.
- The study is limited to selected topics in the chemistry syllabus.
- The sample consists of a specific group of secondary school students.
- The findings aim to provide insights into improving instructional practices in



chemistry education.

- The study does not extend to other subjects, grade levels, or wider geographical regions.

1.4 Hypotheses

- **H₀1:** There is no significant difference between the pre-test and post-test scores of the control group in terms of concept application and problem-solving skills in chemistry.
- **H₀2:** There is no significant difference between the pre-test and post-test scores of the experimental group in terms of concept application and problem-solving skills in chemistry.
- **H₀3:** There is no significant difference between the post-test scores of the control group and the experimental group in concept application and problem-solving skills in chemistry.
- **H₀4:** There is no significant difference between boys and girls in the post-test scores of the experimental group.

1.5 Limitations of the Study

1. The study was limited to a small sample of secondary school students, which may affect the generalizability of the findings.
2. The research focused only on selected topics in the chemistry syllabus and did not cover the entire curriculum.
3. The duration of the intervention was limited, which may have influenced the extent of learning outcomes.
4. The effectiveness of design thinking instruction may vary depending on the teacher's implementation and instructional style.
5. Individual differences among students, such as prior knowledge and learning pace, were not controlled in the study.

2. Research Methodology

This study employed a quasi-experimental pre-test and post-test control group design to evaluate the impact of design thinking-based chemistry instruction on students concept application and problem-solving skills.

2.1 Design of the Study

- The study adopted a quasi-experimental **pre-test, post-test, control group design.**
- **Two groups** of secondary school students were selected for the **investigation.**
- The experimental group received **chemistry instruction** integrated with **design thinking strategies.**
- The **control group** was taught using **conventional teaching methods.**



- A pre-test was administered to both groups to assess their **initial level of concept application and problem-solving skills.**
- After the **instructional intervention**, a post-test was conducted to measure **learning outcomes.**
- The design enabled a comparative analysis of **the effectiveness of design thinking-based instruction.**

2.2 Sample of the Study

- The sample of the present study consisted of 60 students studying in Standard XI.
- The participants were selected from Velammal School, Chennai, Tamil Nadu.
- The students were divided equally into two groups: 30 students in the experimental group and 30 students in the control group.
- The experimental group received chemistry instruction integrated with design thinking strategies, while the control group was taught using conventional teaching methods.
- The sample was selected using an appropriate sampling technique suitable for the study.
- Although the sample size was limited to 60 students, it was considered adequate for conducting meaningful statistical analysis within a quasi-experimental research framework. Future studies may consider larger and more diverse samples to enhance the generalizability of the findings.

2.3 Ethical Clearance Statement

The study was conducted following ethical research standards. Permission was obtained from the school administration before carrying out the study. Informed consent was secured from the participating students and their parents, and confidentiality of the collected data was strictly maintained. The participants were informed that their involvement in the study was voluntary and that the data would be used solely for academic research purposes.

2.4 Variables of the Study

- **Independent Variable:** Design thinking-based chemistry instruction.
- **Dependent Variables:** Concept application skills in chemistry, Problem-solving skills in chemistry.
- **Control Variables:** Grade level (Standard XI), School environment, Subject content covered during the study, Duration of instruction.

2.5 Procedure of the study

Phase I – Preparation

- Permission was obtained and 60 Standard XI students were divided into experimental and control groups.



- Lesson plans were prepared for both groups.

Phase II – Pre-Test

- A pre-test was administered to assess students' initial concept application and problem-solving skills.

Phase III – Intervention

- The experimental group received design thinking-based chemistry instruction.
- The control group was taught using conventional methods.

Phase IV – Post-Test

- A post-test was conducted after the intervention.
- The data were collected for statistical analysis.

2.6 Statistical Techniques Used

- **Descriptive statistics** such as mean and standard deviation were used to analyse the overall performance of the students.
- **Inferential statistics**, specifically the independent and paired sample *t*-test, were applied to determine the significance of differences between pre-test and post-test scores and between the experimental and control groups.

3. Data Analysis and Interpretation

The data collected through the pre-test and post-test were analysed using appropriate statistical techniques to determine the effectiveness of design thinking-based chemistry instruction. Mean and standard deviation were calculated to examine the performance levels of students. The *t*-test was applied to test the stated hypotheses.

3.1 Testing of Hypothesis

Hypothesis I

- H_{01} : There is no significant difference between the pre-test and post-test scores of the control group.



Table-1

Table-1 presents the Level of Significance between Control Group and Experiment Group Boys in Post Test in Achievement in Chemistry

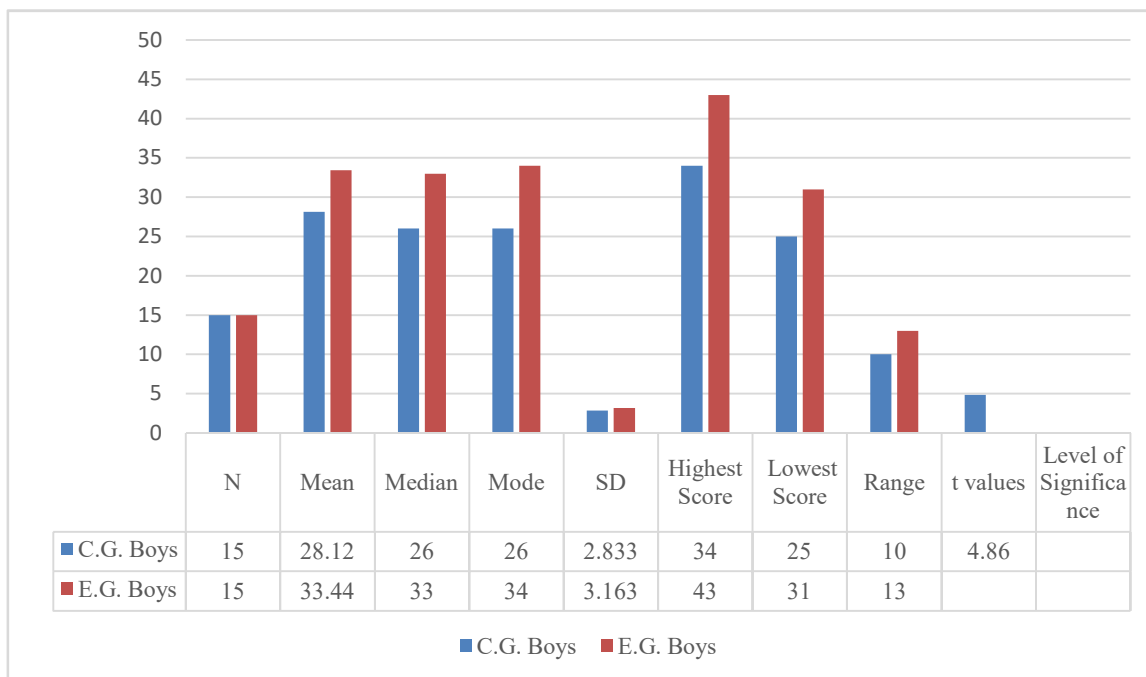
Sl. No	Description	C.G. Boys	E.G. Boys
1	N	15	15
2	Mean	28.124333	33.4444333
3	Median	26	33
4	Mode	26	34
5	SD	2.83305515	3.163925134
6	HighestScore	34	43
7	LowestScore	25	31
8	Range	10	13
9	Tvalue	4.86	
10	Level of Significance	Significance	

- The mean post-test score of the **Experimental Group Boys (34.44)** is **higher** than that of the Control Group Boys (28.12).
- The **standard deviation** is relatively similar, suggesting comparable variance in both groups.
- The **t-value = 4.86** is statistically significant at $p < 0.01$ level, indicating a **very strong difference** between groups.

Conclusion: The calculated t-value ($t = 4.86, p < 0.001$) indicates a statistically significant difference between the control and experimental groups. Therefore, **the null hypothesis is rejected**. The experimental group boys performed significantly better than the control group boys in the post-test.

Graph-1

Graph-1 present the Level of Significance between Experiment Group and Control Group Boys in Post Test in the Achievement in Chemistry



Hypothesis-II

- There is no significant difference between control group and experimental group girls in Post Test

Table-2

Table-2 presents the Level of Significance between Control Group and Experiment Group Girls in Post Test in Achievement in Chemistry

Sl. No	Description	C.G. Girls	E.G. Girls
1	N	15	15
2	Mean	28.3333	33.5666
3	Median	28	31
4	Mode	27	33
5	SD	3.309416	2.820321
6	HighestScore	33	42
7	LowestScore	23	29
8	Range	10	13
9	Tvalue	4.66	
10	Levelof Significance	Significance	

- The **Experimental Group Girls** achieved high rmean (33.56) than the Control



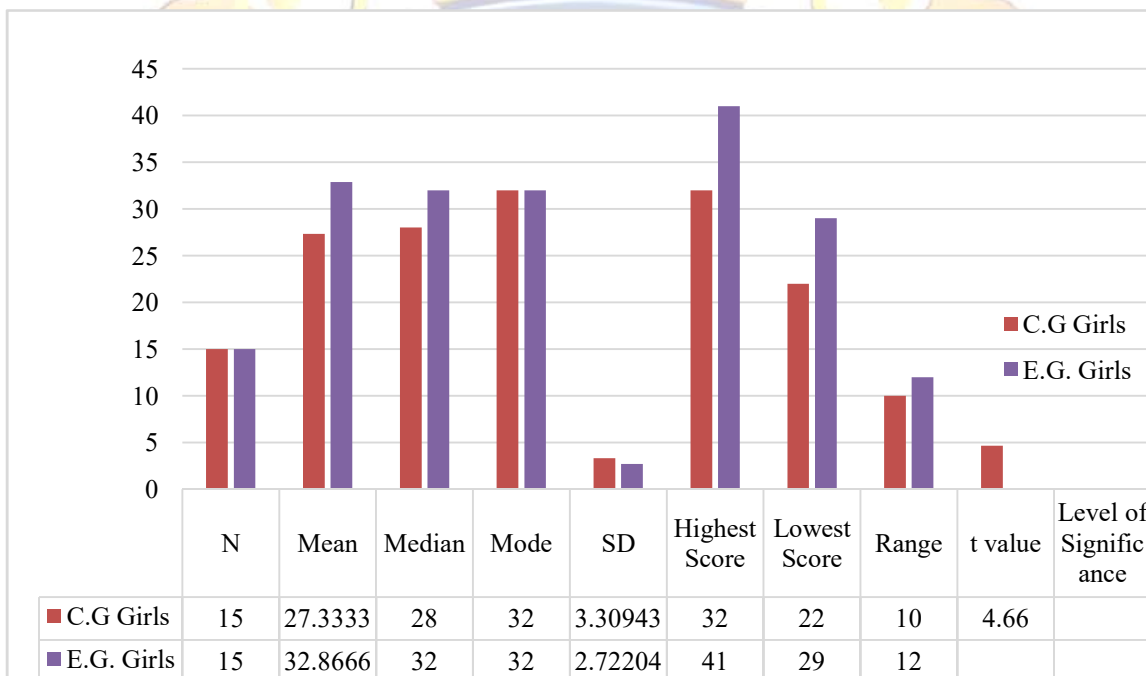
Group Girls (28.33).

- There latively lower SD in the experimental groups hows **moreconsistency** in performance.
- Thet-value= **4.66** is statistically significant($p < 0.01$).

Conclusion:The calculated t-value ($t = 4.66, p < 0.001$) indicates a statistically significant difference between control and experimental group girls. Therefore, **the null hypothesis is rejected**. The experimental group girls performed significantly better than the control group girls in the post-test.

Graph-2

Graph-2 presents the Level of Significance between Control Group and Experiment Group Girls in Post Test inAchievement in Chemistry



➤ Hypothesis-III

Thereis no significant differencebetween Control groupand Experiment groupRural students and their Post Test Scores



Table-3

Table-3 presents the Level of difference between the Experiment Group and Control Group Rural Students in Post Test in the Achievement in Chemistry

Sl. No	Description	C.G. Rural	E.G. Rural
1	N	21	19
2	Mean	26.8254621	32.402941
3	Median	30	34
4	Mode	29	34
5	SD	2.8863841	3.3425166
6	HighestScore	32	43
7	LowestScore	23	29
8	Range	10	12
9	Tvalue	5.62	
10	Levelof Significance	Significance	

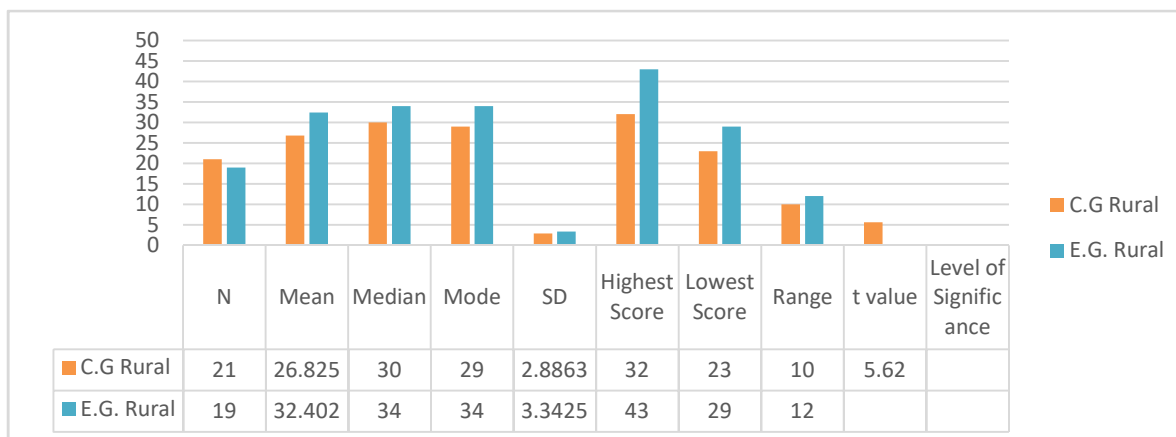
- Rural students in the **Experimental Group** scored significantly higher (Mean=32.40) than those in the Control Group (Mean = 26.82).
- The **t-value=5.62** is extremely significant ($p < 0.01$), indicating a highly reliable difference.

Conclusion: The calculated t-value ($t = 5.62$, $p < 0.001$) indicates a statistically significant difference between rural students in the control and experimental groups. Therefore, **the null hypothesis is rejected**. The experimental group rural students performed significantly better than the control group rural students in the post-test.



Graph-3

Graph-3 Shows the Level of difference between the Experiment Group and Control Group Rural Students in Post Test in the Achievement in Chemistry



Hypothesis-IV

- There is no significant difference between Control group and Experiment group Urban students and their Post Test Scores

Table-4

Table-4 presents the level of Significance between the Experiment Group and Control Group Urban Students and their Post Test in the Achievement of Chemistry

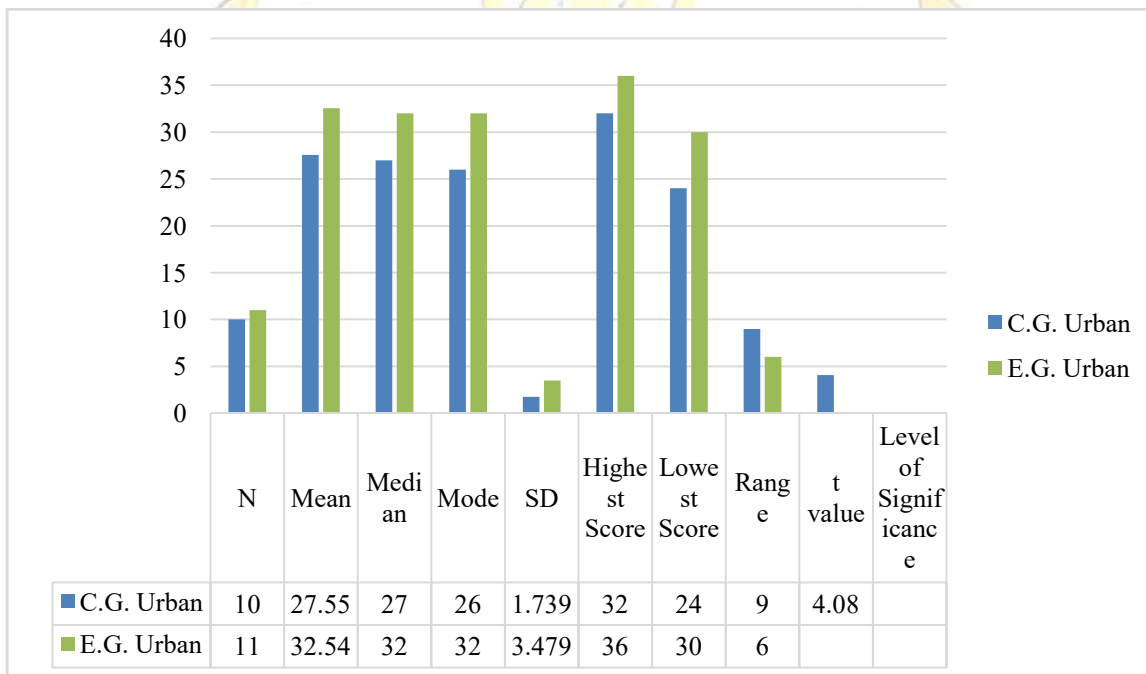
Sl. No	Description	C.G. Urban	E.G. Urban
1	N	10	11
2	Mean	27.5551	32.545361
3	Median	27	32
4	Mode	26	32
5	SD	1.739267	3.479271
6	HighestScore	32	36
7	LowestScore	24	30
8	Range	9	6
9	tvalue	4.08	
10	Levelof Significance	Significance	

- Urban students in the **Experimental Group** scored higher (Mean = 32.54) than the Control Group (Mean = 27.55).
- The **SD is lower** in the experimental group, indicating greater consistency in scores.
- The **t-value=4.08** is statistically significant ($p < 0.01$).

Conclusion: The calculated t-value ($t = 4.08$, $p < 0.001$) indicates a statistically significant difference between urban students in the control and experimental groups. Therefore, the null hypothesis is rejected. The experimental group urban students performed significantly better than the control group urban students in the post-test.

Graph-4

Graph-4 Shows the Significance between the Experiment Group and Control Group Urban Students and their Post Test in the Achievement of Chemistry



The calculated t-value ($t = 4.08$, $p < 0.001$) indicates a statistically significant difference between urban students in the control and experimental groups. Therefore, **the null hypothesis is rejected**. The experimental group urban students performed significantly better than the control group urban students in the post-test.

4. Findings

1. The results show that boys in the experimental group performed better than those in the control group in the post-test. The higher mean score and statistically significant difference indicate that the design thinking approach contributed



- positively to their achievement in chemistry.
2. A similar pattern was observed among girls. Students exposed to design thinking-based instruction demonstrated stronger performance compared to those taught through conventional methods, suggesting that the approach effectively supported their conceptual understanding and problem-solving ability.
 3. Rural students in the experimental group achieved notably higher scores than rural students in the control group. The significant difference between the groups suggests that the intervention was beneficial regardless of students' background.
 4. Urban students in the experimental group also showed improved performance compared to their control group counterparts. This indicates that the instructional strategy was effective across different localities.
 5. Overall, the findings consistently demonstrate that integrating design thinking into chemistry instruction positively influenced students' concept application and problem-solving skills across gender and locality.

5. Discussion

The findings of the present study clearly indicate that integrating design thinking into chemistry instruction resulted in improved concept application and problem-solving skills among secondary school students. The experimental group consistently outperformed the control group across gender and locality, suggesting that the instructional approach contributed meaningfully to students' academic performance.

One possible explanation for this improvement is that design thinking encourages active engagement with learning content. Unlike traditional lecture-based methods, the design thinking approach requires students to identify problems, explore possible solutions, and apply conceptual knowledge in practical contexts. This process promotes deeper cognitive involvement and helps students connect abstract chemistry concepts to real-life situations.

The improvement observed among both boys and girls indicates that the approach is inclusive and effective across gender groups. Similarly, the positive outcomes among rural and urban students suggest that design thinking-based instruction can be implemented successfully in diverse educational settings. The consistent pattern of results strengthens the argument that student-centered and problem-based instructional strategies enhance meaningful learning.

Overall, the discussion highlights that when students are given opportunities to think critically, collaborate, and experiment with ideas, their understanding becomes more structured and application-oriented. The results support the integration of innovative pedagogical approaches in chemistry classrooms to foster higher-order thinking skills and improve academic achievement.



6. Conclusion

The present study examined the effectiveness of design thinking-based instruction in enhancing concept application and problem-solving skills in chemistry among secondary school students. The findings demonstrated that students who were taught using the design thinking approach achieved significantly higher performance compared to those who received conventional instruction. The improvement was consistent across boys, girls, rural, and urban students, indicating that the approach is broadly effective and adaptable to different learner groups.

The results suggest that integrating design thinking into chemistry classrooms can promote deeper understanding, analytical reasoning, and meaningful application of concepts. By encouraging students to engage actively in problem identification and solution development, the approach strengthens higher-order thinking skills essential for science learning.

In conclusion, design thinking-based instruction can be considered a valuable pedagogical strategy for improving students' academic achievement and fostering more engaging and effective chemistry education.

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