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Bridging Traditional And Digital: Effects of Technology-Supported Instruction on Grade 9 Students' Performance in Chemical Bonding

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ABSTRACT

This study examined the effects of traditional and technology-supported instruction on the academic performance of Grade 9 students in Chemical Bonding. Specifically, it sought to: (1) determine the academic performance of students taught using traditional and technology-supported lessons; (2) identify whether a significant difference exists between the two instructional approaches; and (3) assess the effectiveness of technology-supported instruction in improving students' conceptual understanding. The research employed a quantitative quasi-experimental pretest–posttest control group design in a private secondary school during the 2025–2026 academic year. Two comparable Grade 9 sections (n = 50) were selected through purposive sampling: one received traditional lecture-based instruction, while the other was taught using technology-supported lessons such as simulations, animations, and multimedia. Data were gathered through a validated 30-item achievement test, and the results were analyzed using descriptive statistics, independent samples t-tests, and paired samples t-tests.

Findings showed that both groups began with nearly identical pretest scores (Traditional = 11.56; TSI = 11.48) and both improved after instruction. The technology-supported group obtained a slightly higher posttest mean (13.28) compared to the traditional group (12.96). Despite this slight advantage, the independent samples t-test revealed no statistically significant difference in academic performance between the two groups in both pretest ($p = .934$) and posttest ($p = .798$), indicating comparable effectiveness of the instructional approaches.

Within the technology-supported group, the paired t-test revealed a modest increase of 1.80 points from the pretest to the posttest; however, this gain was not statistically significant ($p = .102$) and yielded a small effect size ($d = 0.34$). These results suggest that while technology-supported instruction led to slight improvement in conceptual understanding, the impact was limited. Overall, both traditional and technology-supported instruction improved student performance; however, neither approach demonstrated a statistically significant advantage.

Keywords: academic performance,technology-supported instruction, traditional teaching, Chemical Bonding

INTRODUCTION

Teaching Chemical Bonding poses a significant challenge in secondary science education due to its abstract and microscopic nature. Students often struggle to visualize atomic interactions, electron sharing, and ionic formation, leading to misconceptions and lower achievement levels in chemistry. As classrooms evolve into hybrid learning environments, educators are increasingly exploring ways to combine traditional teaching methods with modern technology to enhance conceptual understanding.

According to Mayer's (2017) Cognitive Theory of Multimedia Learning, the integration of text, audio, and visuals promotes deeper learning by engaging both visual and auditory channels. In science education, technology-supported instruction—through simulations, animations, and interactive tools—helps learners visualize atomic structures and bonding processes that are otherwise invisible to the naked eye. This integration creates meaningful connections between theory and experience, aligning with constructivist principles that promote active learning.

However, despite the benefits of technology integration, many schools, especially in developing contexts, continue to rely on traditional, teacher-centered methods due to limited access to digital resources and teacher training. Therefore, the concept of bridging traditional and digital approaches emphasizes a balanced model—where teachers retain the strengths of traditional instruction while enhancing it with technological tools to support visualization, interactivity, and engagement.

This study aims to investigate the impact of technology-supported science lessons on students' achievement in Chemical Bonding. By comparing the outcomes of traditional and technology-integrated instruction, this research seeks to provide empirical evidence on how digital tools enhance understanding of abstract chemistry concepts.

While numerous studies highlight the advantages of digital learning tools in science education, there is limited empirical evidence on their effectiveness specifically in teaching Chemical Bonding—a topic known for its abstractness and difficulty among secondary students. Existing research primarily focuses on general chemistry instruction or conceptual learning in advanced contexts, overlooking the integration of traditional and digital methods in typical high school settings, particularly in developing countries. Hence, this study bridges that gap by examining how a hybrid instructional approach influences student achievement in Chemical Bonding compared to purely traditional methods.

Research Objectives

1. What is the academic performance of Grade 9 students taught using traditional and technology-supported lessons in Chemical Bonding?
2. Is there a significant difference in Academic Performance between students exposed to the two instructional approaches?
3. What is the effectiveness of technology-supported instruction in improving conceptual understanding of Chemical Bonding?

Hypothesis

Ho: There is no significant difference between the pretest and posttest scores of students taught using traditional instruction and those taught using technology-supported lessons.

METHODOLOGY

Research Design

This study will employ a quantitative quasi-experimental design utilizing a pretest-posttest control group approach. Two groups of Grade 9 students will be selected: one will receive traditional instruction (the control group), while the other will receive technology-supported instruction (the experimental group). Both groups will take the same pretest and posttest to measure learning gains.

Before the conduct of the study, permission to carry out the research was formally requested and approved by the school principal. The purpose, procedures, and duration of the study were clearly explained to the school administration.

Since the participants were Grade 9 students, parental consent was obtained through a written permission letter, and the students were informed about the study in simple and age-appropriate language. Participation in the study was voluntary, and students were assured that they could withdraw at any point without any academic consequences.

To ensure confidentiality, students' names were not recorded in any research instrument. Codes were used instead, and all collected data were kept confidential and used only for academic research purposes.

Participants and Sampling

The participants of the study will consist of 50 Grade 9 students enrolled in a private secondary school during the 2025–2026 academic year. Purposive sampling will be employed to select two intact and comparable Grade 9 sections with similar academic backgrounds to ensure group equivalence. The total sample size is fixed at 50 students, determined by the actual class sizes of the selected sections and the requirements of the quasi-experimental design. Control Group (n = 25): Students will receive instruction using the traditional lecture–discussion method with chalkboard explanations. Experimental Group (n = 25): Students will receive instruction using the proposed instructional intervention.

Research Instrument

A 30-item multiple-choice achievement test on Chemical Bonding will be developed based on the Department of Education's K–12 curriculum guide guided with the Table of Specification (TOS). The instrument will undergo content validation by three science teachers and one subject matter expert. The test items assessed students' understanding of ionic and covalent bonding, molecular polarity, and the properties of compounds. The reliability coefficient was found to be 0.87, indicating high internal consistency.

Data Gathering Procedure

The data collection process began with the administration of a pretest to both the control and experimental groups to determine their baseline knowledge of Chemical Bonding. Following this, the intervention phase was carried out: the control group received instruction through the traditional lecture-discussion method, while the experimental group was taught using technology-supported lessons that included simulations, digital visualizations, and interactive quizzes designed to enhance conceptual understanding. After the instructional period, both groups completed the same posttest to measure learning gains and compare performance across the two approaches. All test responses were checked, validated, and scored The data were then analyzed using descriptive statistics (mean and standard deviation) to summarize student performance, and an independent samples t-test to determine whether there was a significant difference in achievement between the control and experimental groups, thereby evaluating the effectiveness of the instructional methods.

RESULTS

1. What is the academic performance of Grade 9 students taught using traditional and technology-supported lessons in Chemical Bonding?

Table 1. Students' Academic Performance using traditional and technology-supported lessons in Chemical Bonding

Group	N	Pretest		Posttest	
		Mean	SD	Mean	SD
Traditional	25	11.56	3.50095	12.9600	4.24735
Technology Supported Instruction	25	11.48	3.33067	13.28	4.54166

Table 1 presents the mean pretest and posttest scores of both groups, which serve as the basis for analyzing and interpreting their academic performance before and after the instructional interventions.

The results show that both groups started at almost the same level in the pretest, with mean scores of 11.56 for the Traditional group and 11.48 for the TSI group. Following the intervention, both groups showed improvement. The Traditional group increased to 12.96**,** while the Technology-Supported Instruction group increased to 13.28**.** Although both approaches resulted in improved performance, the TSI group displayed a slightly higher posttest mean compared to the Traditional group.

Both groups also show increased variability in the posttest, as reflected by slightly higher standard deviations, indicating differences in the degree of improvement among learners.

The findings suggest that traditional teaching and technology-supported instruction are both effective in enhancing students' academic performance in Chemical Bonding. However, the slightly higher posttest mean of the TSI group indicates that students who were taught using interactive, technology-based activities may have benefited more in terms of conceptual understanding and engagement. The closer similarity of pretest scores indicates that the two groups were initially comparable; however, the TSI group demonstrated somewhat greater improvement after the intervention.

The results align with several studies highlighting the benefits of integrating technology into science instruction. According to Srisawasdi&Panjaburee (2015)**,** technology-based learning environments enhance the visualization of abstract concepts, such as chemical bonding, leading to improved conceptual understanding. This supports the present study's finding that the TSI group achieved slightly higher performance.

Similarly, Chiu & Wu (2009) reported that digital simulations and interactive models help students overcome common misconceptions in chemical bonding, which may explain the improved scores of the TSI group in this research.

Studies by Lim and Kim (2016) also showed that students exposed to technology-supported lessons demonstrated higher motivation, which often translates to better academic performance.

However, the results do not contradict research supporting traditional instruction. Sesen and Tarhan (2010**)** found that well-delivered traditional instruction can still produce substantial learning gains, which is consistent with the noticeable improvement of the traditional group in this study.

In summary, the literature suggests that while both instructional methods can be effective, technology-supported instruction tends to offer additional benefits, especially for topics requiring visualization of microscopic or abstract processes—such as Chemical Bonding. This supports the slightly higher improvement observed in the TSI group compared to the traditional group.

2. Is there a significant difference in academic performance between students exposed to the two instructional approaches?

Table 2. Difference in Academic Performance Between Students Exposed to the Two Instructional Approaches

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Pretest	Equal variances assumed	.005	.944	.083	48	.934	.08000	.96644	-1.86315	2.02315

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	Equal variances not assumed			.083	47.881	.934	.08000	.96644	-1.86328	2.02328
Posttest	Equal variances assumed	.274	.603	-.257	48	.798	-.32000	1.24365	-2.82053	2.18053
	Equal variances not assumed			-.257	47.786	.798	-.32000	1.24365	-2.82082	2.18082

Table 2 displays the results of the independent samples t-test conducted to determine whether students taught using traditional instruction and technology-supported instruction differed significantly in their academic performance. The table includes the results for both pretest and posttest scores, along with Levene's Test for equality of variances.

For the pretest, Levene's Test shows a significance value of .944**,** indicating equal variances. The corresponding t-test reveals t(48) = .083**,** *p* = .934**,** and a mean difference of .080**,** suggesting no statistically significant difference between the two groups before instruction.

For the posttest**,** equality of variances was again observed (Levene's Sig. = .603). The t-test result shows t(48) = –0.257, p = 0.798, with a mean difference of –0.320, also indicating no significant difference in academic performance between the traditional and technology-supported instruction groups after the intervention.

Overall, both groups performed similarly in both pretest and posttest assessments.

Based on the results, the p-values for both the pretest (.934) and posttest (.798) are greater than 0.05**,** indicating no statistically significant difference between the two instructional approaches.

Therefore, the null hypothesis (Ho) is accepted.

This means that there is no significant difference between the pretest and posttest scores of students taught using traditional instruction and those taught using technology-supported lessons.

Although the technology-supported group had a slightly higher posttest mean score, the difference was not large enough to be considered statistically meaningful. This suggests that both teaching approaches were similarly effective in improving the students' academic performance.

The findings align with research showing that both traditional and technology-supported instruction can produce comparable learning outcomes. Sesen and Tarhan (2010) noted that well-structured traditional instruction can effectively support student understanding in chemistry topics, which supports the non-significant difference observed in this study.

On the other hand, studies like Srisawasdi&Panjaburee (2015) and Chiu & Wu (2009) reported that technology-supported environments enhance visualization and engagement, often leading to improved performance. However, these studies also highlight that the effectiveness of technology depends on factors such as duration of exposure, student readiness, and teacher facilitation. This may explain why the technology-supported group in the current study—though slightly higher in mean score—did not show a statistically significant advantage.

The similarity between the findings of this study and those from previous research suggests that both methods can be effective, but neither is guaranteed to produce significantly higher achievement unless supported by enhanced instructional design, prolonged exposure, or deeper integration of technology.

3. The effectiveness of technology-supported instruction in improving conceptual understanding of Chemical Bonding

Table 3. Effectiveness of Technology-Supported Instruction in Improving Conceptual Understanding of Chemical Bonding

Measure	**Mean**	**SD**	**SE**	**t**	**df**	**p-value**	**Mean Difference**	**Effect Size (Cohen's d)**
Pretest (TSI)	11.48	3.33	0.67					
Posttest (TSI)	13.28	4.54	0.91	–1.701	24	0.102	–1.80	0.34 (Small)

Table 3 displays the paired samples results for students exposed to technology-supported instruction. It includes the pretest and posttest mean scores, standard deviations, and the corresponding paired t-test indicators such as the t-value, degrees of freedom, significance level, mean difference, and effect size. These values demonstrate the extent of learning gains achieved after implementing technology-based lessons.

The table shows that the pretest mean score of 11.48 increased to 13.28 in the posttest, indicating an improvement of 1.80 points. Although there was an increase in the mean, the standard deviation also rose from 3.33 to 4.54, signifying that students' posttest performance varied more widely.

The paired samples t-test produced a t-value of 1.701 with a p-value of 0.102, which is greater than the 0.05 significance level. This means that the increase in scores, while present, is not statistically significant. Additionally, the effect size (Cohen's d = 0.34) is categorized as small, suggesting that the improvement had a limited magnitude.

The results indicate that technology-supported instruction led to slight improvement in students' conceptual understanding of Chemical Bonding. However, the improvement was not statistically significant, implying that the observed gains might not be strong enough to conclude that the technology-based lessons produced a measurable impact. The small effect size supports this interpretation, showing that although the strategy helped some students, the overall effect was modest.

This suggests that while technology provides interactive tools and visualizations, its effectiveness depends on additional factors, such as the duration of exposure, student readiness, the quality of activities, and teacher facilitation.

The findings of this study align with mixed results found in existing literature. For example, Srisawasdi&Panjaburee (2015) and Chiu & Wu (2009) found that technology-supported instruction improves students' understanding of abstract chemistry concepts, particularly through simulations and visual models. These studies support the slight improvement shown in the current data.

However, these researchers also emphasized that the effectiveness of technology depends on how deeply students engage with digital tools. Short exposure or limited interaction may result in minimal gains—similar to the small effect size observed in this study.

Additionally, Lim and Kim (2016) highlighted that technology enhances motivation but does not always guarantee significant cognitive improvement unless paired with strong pedagogy. This aligns with the findings here, where motivation may have increased but the statistical improvement remained modest.

On the other hand, traditional instructional research, such as that of Sesen and Tarhan (2010), shows that well-structured teacher-led approaches can produce meaningful learning even without the use of technology. This suggests that the small effect observed in this study may be due to the technology not being fully maximized or integrated.

Overall, the literature suggests that technology-supported instruction has potential, but its impact varies depending on the quality of implementation—similar to the slight but positive improvement observed in this study.

CONCLUSION AND RECOMMENDATIONS

Conclusions

Both traditional and technology-supported instruction enhanced students' academic performance in Chemical Bonding. However, although the TSI group showed a slightly higher mean gain, the improvements in both groups indicate that the two approaches were similarly effective in promoting learning. Moreover, the results of the independent samples t-test showed no significant difference between the academic performance of students taught traditionally and those taught using technology-supported lessons, thereby indicating that both instructional methods performed equally well within the duration and structure of the intervention. In addition, while the technology-supported instruction produced slight improvements in conceptual understanding, these gains were not statistically significant and were accompanied by a small effect size. Consequently, the overall impact of technology integration was modest under the study's conditions, despite the slight numerical advantage shown by the TSI group.

Recommendations

1. Teachers may consider blending traditional explanations with occasional technological tools to enrich visualization of abstract concepts.

2. School administrators are encouraged to explore flexible integration of digital resources to support both traditional and technology-enhanced lessons.

3. Students may be encouraged to use interactive chemistry applications to reinforce lessons outside class time.

4. Curriculum planners may consider including optional digital supplements in science modules to complement existing instructional strategies.

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