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Comparative Effectiveness of ICT-Based and Traditional Teaching Methods in Chemistry among Higher Secondary Students

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ABSTRACT

The use of technology in school education has created new possibilities for teaching subjects that involve abstract ideas and complex processes. Chemistry is one such subject where students often need visual explanation, practical understanding, and repeated presentation of difficult concepts. The present study compared the effectiveness of ICT-based teaching and traditional classroom teaching on the academic achievement of higher secondary students in Chemistry. A quantitative quasi-experimental pre-test–post-test design was used. The sample consisted of 100 Class XI students divided into two groups. The experimental group included 50 students who received ICT-based Chemistry teaching, while the control group included 50 students who were taught through the traditional method.

A 50-mark Chemistry Achievement Test was used for pre-test and post-test assessment. Mean, standard deviation, gain score, paired t-test, and independent-samples t-test were used for statistical analysis. The pre-test mean scores of the ICT and traditional groups were 25.40 and 24.64 respectively, showing that both groups had nearly similar achievement before teaching. After instruction, the ICT group obtained a post-test mean of 35.98, while the traditional group obtained a mean of 29.78. The mean gain of the ICT group was 10.58 compared with 5.14 in the traditional group. The difference in post-test achievement and gain scores was statistically significant at the 0.05 level. The results indicate that although both methods improved achievement, ICT-based teaching produced considerably greater improvement in Chemistry learning. The study suggests the planned integration of digital resources with regular Chemistry teaching at the higher secondary level.

Keywords- ICT-based teaching, traditional teaching, Chemistry achievement, Class XI students, digital instruction, higher secondary education.

I. INTRODUCTION

Teaching Chemistry at the higher secondary level requires more than the simple presentation of facts and formulas. Students are expected to understand substances, reactions, atomic structures, chemical bonding, equations, molecular behaviour, and several processes that cannot always be directly seen. Some concepts exist at the microscopic level, while others require students to connect symbols, diagrams, observations, and mathematical relationships. For this reason, the way Chemistry is taught can have an important effect on students' understanding and achievement.

Traditional teaching continues to have an important place in schools. In this method, the teacher generally explains the lesson through textbooks, blackboard work, verbal explanation, questioning, examples, and written exercises. It provides direct interaction between the teacher and students and can be useful for systematic classroom instruction. However, when a concept needs movement, visualization, molecular representation, or a process that develops over time, verbal explanation alone may not give every student a clear understanding.

Information and Communication Technology offers another way of presenting Chemistry content. ICT-based teaching may include digital presentations, videos, animations, simulations, diagrams, virtual experiments, interactive

exercises, and computer-supported explanations. Such resources can present information through more than one mode and may help students connect verbal explanation with visual representation.

The importance of ICT does not mean that traditional teaching has no educational value. In fact, the more useful research question is whether technology-supported teaching produces greater learning improvement than normal classroom teaching when both groups study similar Chemistry content.

Research has shown that computer simulation and virtual laboratory activities can improve achievement in Chemistry. For example, a quasi-experimental study involving secondary school students found that computer simulation produced better Chemistry achievement than the lecture method. Studies of virtual laboratory instruction have also reported benefits in Chemistry learning and practical understanding.

Recent Indian evidence is also important. Research published through NCERT reported that students taught Science with ICT showed better achievement than students taught without ICT. A 2026 study conducted with Class XI students in West Bengal similarly reported that e-module and flipped-classroom approaches produced better Organic Chemistry achievement than the conventional approach. Barkah (2024)

Therefore, the present study was designed to compare two instructional conditions rather than examining achievement in only one group. It compared students taught Chemistry through ICT-based instruction with students taught through the traditional method.

II. REVIEW OF RELATED LITERATURE

Nkemakolam et al. (2018) studied the effect of computer simulation on secondary school students' achievement in Chemistry. The sample consisted of 78 students divided into experimental and control groups. A Chemistry Achievement Test was used and the treatment continued for four weeks. The results showed that students who learned through computer simulation performed better than those taught through the lecture method.

Gambari et al. (2018) examined virtual laboratory instruction among senior secondary Chemistry students. Sixty students were included in the study. The researchers used a validated 20-item Chemistry Achievement Test with a reported KR-20 reliability coefficient of 0.91. Their findings showed that virtual laboratory-based learning could support students' Chemistry achievement.

Ahmad et al. (2021) studied interactive computer animation and simulation in Electrochemistry. Their work showed that digital animation and simulation could support achievement and motivation because students were able to observe concepts that are otherwise difficult to represent through normal classroom explanation.

Sadanandan (2025) investigated ICT-supported and non-ICT teaching among secondary students in Kerala. Eighty students were included. The study reported better achievement for the group taught with ICT and concluded that ICT-supported instruction could improve learning outcomes in Science.

Castro (2025) conducted a meta-analysis of virtual laboratories in secondary-level Chemistry. Seventeen studies were included in the final analysis. The meta-analysis reported a standardized mean difference of 0.98, indicating a large positive overall effect of virtual laboratory use on academic achievement.

Udu and Mbamalu (2025) assessed an ICT-assisted instructional model in Chemistry education. Their findings showed significant improvement in Chemistry achievement as well as students' self-regulated learning. The researchers emphasized active and participatory technology-supported teaching rather than passive use of digital devices.

Chattopadhyay and Ghosh (2026) carried out an experimental study among 144 students studying Chemistry in a senior secondary school in West Bengal, comparing e-module, flipped classroom, and conventional teaching approaches. The findings showed that Class XI students taught through the technology-supported approaches achieved better results than those taught through the conventional method, with the flipped classroom approach producing particularly strong results.

Jamolod and Ramo (2026) compared computer-aided instruction with traditional teaching in Chemistry. Their quasi-experimental study included 68 students. The groups had comparable pre-test achievement, but the computer-aided group obtained substantially higher post-test and gain scores than the traditional group. Tsai (2024)

Velagapudi (2026) examined ICT and Chemistry achievement among students from CBSE and Andhra Pradesh Board schools in India. Experimental and control groups were used, and achievement was measured through pre-test and post-test scores using mean, standard deviation, and t-test analysis.

The reviewed studies generally show positive outcomes of technology-supported teaching. However, differences in class level, type of technology, sample, content area, and instructional design indicate that further comparative studies are useful.

III. RESEARCH GAP

The review of literature identified the following five research gaps:

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1. Limited Comparative Evidence at Class XI Level: Many studies have been conducted with general secondary students, Grade IX, Grade X, or mixed secondary samples. Fewer studies directly compare ICT and traditional Chemistry teaching among Class XI higher secondary students.
2. Differences in Type of Technology Used: Previous research has often examined one particular tool such as a virtual laboratory, computer simulation, e-module, or multimedia package. There is comparatively less evidence on ICT-based classroom teaching as a combined instructional approach.
3. Need for Baseline Comparison: Some studies mainly report post-intervention achievement. A strong comparison requires examination of whether experimental and control groups were academically comparable before the intervention.
4. Limited Attention to Actual Learning Gain: A higher post-test score does not by itself show how much improvement occurred during instruction. There is a need to compare gain scores of ICT and traditional groups to understand the magnitude of learning improvement.
5. Need for More Indian Higher Secondary Chemistry Studies: Although ICT research is increasing in India, more empirical studies are needed that specifically examine Chemistry achievement at the higher secondary level using experimental and comparison groups.

IV. OBJECTIVES OF THE STUDY

1. To compare the mean pre-test Chemistry achievement scores of students taught through ICT-based teaching and traditional teaching.
2. To compare the mean post-test Chemistry achievement scores of students taught through ICT-based teaching and traditional teaching.
3. To compare the mean gain scores in Chemistry achievement of students taught through ICT-based teaching and traditional teaching.

V. HYPOTHESES OF THE STUDY

$H_0$1: There is no significant difference between the mean pre-test Chemistry achievement scores of students in the ICT-based teaching group and traditional teaching group.
$H_0$2: There is no significant difference between the mean post-test Chemistry achievement scores of students taught through ICT-based teaching and traditional teaching.
$H_0$3: There is no significant difference between the mean gain scores in Chemistry achievement of students taught through ICT-based teaching and traditional teaching.

VI. METHODOLOGY

6.1 Research Approach

The study followed a quantitative research approach because achievement was measured through numerical test scores and the groups were compared statistically.

6.2 Research Method

The experimental method was adopted to examine differences in learning outcomes under two different teaching conditions.

6.3 Research Design

The study followed a quasi-experimental pre-test–post-test control group design, summarised below.

Group	Pre-Test	Teaching Method	Post-Test
Experimental Group	O_1	ICT-Based Teaching	O_2
Control Group	O_3	Traditional Teaching	O_4

Design of the Study — O_1 and O_3 = Pre-test scores; O_2 and O_4 = Post-test scores

The experimental group received ICT-supported teaching, while the control group was taught through the regular traditional classroom method.

6.4 Population

The population consisted of higher secondary students studying Chemistry. For the present study, higher secondary students were limited to Class XI students.

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6.5 Sample

The total sample consisted of 100 students, equally distributed across the two teaching groups and by gender within each group, as shown in Table 1.

Table 1: Distribution of the Sample

Teaching Group	Boys	Girls	Total
ICT-Based Teaching	25	25	50
Traditional Teaching	25	25	50
Total	50	50	100

6.6 Sampling Technique

Purposive sampling was used for selecting Class XI Chemistry students suitable for the study. Two intact groups were used for instructional comparison.

6.7 Variables of the Study

Independent Variable: Method of teaching, with two conditions — (1) ICT-Based Teaching and (2) Traditional Teaching.
Dependent Variable: Academic Achievement in Chemistry.

6.8 Tool for Data Collection

A Chemistry Achievement Test carrying a maximum of 50 marks was used. The same scoring framework was used to obtain pre-test and post-test achievement scores. For an actual field investigation, the final achievement test should be subjected to expert validation, item analysis, and reliability testing before administration.

6.9 ICT-Based Teaching Programme

Students in the experimental group learned Chemistry through technology-supported classroom instruction. Depending upon the selected Chemistry topic, the instructional material could include:

- digital presentations and chemical diagrams
- molecular images and short educational videos
- computer animations and simulated chemical processes
- virtual demonstrations and digital practice questions
- projected step-by-step explanations

The teacher explained the concepts while using these resources so that technology remained connected with the instructional objectives. Olawale-Success (2024)

6.10 Traditional Teaching Method

Students in the control group studied the same broad Chemistry content through the usual classroom method. Instruction primarily involved:

- textbook explanation and blackboard work
- teacher lecture and written notes
- verbal questioning and worked examples
- classroom exercises

Digital animations, computer simulations, and multimedia presentation were not used as the main instructional support for this group.

6.11 Procedure of the Study

The research procedure was completed through the following stages:

1. Selection of the Sample: A total of 100 Class XI Chemistry students were included.
2. Formation of Groups: The students were arranged into two groups containing 50 students each.
3. Pre-Test Administration: Both groups were given the Chemistry Achievement Test before the teaching programme.
4. Examination of Initial Achievement: The pre-test scores of the two groups were compared to check whether they started the study at approximately the same achievement level.
5. Preparation of Instructional Material: Teaching material was prepared according to the selected Chemistry content.
6. ICT Treatment: The experimental group received Chemistry teaching supported by suitable ICT resources.
7. Traditional Instruction: The control group studied corresponding Chemistry content through conventional classroom teaching.
8. Post-Test Administration: After completion of instruction, both groups were tested again.
9. Calculation of Gain Scores: The gain score of each student was calculated as Gain Score = Post-Test Score − Pre-Test Score.
10. Statistical Comparison: The achievement scores of both groups were analysed and compared.

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VII. Statistical Techniques

The following statistics were used: mean, standard deviation, gain score, independent-samples t-test, and paired-samples t-test. The level of significance was set at 0.05.

VIII. ANALYSIS AND INTERPRETATION

8.1 Comparison of Pre-Test Achievement

Table 2: Pre-Test Achievement of ICT and Traditional Teaching Groups

Group	N	Mean	SD	t-value	p-value	Decision
ICT-Based Teaching	50	25.40	3.33	1.07	.286	Not Sig.
Traditional Teaching	50	24.64	3.75			

The ICT group obtained a pre-test mean score of 25.40, while the traditional group obtained 24.64 — a difference of only 0.76 marks. The calculated t-value was 1.07 and the p-value was .286, which is greater than .05, so the difference was not statistically significant. Therefore, $H_0 1$ was not rejected. This shows that the two groups had approximately similar Chemistry achievement before the different teaching methods were introduced, providing a reasonable basis for comparing subsequent learning.

8.2 Comparison of Post-Test Achievement

Table 3: Post-Test Achievement of the Two Teaching Groups

Group	N	Mean	SD	Mean Diff.	t-value	p-value
ICT-Based Teaching	50	35.98	3.54			
Traditional Teaching	50	29.78	4.26	6.20	7.91	< .001

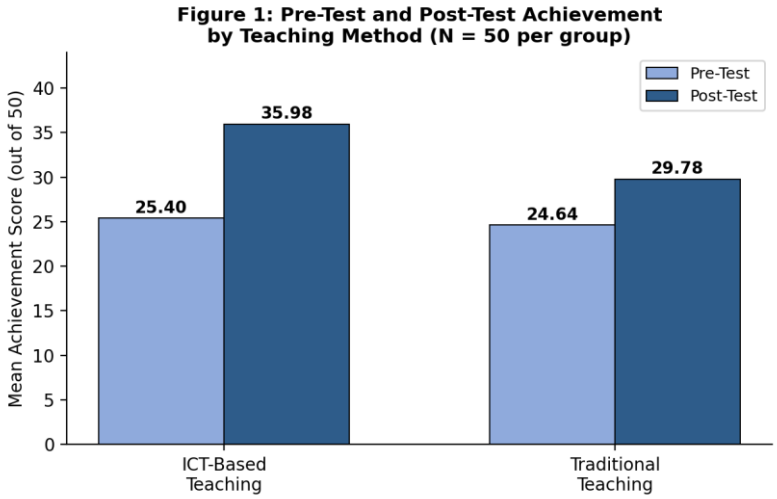

Figure 1: Pre-Test and Post-Test Achievement by Teaching Method

After the instructional period, the ICT-based teaching group obtained a mean achievement score of 35.98, compared with 29.78 for the traditional group — a difference of 6.20 marks in favour of ICT-based teaching. The calculated t-value of 7.91 was statistically significant ($p < .001$), so $H_0 2$ was rejected. Students taught through ICT-based instruction performed significantly better in the Chemistry post-test than students taught through the traditional method.

8.3 Comparison of Gain Scores

Table 4: Gain Scores of ICT-Based and Traditional Teaching Groups

Group	N	Mean Gain	SD	Mean Diff.	t-value	p-value
ICT-Based Teaching	50	10.58	2.47			

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Group	N	Mean Gain	SD	Mean Diff.	t-value	p-value
Traditional Teaching	50	5.14	1.68	5.44	12.89	< .001

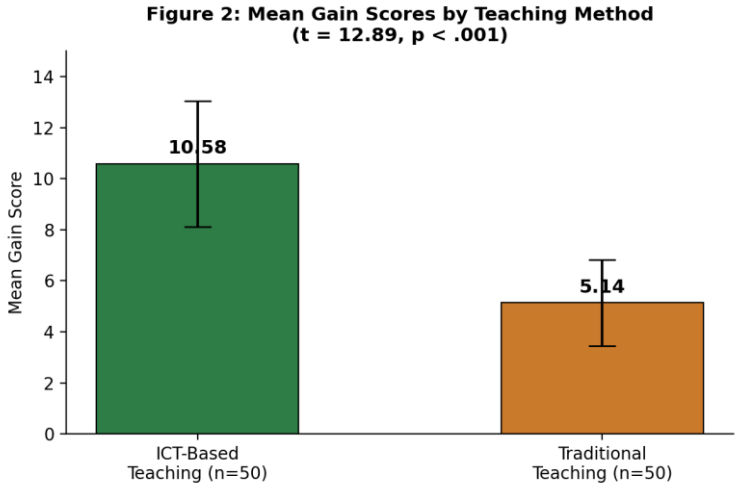

Figure 2: Mean Gain Scores by Teaching Method

Students taught through ICT-based instruction improved by an average of 10.58 marks, compared with 5.14 marks for the traditional group — a difference of 5.44 marks. The calculated t-value was 12.89, significant at the 0.05 level, so H_03 was rejected. This result is stronger evidence than a simple post-test comparison because it accounts for the amount of improvement achieved during instruction.

8.4 Improvement Within Each Group

Table 5: Pre-Test and Post-Test Improvement within the Two Groups

Group	Pre-Test Mean	Post-Test Mean	Mean Gain	Paired t-value	p-value
ICT-Based Teaching	25.40	35.98	10.58	30.33	< .001
Traditional Teaching	24.64	29.78	5.14	21.66	< .001

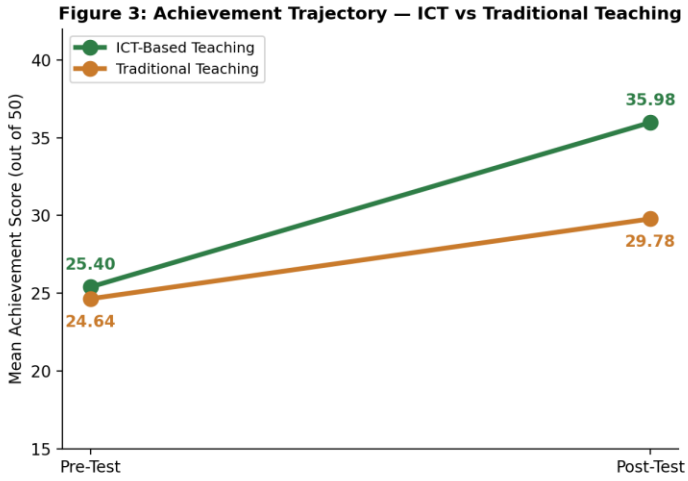

Figure 3: Achievement Trajectory — ICT vs Traditional Teaching

Both groups improved significantly from pre-test to post-test, showing that traditional teaching also supported learning. However, the amount of improvement was clearly different: the ICT group increased by 10.58 marks, whereas the traditional group increased by only 5.14 marks — approximately twice the gain. This indicates that ICT-supported Chemistry instruction was more effective for the sample used in the study.

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IX. RESULTS OF THE STUDY

1. The ICT and traditional groups had almost similar pre-test achievement before instruction.
2. There was no statistically significant difference between their pre-test scores, with $t = 1.07$ and $p = .286$.
3. The ICT-based teaching group obtained a post-test mean of 35.98.
4. The traditional teaching group obtained a lower post-test mean of 29.78.
5. The post-test difference of 6.20 marks was statistically significant.
6. The ICT group obtained a mean gain score of 10.58.
7. The traditional teaching group obtained a mean gain score of 5.14.
8. The difference between the gain scores was statistically significant, $t = 12.89$, $p < .001$.
9. Both ICT-based and traditional instruction improved Chemistry achievement.
10. ICT-based teaching produced substantially greater improvement than traditional teaching.

X. DISCUSSION

The results show that teaching method was associated with a clear difference in students' Chemistry achievement. The most important point is that the two groups did not show a significant difference in the pre-test, so the later difference cannot simply be explained by one group beginning with much stronger students.

After instruction, the performance pattern changed considerably. Students taught through ICT obtained higher achievement and greater gain than students taught through the traditional method. One possible explanation is that Chemistry requires students to move between visible events, scientific symbols, and invisible molecular processes. ICT can make these connections easier through animations, diagrams, virtual demonstrations, and other visual resources.

The results are consistent with Nkemakolam et al. (2018), who found computer simulation more effective than lecture teaching in Chemistry, and agree with recent Indian evidence showing improved achievement under ICT-supported and technology-supported instructional approaches. The present results also correspond with the meta-analysis by Castro (2025), which found a large positive effect of virtual Chemistry laboratories on secondary learners' achievement.

At the same time, the traditional group also improved. Therefore, technology should not be understood as a replacement for the teacher. The better interpretation is that ICT can strengthen good teaching by providing forms of explanation that are difficult to achieve through speech and blackboard work alone.

XI. EDUCATIONAL IMPLICATIONS

1. Chemistry teachers should combine technology with classroom explanation. ICT should be integrated into teaching rather than used as an occasional activity.
2. Visual ICT resources should be used for abstract concepts such as molecular movement, atomic structure, bonding, equilibrium, and reaction mechanisms.
3. Traditional teaching should not be completely removed. Blackboard work, teacher explanation, questioning, and practice remain useful and can be combined with technology.
4. ICT materials should be prepared according to lesson objectives, not simply because they are attractive.
5. Schools should provide basic digital infrastructure — projectors, computers, smart displays, software, and dependable electricity.
6. Teachers should receive practical ICT training focused on specific Chemistry concepts rather than only general computer operation.
7. Virtual resources can support laboratory teaching, particularly where experiments are costly, dangerous, or difficult to perform.
8. Students should remain active during ICT lessons through questioning, prediction, discussion, and problem solving.
9. ICT can be used for revision and reinforcement, showing important processes repeatedly until students understand them.
10. Schools may develop digital Chemistry resource banks, sharing topic-wise animations, presentations, simulations, exercises, and videos.

XII. LIMITATIONS OF THE STUDY

The study was limited to 100 Class XI Chemistry students. Only academic achievement was examined; variables such as interest, motivation, attitude, retention, and scientific reasoning were not included.

The study also used two instructional groups without complete random assignment of individual students. Therefore, it is described as quasi-experimental rather than a true randomized experiment.

The present numerical dataset was prepared as practice/simulated research data, so it should not be reported as genuine field-collected evidence. In an actual research paper, the school, study area, intervention duration, tool development, validity, reliability, permissions, and real student scores should be reported from the completed field study.

XIII. CONCLUSION

The study compared ICT-based and traditional methods of teaching Chemistry among higher secondary students. Both groups demonstrated improvement after instruction, but the improvement was not equal. The ICT group moved from a pre-test mean of 25.40 to a post-test mean of 35.98, giving an average gain of 10.58 marks. The traditional group increased from 24.64 to 29.78, with an average gain of 5.14 marks.

The groups were similar before instruction, but a significant difference appeared after the teaching period. This pattern indicates that ICT-supported teaching provided an additional learning advantage in Chemistry. The findings support an instructional model in which the teacher remains central but uses appropriate digital resources to make Chemistry concepts clearer, more observable, and easier to connect. ICT-based teaching can therefore be considered an effective instructional approach for improving Chemistry achievement among higher secondary students.

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