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Macromedia Flash 8: Learning Media to Enhance Students' Understanding of Chemical Bonding

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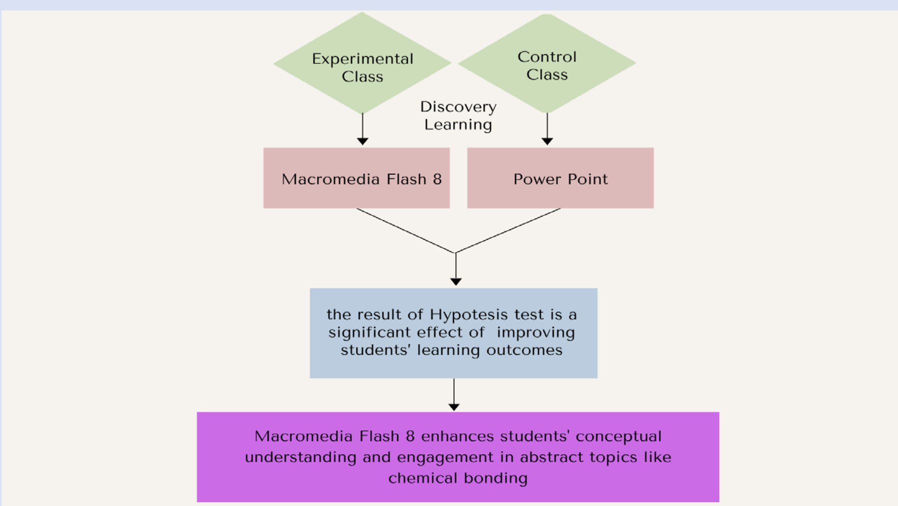
Abstract

This study aims to examine the effect of Macromedia Flash 8-based learning media on students' learning outcomes in the topic of chemical bonding. The research employed a quasi-experimental design with a pretest-posttest control group, involving two randomly selected classes from a public secondary school in Medan. The experimental class was taught using interactive media developed with Macromedia Flash 8, while the control class received instruction using conventional PowerPoint-based methods. Both classes were instructed using the Discovery Learning model to ensure consistency in pedagogy. A multiple-choice test served as the research instrument and was administered to both groups as a pretest and a posttest. The collected data were analyzed using normality and homogeneity tests, N-Gain calculations, and a one-tailed t-test to determine statistical significance. The results indicated a significant improvement in students' learning outcomes in the experimental class compared to the control class, based on the N-Gain value (0.64) compared to the control class (0.56). These findings suggest that using Macromedia Flash 8 enhances students' conceptual understanding and engagement, particularly in abstract topics such as chemical bonding. The interactive animations and visual elements embedded in the media helped bridge the gap between microscopic chemical representations and student comprehension. Therefore, integrating multimedia learning tools in chemistry instruction can contribute to more effective teaching and improved student performance.

Graphical Abstract



Keywords:

Macromedia Flash 8; Chemical Bonds; Learning Media

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Introduction

In recent years, the integration of multimedia into the learning process has become an essential aspect of effective teaching. Among various multimedia tools, Macromedia Flash 8 stands out as a program that produces interactive animations and visual presentations, enhancing student engagement (Taher & Bentri, 2024; Varadila et al., 2023). It allows educators to present learning content in the form of moving text, images, and analogies, which are especially beneficial in subjects like chemistry that involve abstract concepts (Sari & Yenti, 2022; Al-Muqtafa, 2019). The visual and interactive nature of Macromedia Flash 8 makes it a powerful medium for conveying complex scientific ideas in a more comprehensible and engaging way (Izzati et al., 2022; Nasution et al., 2022).

However, in real classroom settings, particularly in chemistry instruction, many teachers continue to depend heavily on traditional methods such as lectures and textbooks (Ayittey et al., 2023;Titilade Adewumi et al., 2024). These teacher-centered approaches often overlook students' diverse learning styles and do not meet their intrinsic motivational needs, resulting in passive learning and low academic performance (Demelash et al., 2024). Research indicates that chemistry, as an abstract and complex subject, requires active engagement through multimodal strategies, yet traditional methods dominate due to factors like curriculum constraints, limited teacher training in innovative pedagogies, and institutional resistance to change (Oladejo, 2022). For instance, classroom observations and interviews with chemistry teachers at SMA Negeri 14 Medan revealed that lessons were largely monologic, with students passively listening and taking notes while teachers controlled the instructional process—a pattern consistent with studies in other developing educational contexts (Chiu et al., 2021). This passive dynamic not only limits conceptual understanding but also diminishes students' interest in STEM careers (Salta & Koulougliotis, 2020).

This issue becomes more critical in topics like chemical bonding, which is consistently reported as one of the most abstract and challenging concepts in high school chemistry due to its reliance on sub-microscopic representations (Muljana et al., 2020). Understanding chemical bonding requires strong conceptual thinking and visualization skills, yet traditional instruction often reduces it to rote memorization of rules (e.g., the octet rule) without addressing misconceptions (Wijaya, 2020; Kurniawan et al., 2016). While prior studies acknowledge the role of technology in mitigating these challenges (Dori & Barak, 2001), there remains a lack of research examining how specific tools like Macromedia Flash 8, with its dynamic animation capabilities, can support spatial reasoning and conceptual mastery in the topic of chemical bonding (Huk, 2006; Ardac & Akaygun, 2004).

This study focuses specifically on Macromedia Flash 8 due to its unique capacity to create lightweight, frame-by-frame animations and interactive elements with low system requirements, which are highly compatible with the technological infrastructure available in many Indonesian schools (Taher & Bentri, 2024). Unlike more recent animation software, which may require higher specifications or consistent internet access, Flash 8 enables the development of offline, user-friendly, and pedagogically rich content that aligns well with the Discovery Learning model. The practicality and effectiveness of Flash 8-based learning media have been demonstrated in various educational contexts in Indonesia, including vocational high schools and elementary schools, where it has been successfully utilized to enhance student engagement and learning outcomes in subjects requiring visualization of abstract concepts (Varadila et al., 2023; Taher & Bentri, 2024).

Although interactive media in science education has been widely studied (e.g., Mayer, 2017; Plass et al., 2020), few investigations focus on Macromedia Flash 8's efficacy for chemical bonding. For instance, Kotimah (2024) demonstrated that animation-based media improved cognitive outcomes in general chemistry, but their study did not isolate chemical bonding or compare software tools. Similarly, Waruwu & Sitinjak (2022) observed heightened student engagement with multimedia, yet their findings lacked granularity on how design elements (e.g., interactivity levels in Flash) affect topic-specific achievement. This gap echoes broader calls for 'tool-specific' rather than 'media-general' studies (Kozma, 1994; Akaygun & Jones, 2014), particularly in under-researched contexts like Indonesian classrooms (Rahayu et al., 2022).

Furthermore, the persistent lack of instructional media that effectively supports visualization and interactivity remains a critical barrier in chemistry education (Jaber & BouJaoude, 2012; Wu & Shah, 2004). As emphasized by Karpudewan et al. (2015), visualization-based instructional strategies are particularly crucial for helping students bridge the gap between macroscopic observations and sub-microscopic particle representations - a fundamental challenge in chemistry learning known as 'representational competence' (R. Kozma & Russell, 2005). This cognitive hurdle is especially pronounced in chemical bonding, where students must mentally visualize abstract concepts like electron clouds and molecular orbitals (Harrison & Treagust, 2000). Research in the cognitive theory of multimedia learning (Mayer, 2002) supports that well-designed animated media, such as Macromedia Flash 8, with its capability for gradual visual scaffolding (Kelly & Jones, 2007) and interactive simulations (Rutten et al., 2012)could serve as an effective tool to overcome these obstacles by providing dynamic, manipulable representations that align with human cognitive architecture (Sweller, 2011).

The primary research problem in this study is the low learning outcomes of students in chemical bonding, which is attributed to the lack of interactive and concrete media that can effectively visualize abstract chemical concepts. This condition hampers students' conceptual understanding and reduces their learning motivation. Quantitative studies have shown that student achievement in chemical bonding remains low; for example, Putra (2021) found that the average student score in chemical bonding topics was only 58.675 out of 100, indicating weak mastery. Additionally, Widarti et al. (2024) reported that misconceptions about chemical bonding are still prevalent and significantly contribute to learning difficulties. Given the abstract nature of chemical bonding, effective visualization is crucial for supporting meaningful learning and cognitive engagement. Therefore, the objective of this study is to analyze the effect of using Macromedia Flash 8-based learning media on students' learning outcomes in the topic of chemical bonding. The results of this study are expected to provide empirical evidence supporting the use of interactive multimedia in enhancing student understanding and performance in chemistry education, particularly for abstract topics that require high cognitive engagement.

Method

This research employed a quasi-experimental design with a pretest-posttest control group format. This method was chosen because it allows for comparison between a treatment (experimental) group and a control group in real classroom settings, where random assignment of individual students is not feasible due to institutional constraints (Creswell & Creswell, 2017). The quasi-experimental approach is particularly suitable for educational research where intact classes must be used, yet valid causal inferences are still desired (Fraenkel et al., 2019).

The study was conducted at SMA Negeri 14 Medan during the 2023/2024 academic year, involving students from the grade X science classes. The population consisted of all ten science classes (X-IPA), with each class having an average of 36 students. Two intact classes were randomly assigned as experimental and control groups: class X-7 received instruction using Macromedia Flash 8-based learning media, while class X-5 was taught with conventional PowerPoint-based media. Although the classes were randomly assigned to conditions, this approach constitutes cluster sampling rather than individual random sampling, as the intervention was applied to pre-existing classroom groups. Both groups were taught using the Discovery Learning model to ensure pedagogical consistency.

The research instrument included a multiple-choice test used for both the pretest and post-test, aimed at assessing students' conceptual understanding of chemical bonding. The pretest was administered before the instructional intervention to determine the initial equivalence between the two groups. Following the intervention, a post-test was administered to assess the improvement in learning outcomes. To evaluate the effectiveness of the learning media, a systematic statistical analysis was conducted using Microsoft Excel.

Normality Test

The normality of the data was assessed using the Chi-Square test (χ^2) at a significance level of $\alpha = 0.05$. The test was applied to the pretest and post-test scores from both the experimental and control groups. The criterion for normality stated that if the calculated Chi-Square value (χ^2count) was less than the critical value (χ^2table), the data were deemed normally distributed. This step was crucial to ensure that the data satisfied the assumptions required for subsequent parametric testing.

Homogeneity Test

To assess whether the variance of the two groups was statistically similar, a homogeneity of variance test was performed. This test involved comparing the most significant variance to the smallest variance using the F-test. If the calculated F-value (F_{count}) was smaller than the F critical value (F_{table}) at $\alpha = 0.05$, the data were considered homogeneous. This test was conducted on both pretest and post-test data as well as on the N-Gain scores, to ensure that both groups had similar levels of variability before and after treatment.

N-Gain Analysis

The improvement in students' learning outcomes was measured using the Normalized Gain (N-Gain) formula (Hake, 1998):

$$\text{N-Gain} = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Maximum score} - \text{Pretest score}}$$

The N-Gain values were categorized into three criteria: low ($g < 0.3$), medium ($0.3 \leq g \leq 0.7$), and high ($g > 0.7$), to interpret the level of improvement in student learning. To determine whether a significant difference in learning outcomes existed between the experimental and control groups, a one-tailed (right-sided) independent sample t-test was conducted at a significance level of $\alpha = 0.05$. This test compared the mean N-Gain scores of both groups. The null hypothesis (H_0) stated that there was no significant difference, while the alternative hypothesis (H_1) suggested that the experimental group had higher learning outcomes. If the calculated t-value (t-count) exceeded the critical t-value (t-table), the null hypothesis would be rejected, indicating a statistically significant effect of the learning media.

Results & Discussion

This study aimed to evaluate the effectiveness of Macromedia Flash 8-based learning media on students' learning outcomes regarding the topic of chemical bonding. The results indicated a significant improvement in students' performance following the intervention.

Description of Learning Outcome Data

Before the two samples received different treatments, they were first administered a pretest designed to assess the initial abilities of students in both the experimental and control classes. Furthermore, various treatments were applied: in the experimental class, learning was facilitated using Macromedia Flash 8 media with the discovery learning model, while in the control class, PowerPoint media was used alongside the same discovery learning model. Finally, at the end of the learning process, a post-test will be administered to assess the students' final learning outcomes after they have received the various treatments.

Table 1. Students' Learning Outcomes

Data	Statistics	Class	
		Experiment	Control
		Macromedia Flash 8 with DL	*PowerPoint* with DL
pretest	The number of students	36	36
	Average	47.9	41.5
	Standard Deviation	10.4	9.0
	Variance	109.1	82.5
	Smallest Value	25	20
	Greatest Value	65	60
	Total Value	1725	1495
Post-test	The number of students	36	36
	Average	81.1	74.4
	Standard Deviation	7.3	5.7
	Variance	54.4	32.5
	Smallest Value	60	60
	Greatest Value	95	85
	Total Value	2920	2680

According to Table 1, the pretest and posttest averages in the experimental class were 47.9 and 81.1, respectively, while the control class recorded average scores of 41.5 and 74.4. To determine if the students' initial abilities were statistically equivalent, an independent samples t-test was performed on the pretest scores of both classes. The results revealed no statistically significant difference between the experimental and control groups ($p > 0.05$), indicating that both groups had comparable initial abilities before the intervention. Thus, any difference in posttest performance can be attributed to the treatment. The learning gain is also visually represented in Figure 1, which illustrates the differences in average scores before and after the intervention.

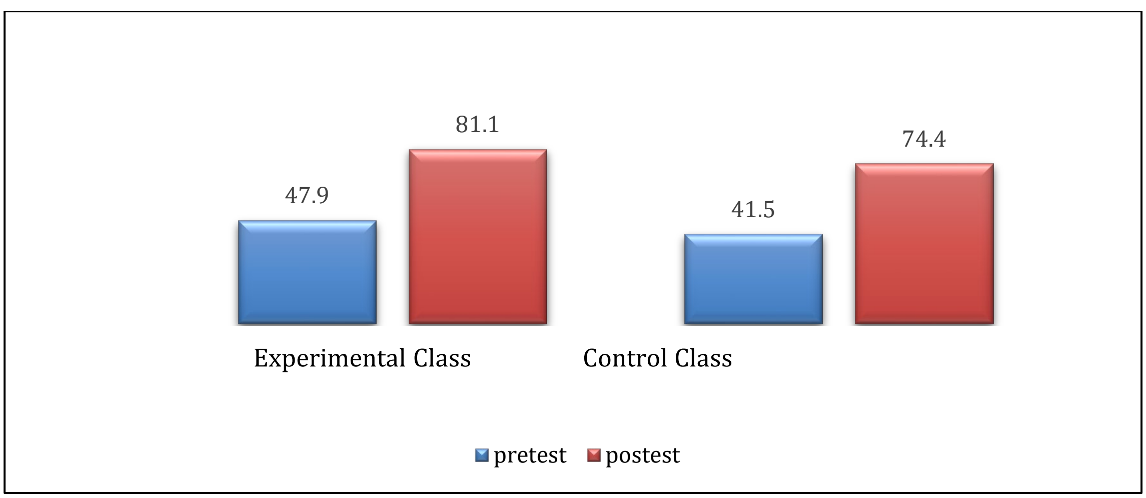

Figure 1. Student learning outcomes

Data on Increasing Learning Outcomes (Gain)

The results of calculating the increase in learning outcomes can be obtained using the N-Gain value formula, which is derived from pretest and posttest data. As shown in Table 2, an increase in learning outcomes of 0.64, equivalent to 64%, for the experimental class and 0.56, equivalent to 56%, for the control class can be observed.

Table 2. Motivational N-Gain Normality Test Results

Class	Criteria	$\bar{X}$	%N-Gain	Criteria
Experimental Class Control Class	g < 0.3 = Low 0.3< g <0.7 = Medium g > 0.7 = High	0.64 0.56	64 56	Medium Medium

From Table 2, it is clear that the increase in learning outcomes in the experimental class is higher than that in the control class, even though they fall into the same criterion, namely the "medium" criterion.

Analysis of the effect of using Macromedia Flash 8-based media on student learning outcomes

The results of calculating the increase in learning outcomes can be obtained using the N-Gain value formula from pretest and posttest data.

Analysis of Normality and Homogeneity of N-Gain Data from Experimental and Control Classes

The results of the normality test, conducted using the Chi-Square method at a significance level of $\alpha = 0.05$, showed that all calculated values (χ^2count) for the pretest and posttest in both the experimental and control classes were lower than the χ^2table value of 11.07. This indicates that the data were normally distributed. Furthermore, the homogeneity test, using the F-test, showed that all calculated F values (F_{count}) for the pretest, posttest, and N-Gain data were less than the Ftable value of 1.75, meaning the variances between groups were homogeneous. These findings confirm that the data met the assumptions for using parametric statistical tests, thereby validating the application of a one-tailed t-test for hypothesis testing.

Analysis of the hypothesis test on the effect of using Macromedia Flash 8-based media on student learning outcomes.

Based on Table 3. Above, the one-tailed t-test revealed a t-count of 3.547, which was greater than the t-table value of 1.666 at a significance level of 0.05. Thus, the null hypothesis was rejected, and the alternative hypothesis was accepted, indicating a significant effect of using Macromedia Flash 8-based media on student learning outcomes. The results of this study showed a substantial increase in the average posttest score of the experimental group (from 47.9 to 81.1), compared to the control group (from 41.5 to 74.4). The average N-Gain of the experimental group was categorized as medium to high, indicating meaningful improvement in conceptual understanding of chemical bonding. These findings align with the Cognitive Theory of Multimedia Learning (Mayer, 2002), which posits that students learn more effectively from a combination of words and pictures than from words alone, particularly when both channels (visual and verbal) are utilized effectively. Macromedia Flash 8 supports this dual-channel processing by enabling animated visualizations of electron sharing, bond formation, and molecular shapes—concepts that are difficult to grasp through static media, such as PowerPoint.

Table 3. Research Hypothesis

Class	Data source	X	S ^{2}	t $_{count}$	t $_{table}$	Information
Experiment	N-Gain	64.31	111.19	3,547	1,666	Ha Accepted
Control		56.06	83.78			

In Mayer's theory, three core principles—the multimedia principle, the contiguity principle, and the segmenting principle—are particularly relevant. Flash 8's interactive animations enabled students to control the pace (segmenting), presented text and visuals simultaneously (contiguity), and combined images with narration or on-screen text (multimedia), thereby reducing extraneous cognitive load (Sweller, 2011) and enhancing cognitive processing. Furthermore, the statistical results confirmed that the difference in posttest performance between groups was significant, as shown by the independent sample t-test. This supports the theoretical view that well-designed multimedia not only aids understanding but also leads to measurable learning gains.

These findings are consistent with previous studies. For example, Izzati et al. (2022) found that Flash 8-based media improved representational understanding in science, while Nasution et al. (2022) noted increased student engagement and achievement in chemistry learning through interactive visual media. In line with Ryan & Deci's Self Determination Theory (2000), students in the experimental group also reported higher levels of interest and participation, which could be attributed to the autonomy and feedback features embedded in the Flash media. Overall, the integration of Macromedia Flash 8 into the Discovery Learning framework did not merely supplement traditional instruction—it enhanced the depth of student learning through interactivity and visualization. This supports the argument that media selection is not a neutral component in instructional design; instead, it has a direct pedagogical impact, especially in conceptually demanding subjects like chemical bonding.

Conclusion

This study found that the use of Macromedia Flash 8-based learning media has a significant positive effect on improving students' learning outcomes in the topic of chemical bonding. The experimental group, which received instruction through interactive multimedia, demonstrated higher post-test scores and greater learning gains compared to the control group, which was taught using conventional PowerPoint media. These findings suggest that integrating interactive and visual learning tools, such as Macromedia Flash 8, can enhance students' conceptual understanding and engagement, especially in abstract topics within chemistry education. Therefore, this study provides empirical evidence supporting the implementation of multimedia-based instructional media to improve the quality of teaching and learning processes in senior high school chemistry classes.

AI-assisted technology statement

While preparing this work, the authors used ChatGPT from OpenAI to help enhance the clarity, grammar, and academic tone of the manuscript, especially in revising the abstract, methodology, and discussion sections. After using this tool, the authors reviewed and edited the content as necessary and assumed full responsibility for the publication's content.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this article. All research activities were conducted independently, and no financial or personal relationships influenced the study's outcomes or interpretations.

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