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IMPACT OF COMPUTER-ASSISTED INSTRUCTION (CAI) ON ACADEMIC ACHIEVEMENT AND KNOWLEDGE RETENTION IN SECONDARY-LEVEL CHEMISTRY

BY
J.IBRAHIM [1], R. SABO[2], M. UMAR [3], Z. DANYARO[4], U.O.YAHAYA[5]

[1]Department of Chemistry,
Faculty of Science,
Confluence University of Science and Technology,
Osara, Kogi State, Nigeria.

Corresponding Author:ibrahimj@custech.edu.ng

[2 & 3]Department of Chemistry,
Faculty of Sciences,
Sule Lamido University,
Jigawa State, Nigeria.

[4]Department of Chemistry, Faculty of Science,
Jigawa State College of Remedial and Advanced Studies,
Babura, Jigawa State, Nigeria.
and
[5]Department of Chemistry,
Faculty of Physical Sciences,
Bayero University Kano, Kano State, Nigeria.

Abstract
The research aimed to explore the impact of computer-assisted instruction (CAI) on the academic performance and retention of secondary school students in Chemistry. The population for this study comprised 46 Senior Secondary School (SSS) II students from First Grade Comprehensive School in Kano. Using a pretest-posttest quasi-experimental design, data were collected to evaluate the effects of different teaching methods on students' performance in chemistry. The sampling method involved random selection of students from the SSS II level. The pretest was administered to establish the baseline knowledge of chemistry among the students. Based on their pretest scores, the participants were divided into two groups: the control group and the experimental group. The experimental group received instruction through Computer-Assisted Instruction (CAI), while the control group received traditional teaching methods. After a six-week period, both groups were assessed using a posttest to measure their performance. A retention test was

conducted two weeks later to assess the long-term impact of the teaching methods. Statistical analysis, including mean, standard deviation, and independent samples t-test via SPSS, along with Pearson's product moment correlation, was conducted. A reliability coefficient of 0.81 indicated test reliability. Hypotheses were tested using t-test statistics at a significance level of $P \leq 0.05$. Results revealed no significant difference between the groups in the pretest, but significant disparities emerged in posttest performance and retention between CAI and traditional instruction groups. Moreover, significant differences were found in students' academic performance across various cognitive domains in the posttest. These findings underscored the positive impact of CAI on students' chemistry performance and retention. Consequently, recommendations include providing schools with computers, educational software, and teacher training to enhance chemistry instruction at the secondary level, emphasizing the use of CAI to enhance student performance and retention in Chemistry.

Keywords: Computer-assisted, instruction, academic performance, retention, chemistry,

Introduction

In recent years, the integration of technology into educational frameworks has experienced a marked ascent, fundamentally reshaping traditional pedagogical methodologies and instructional frameworks (Smith et al., 2023). Central to this technological evolution is the adoption of Computer-Assisted Instruction (CAI), which has garnered considerable attention for its perceived ability to enhance academic performance and bolster knowledge retention, particularly within the domain of secondary-level Chemistry (Smith et al., 2023). As educators navigate the dynamic terrain of an evolving educational landscape, understanding the implications of CAI on student learning outcomes emerges as an imperative concern (Jone and Wang, 2022). The burgeoning body of literature accentuates the transformative potential of CAI in reshaping educational practices and pedagogical strategies (Yeşilyurt, 2011; Bakaç et al., 2011; Kayri et al., 2012; Danjuma, 2015). By leveraging digital tools and interactive platforms, CAI seeks to foster deeper student engagement, cultivate conceptual comprehension, and enhance the long-term retention of subject matter (Garcia & Hernandez, 2021). Recent research illuminates the diverse benefits of CAI interventions, elucidating their role in augmenting student motivation, facilitating active learning, and fostering critical thinking skills. Such insights underscore the significance of exploring the intricate interplay between CAI and academic achievement, especially within the context of secondary-level Chemistry education (Smith et al., 2023). Moreover, the relentless march of technological innovation has precipitated the emergence of sophisticated

CAI platforms and software applications tailored to the specific exigencies of Chemistry instruction. These platforms harness multimedia elements, interactive simulations, and adaptive algorithms to deliver personalized learning experiences that cater to the diverse needs and preferences of students. By offering real-time feedback, scaffolding learning activities, and nurturing metacognitive awareness, CAI platforms empower students to navigate their learning trajectories with autonomy and effectiveness (Jones & Wang, 2022).

However, amidst the burgeoning optimism surrounding the potential of CAI, critical challenges and considerations necessitate careful examination. Issues related to digital equity, equitable access to technology, and teacher readiness loom large as potential obstacles to the widespread adoption and equitable integration of CAI in secondary-level Chemistry education. Furthermore, inquiries into the efficacy of CAI in accommodating diverse learning modalities and addressing the needs of marginalized student populations require nuanced exploration and deliberation (Garcia & Hernandez, 2021). Against this backdrop, this study seeks to contribute empirically grounded insights into the nexus between CAI, academic achievement, and knowledge retention in secondary-level Chemistry education. By employing robust research methodologies and drawing upon recent advancements in educational technology and instructional design, this study aims to elucidate the multifaceted implications of CAI on student learning outcomes. Ultimately, the findings of this study hold the potential to inform educational policy, shape instructional practices, and promote equitable access to high-quality educational experiences in the digital era.

Statement of the problem

The effectiveness of Computer-Assisted Instruction (CAI) in improving academic achievement and enhancing knowledge retention in secondary-level chemistry remains a topic of significant interest and debate. While CAI offers interactive and engaging learning experiences, its impact on student performance and long-term retention of knowledge in chemistry is not yet fully understood. This study seeks to investigate the impact of CAI on academic achievement and knowledge retention in secondary-level chemistry, aiming to provide valuable insights for educators and policymakers seeking to enhance teaching methodologies and improve student learning outcomes in the field of chemistry.

Objectives of the study

1. To investigate the impacts of CAI on secondary-level students' academic performance in Chemistry.

2. To ascertain effects of CAI on students' academic performance across various cognitive domains, including knowledge, comprehension, application, analysis, synthesis, and evaluation, in secondary-level Chemistry.
3. To determine the effects of CAI on secondary-level students' retention capacity in chemistry.

Research questions

1. What is the effect of Computer-Assisted Instruction (CAI) on the academic achievement of secondary-level chemistry students compared to traditional teaching methods?
2. How does Computer-Assisted Instruction (CAI) influence knowledge retention in secondary-level chemistry students over time?
3. How does CAI impact the development of higher-order thinking skills in secondary-level chemistry students compared to traditional teaching methods?
4. How does the duration and frequency of CAI usage impact academic achievement and knowledge retention in secondary-level chemistry students?
5. Are there significant differences in academic performance between students taught using CAI and those taught using traditional instructional methods in secondary-level chemistry?

Research hypotheses

H01: There is no significant difference in the performance of students taught Chemistry using CAI and those taught using conventional method.

H02: There is a significant difference in the post-test academic performance between students who receive instruction through Computer-Assisted Instruction (CAI) and those who are taught using traditional teaching methods.

H03: There are no significant differences in post-test academic performance across various cognitive domains (knowledge, comprehension, application, analysis, synthesis, and evaluation) between students in the experimental group and those in the control group.

H04: Significant differences exist in retention capacity between students who receive instruction through Computer-Assisted Instruction (CAI) and those taught using traditional teaching methods, as measured by the retention test.

Methodology

The study encompassed all secondary school students enrolled in private secondary schools within Kano Municipal. Utilizing a simple random sampling technique, a sample of 46 SSS II students was selected from First Grade Comprehensive School, Kano. Homogeneity across various characteristics such as age, gender, locality, socioeconomic status, etc., was ensured among the participants. Based on the outcomes of a pretest gauging their prior knowledge of chemistry, participants were stratified into control and experimental groups. The present study adopts an experimental approach aimed at investigating the impact of computer-assisted instruction on students' academic performance in Chemistry. Given its experimental nature, a "Pretest-Posttest Quasi Experimental Design" was employed to achieve the desired outcomes. The research instrument utilized was the Chemistry Achievement Test, designed to encompass six levels of cognitive domains: knowledge, comprehension, application, analysis, synthesis, and evaluation. This test was structured around four units of Chemistry covered during the experiment, namely: Matter and its constituents; Structure of an Atom, Periodic Table, and Chemical Families. The Chemistry Achievement Test comprised a total of 60 multiple-choice questions (MCQs), with a total score of 120 marks. Each cognitive domain consisted of 10 MCQs. Following slight modifications in item sequencing, the same Chemistry Achievement Test served as the retention test. Ensuring the validity and reliability of the research instrument is essential to yield accurate and authentic study outcomes. Without establishing the validity and reliability of the instrument, conducting research becomes futile and time-consuming. Therefore, following the development of the achievement test, rigorous validation procedures were undertaken by experts holding doctoral degrees in the relevant field, encompassing criterion validity, content validity, and construct validity. In addition to validity, reliability was assessed using the test-retest reliability technique. To this end, the test was administered to 25 students from other schools not included in the sample. Subsequently, the same test was re-administered to the same group of students after a two-week interval. Pearson's product-moment correlation was employed to analyze the results of the tests. The resulting reliability coefficient was determined to be 0.81, indicating the test's reliability. As the study adopted an experimental approach, data collection involved the administration of pretests, posttests, and retention tests. Subsequently, the collected data underwent meticulous organization, classification, tabulation, analysis, and interpretation using both descriptive statistics (e.g., mean, standard deviation) and inferential statistics (e.g., independent samples t-test) through SPSS. Additionally, the findings were visually presented through graphical representations to enhance reader comprehension. To ensure the smooth execution of the experiment, two teachers with comparable academic qualifications and experience were appointed. The teacher assigned to the experimental group possessed expertise in the application of computers and other information and communication technologies, holding a Diploma in Information Technology (DIT). Prior to commencing the study, formal approval was obtained from the school's head where the experiment was conducted. Following approval, the experimental process commenced with the administration of pretests. While students in the control group received instruction through conventional teaching methods, those in the experimental group were taught using computer-assisted instruction. The experimental phase spanned six weeks, after which posttests were administered to both groups to assess academic achievement. Subsequently, after a two-week interval, the same posttest, with slight sequential modifications to the items, was administered to both groups as a retention test. Upon completion of the experimental phase, raw data underwent organization, tabulation, and analysis using statistical tools such as mean, standard deviation, and independent samples t-test.

Results

$H0_1$: There exists no significant difference in the academic performance between students belonging to the control and experimental groups on the pre-test.

Table 1

Independent-Samples t-test Analysis of the Performance of Experimental & Control Groups on Pretest

Groups	N	Mean	St. Dev.	SEd	Mean Diff:	t-value	p-value
Control	23	71.62	4.93				
Experimental	23	71.51	4.73	1.42	0.11	0.077	0.939

The inferential analysis of table 1 reveals that there is no significant ($p > 0.05$) difference between the performance of the experimental and control groups on the pretest, as the calculated t-value is smaller than the tabulated t-value at 0.05. Furthermore, the mean values clearly indicate that the experimental group (mean = 71.51, SD = 4.73) exhibited slightly superior performance compared to the control group (mean = 71.62, SD = 4.93). Hence, the null hypothesis was upheld.

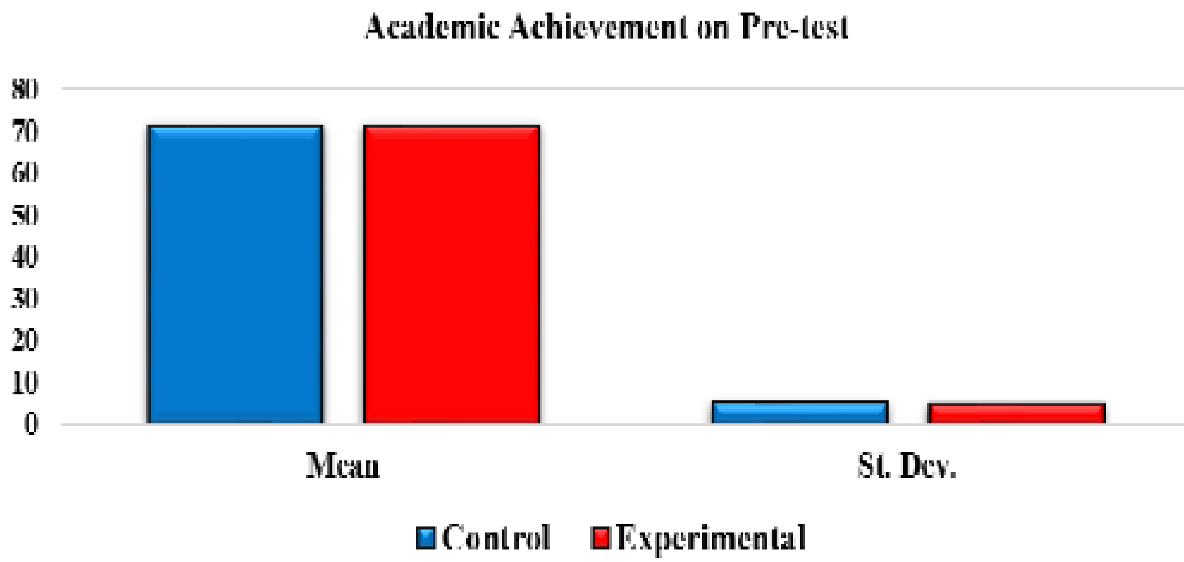

Fig. 01: Showing the academic achievement of control and experimental groups on pretest.

H0₂: A notable contrast exists in the academic achievements of students instructed via CAI compared to those instructed via traditional methods on the posttest.

Table 2

Independent-Samples T-test Analysis of the Achievement Scores of Experimental and Control Groups on Posttest

Groups	n	Mean	St. Dev.	SEd	Mean Diff:	t-value	p-value
Control	23	74.39	9.83				
Experimental	23	98.09	6.56	2.46	23.70	-9.618	0.000

The findings from Table 2 indicate a significant ($p<0.05$) distinction in achievement between the experimental and control groups on the posttest, as evidenced by the calculated t-value exceeding the tabulated t-value at the 0.05 significance level. Additionally, the mean values unequivocally illustrate that the experimental group (mean=98.09, SD=6.56) exhibited superior performance compared to the control group (mean=74.39, SD=9.83). Consequently, the null hypothesis was upheld.

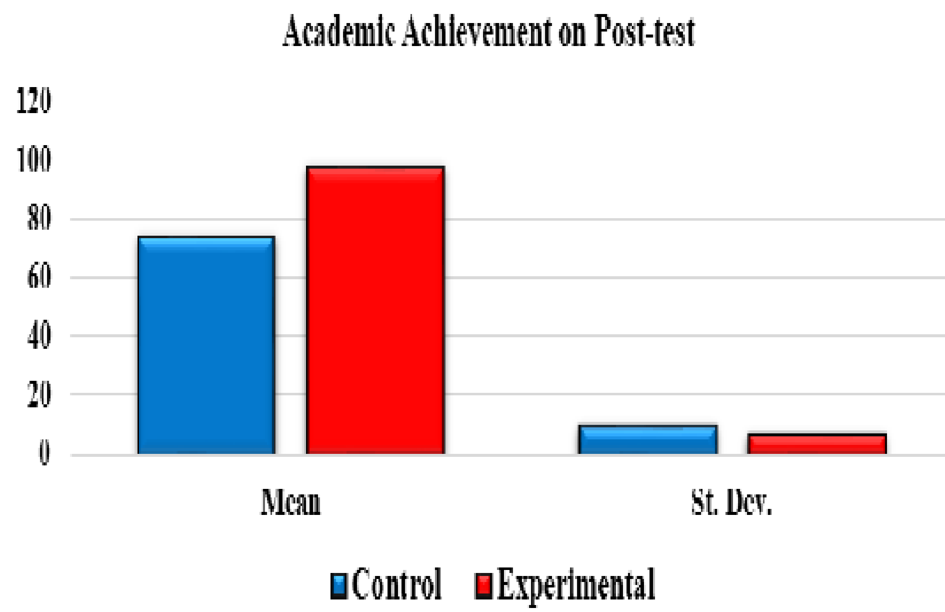

Fig. 02: Showing the academic achievement of control and experimental groups on posttest.

H0₃: There are no notable variances in the academic performance of students between the experimental and control groups across various levels of cognitive domains, namely knowledge, comprehension, application, analysis, synthesis, and evaluation, on the post-test.

Table 3

Inferential Examination of Academic Performance among Students in Experimental and Control Groups Across Various Levels of Cognitive Domains

Levels of Cognitive Domain	Control	Group	Experimental	Group		
	Mean	SD	Mean	SD	t-value	p-value
Knowledge	15.38	7.21	16.03	5.67	-0.340	0.736
Comprehension	11.84	7.23	16.08	6.37	-2.110*	0.041
Application	12.81	6.81	17.23	5.39	-2.441*	0.019
Analysis	10.55	6.96	15.07	5.74	-2.403*	0.067
Synthesis	10.83	7.34	15.85	5.64	-2.601*	0.013
Evaluation	12.98	4.39	17.83	4.98	-3.504*	0.001

Table 3 illustrates that the calculated t-values across five levels were noted as -

2.110, -2.441, -2.403, 2.601, and -3.504, all of which are significant ($p<0.05$) as they surpass the tabulated t-value at 0.05. Consequently, the null hypothesis was dismissed. The mean values distinctly indicate a significant difference between the performance of the control (mean=11.84, 12.81, 10.55, 10.83, and 12.98) and experimental (mean=16.08, 17.23, 15.07, 15.85, and 17.83) groups across five levels of cognitive domains: comprehension, application, analysis, synthesis, and evaluation, respectively, on the post-test. Therefore, it was concluded that students in the experimental group demonstrated superior performance in these five levels of cognitive domains compared to those in the control group. Conversely, no significant difference was observed in the academic achievement between the control and experimental groups concerning knowledge.

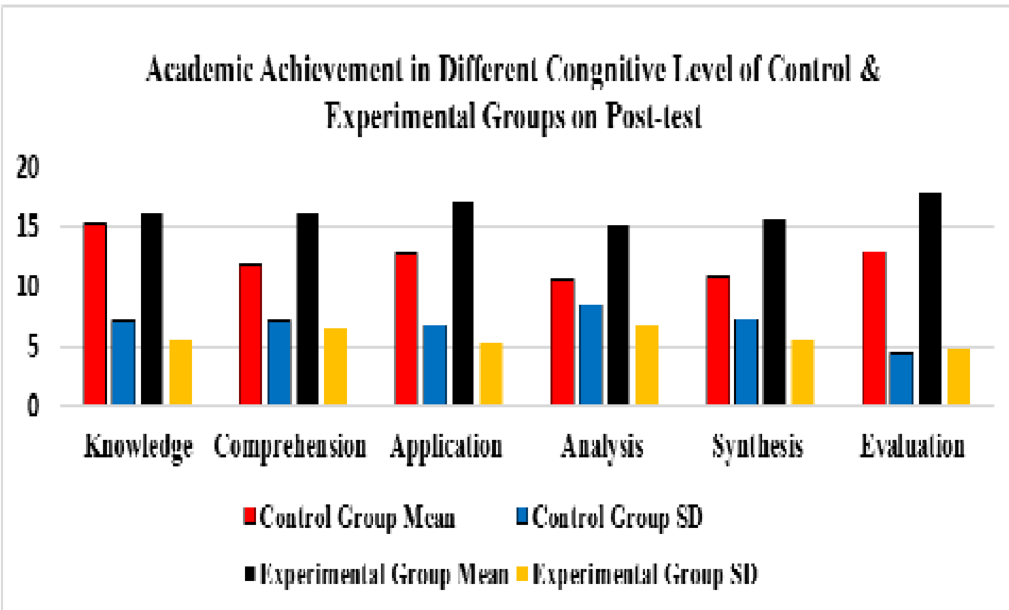

Figure 03: Depicting the academic performance of control and experimental groups across various levels of cognitive domains on the posttest.

$H0_4$: There exists a notable contrast in the retention rates of students instructed via CAI compared to those instructed via traditional methods on the retention test.

Table 4
Analysis of the Achievement of Experimental and Control Groups on Retention Test via Independent-Samples t-test

Groups	n	Mean	St. Dev.	SEd	Mean Diff:	t-value	p-value
Control	23	70.21	8.73				
Experimental	23	96.87	6.49	2.27	26.66	-11.75	0.000

*Significant df = 44 Value of t at 0.05 = 2.0154

According to the inferential analysis, Table 4 reveals a notable ($p<0.05$) distinction in the achievement levels between the experimental and control groups on the retention test, with the calculated t-value surpassing the tabulated t-value at 0.05 significance level. Moreover, the mean values distinctly demonstrate that the experimental group (mean=96.87, SD=6.49) exhibited superior performance compared to the control group (mean=70.21, SD=8.73). Consequently, the null hypothesis was accepted.

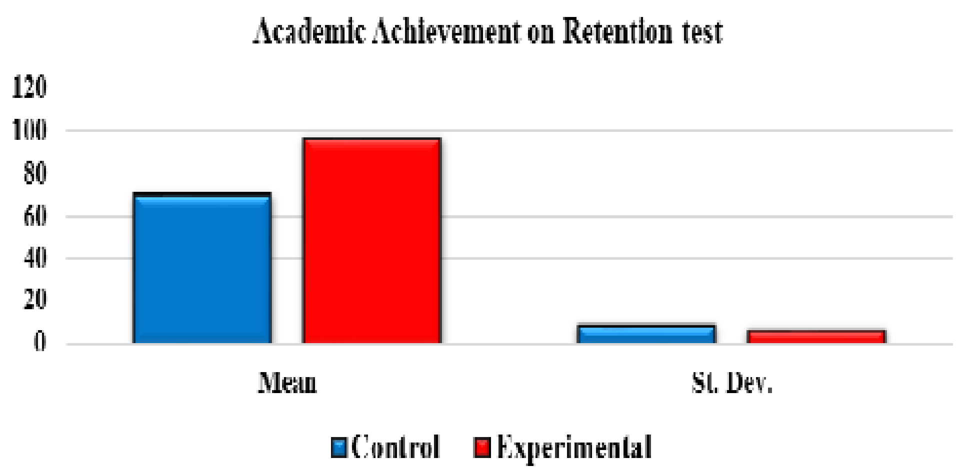

Figure 4 displays the academic performance of both the control and experimental groups on the retention test.

Discussion

The research aimed to investigate the impact of Computer-Assisted Instruction (CAI) on secondary-level students' academic achievement and retention in Chemistry. Employing a quantitative and experimental approach, the study utilized a pretest-posttest quasi-experimental design. Students were divided into two groups and accommodated in similar settings with equivalent facilities. The experimental group received instruction through CAI, benefiting from computers, multimedia, and related devices, while the control group underwent traditional teaching methods. This experimental phase lasted six weeks. Following the intervention, both groups underwent posttests and retention tests to evaluate and compare their academic progress.Results revealed that students in the experimental group exhibited higher levels of cognitive development, performance, and retention compared to their counterparts in the control group. Additionally, students in the experimental group displayed greater interest, enthusiasm, satisfaction, and participation, contrasting with the reported exhaustion and boredom experienced by students in the control group. These findings suggest that CAI represents an effective and successful approach in enhancing students' academic performance and retention in Chemistry, leading to elevated scores.

Through inferential analysis of the academic performance of experimental and control groups across various levels of cognitive domains on the post-test, the study unveiled that students in the experimental group demonstrated superior performance compared to those in the control group across five cognitive domains: comprehension, application, analysis, synthesis, and evaluation. However, no significant difference was observed in terms of knowledge acquisition between the two groups. This underscores the effectiveness of computer-assisted instruction across diverse cognitive domains. Similarly, concerning the retention test, students in the experimental group exhibited notably higher academic achievement and retained learning for a longer duration compared to their counterparts in the control group. The findings of this study align with those of Bayrak (2008) and Yesilyurt (2011), indicating that CAI significantly outperformed traditional teaching methods in enhancing learners' achievement in physics. Furthermore, they resonate with numerous recent research findings, including those of Azar and Sengulec (2011), Bakac et al. (2011), Kayri et al. (2012), Kocakaya (2010), Pondhe (2011), Yigit (2005), Danjuma (2015) and Ankara.Kareem(2015) which highlight the positive impact of CAI on learners' perceptions of computer-supported instruction and their academic success.

Conclusion

The results highlighted the significantly positive impact of computer-assisted instruction (CAI) on students' academic performance and retention in Chemistry. CAI proved to be more effective and successful than traditional teaching methods in the realm of Chemistry education, particularly across various cognitive domains. Additionally, CAI demonstrated greater efficacy in facilitating retention among students compared to traditional methods, and it was particularly effective in elucidating challenging concepts in Chemistry.

Recommendations

As a result, it is recommended that:

1. Science educators, especially those teaching chemistry, embrace the CAI approach over traditional methods.
2. All science instructors should receive specialized training to effectively integrate computers and other technologies into chemistry instruction.
3. Prioritizing the provision of computers, multimedia, and related devices to all secondary schools is also advised to facilitate the widespread implementation of CAI.

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