



## The Effectiveness of Using the Interactive Learning Media PeT-Efig (Periodic Table and Electron Configuration)

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### Abstract

This study aims to examine the effectiveness of the PeT-Efig interactive multimedia in improving students' learning outcomes compared to the use of a textbook. The effectiveness was analyzed by comparing the posttest scores of both groups using an independent t-test. The results showed that the Sig. (2-tailed) value was  $< 0.05$ , indicating a significant difference between the experimental and control classes. Students who learned using PeT-Efig achieved higher learning outcomes, demonstrating that the media provided a positive impact on conceptual understanding. The effect size calculation produced a Cohen's  $d$  value of 1.3, categorized as a large effect, indicating that the influence of PeT-Efig is very strong and practically meaningful. Overall, this study concludes that the PeT-Efig interactive multimedia is effective as a learning medium because it enhances learning engagement, strengthens information retention, and significantly improves students' learning outcomes.

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## INTRODUCTION

The development of technology in the field of education has brought significant changes to learning methods, one of which is the emergence of interactive instructional media (Prayudi, 2024). Learning media serve as an essential component in supporting the achievement of learning objectives, especially in the era of Society 5.0, which demands the integration of technology to ensure learning processes are more effective and efficient (Sihaloho & Tahya, 2023). Twenty-first century learning media are designed not only as tools for transferring knowledge but also as instruments for developing 21st-century skills such as creativity, collaboration, critical thinking, and digital literacy. Interactive technologies such as educational applications, virtual simulations, and e-learning platforms can encourage students to learn independently as well as collaboratively (Faiza & Wardhani, 2024).

Despite the rapid development of interactive learning media in education, their implementation in chemistry learning remains uneven, particularly for abstract and conceptual topics such as electron configuration and the periodic system of elements. These topics are fundamental concepts that form the basis for more advanced understanding in chemistry. Electron configuration requires students to understand electron filling rules based on the Aufbau principle, Hund's rule, and the Pauli exclusion principle, and to relate them to the position of elements in the periodic table. This complexity is further intensified for transition elements, which exhibit less straightforward electron configuration patterns, often leading to misconceptions and conceptual errors among students.

The results of interviews with a chemistry teacher at SMA 11 Pontianak indicate that one of the basic chemistry concepts perceived as difficult by students is electron configuration. Students experience difficulties in writing electron configurations based on the Aufbau principle and relating them to the position of elements, particularly transition elements. These findings are consistent with several studies reporting that students often struggle to write electron configurations according to the Aufbau rules, understand electron configurations of transition elements, and connect them to the position of elements in the periodic table (Fernanda dkk., 2020; Rahman dkk., 2016; Sari dkk., 2024). Such conceptual errors frequently occur when students write electron configurations, which ultimately leads to a low level of understanding of the relationship between electron configuration and the periodic system of elements (Mawarni dkk., 2018).

In addition to content-related factors, the instructional methods and learning media used can also contribute to students' learning difficulties. Teaching methods employed by teachers can influence students' understanding, attitudes, and learning mindset (Krisnawan dkk., 2024). Instruction on electron configuration is still often delivered through lecture-based methods and static media, such as textbooks or presentation slides, which are less effective in visualizing the dynamic and abstract process of electron filling. As a result, students tend to memorize rules without truly understanding the underlying concepts, making learning less meaningful. Therefore, learning media that can present the concepts of electron configuration and the periodic system of elements in a visual, interactive, and contextual manner are needed. This highlights the crucial role of instructional methods as strategies for attracting students' attention, stimulating interest, and directing their focus toward the learning material. In line with this, the implementation of innovative learning media, such as interactive multimedia, represents a viable alternative to support the effectiveness of teaching methods. The use of interactive multimedia also aligns with the demands of 21st-century learning, which emphasizes active student engagement in the learning process. Such media function not only as visual aids but also as tools for creating more meaningful and contextual learning experiences. Through direct interaction between students and the media, the learning process becomes more engaging and challenging, encouraging students to think critically and creatively in understanding abstract chemistry concepts.

Several studies have shown that the use of interactive multimedia can enhance learning motivation, improve learning outcomes, increase self-confidence, and strengthen students' conceptual understanding (Bahri, 2023; Fitriya dkk., 2024; Waruwu & Sitinjak, 2022). Interactivity in multimedia allows students to engage directly in the learning process, develop a deeper understanding of the material, and improve memory retention. Consequently, interactive multimedia has been proven to be more effective than conventional presentation media because it supports various learning styles, including visual, auditory, and kinesthetic. Interactive media also enable students to explore content independently, conduct simulations, and receive immediate feedback, thereby facilitating deeper conceptual understanding.

However, to date, research that specifically examines the use of interactive media integrating the concepts of electron configuration and the periodic system of elements into a unified learning framework remains limited. Many existing studies focus on interactive media in general or on other chemistry topics, without emphasizing the direct relationship between electron configuration and the position of elements in the periodic table. This gap highlights the need for the development and evaluation of interactive media specifically designed to address these learning difficulties.

Based on this gap, the interactive media PeT-EFig (Periodic Table and Electron Configuration) was developed using Articulate Storyline 3. This media is designed to help students understand the relationship between electron configuration and the periodic system of elements through

integrated content presented interactively in the form of text, images, animations, videos, graphics, and audio (Dzikrika dkk., 2024). The presence of this media is expected to serve as a solution to students' difficulties in visualizing abstract chemistry concepts, while also supporting more engaging, interactive, and meaningful learning. Therefore, this study aims to determine the effectiveness of using the PeT-EFig interactive media developed with Articulate Storyline 3 in improving students' learning outcomes on the topics of electron configuration and the periodic system of elements.

## METHOD

This study employed a quantitative pre-experimental approach using a quasi-experimental method with a Nonrandomized Control Group Pretest–Posttest Design (Meitha et al., 2022). This design was selected because the researcher was unable to randomly assign individual participants; therefore, randomization was conducted at the class level. The design allows for a more objective comparison of learning outcomes between the group receiving the treatment and the group not receiving the treatment through measurements taken before and after instruction. The study involved two groups: an experimental class and a control class. The experimental class received treatment in the form of the PeT-EFig interactive multimedia, while the control class used conventional instructional media in the form of textbooks and teaching methods commonly applied by the teacher. The design of the method used in this study is presented in Table 1.

Table 1. Nonrandomized Control Group Pretest–Posttest Research Design

Group	Pretest	Treatment	Posttest
Eksperimental	X1	Y (PeT-EFig)	O <sub>1</sub>
Control	X2	(Buku teks)	O <sub>2</sub>

Notes :

X1 : Pretest score of the experimental class

X2 : Pretest score of the control class

Y : Treatment (PeT-EFig media)

O1 : Posttest score of the experimental class

O2 : Posttest score of the control class

This study was conducted at SMAN 11 Pontianak during the first semester of the 2025/2026 academic year. The population of the study consisted of all Grade X students at SMAN 11 Pontianak, comprising seven classes with a total of 210 students. The sample consisted of two Grade X classes with a total of 71 students, selected using Probability Sampling, a sampling technique that provides equal opportunities for all members of the population to be included as sample participants (Andika, 2019). The selection of sample classes was carried out in several stages. The first stage involved conducting a homogeneity test on the seven Grade X classes to ensure that students' initial abilities were relatively equivalent and that there were no significant differences among the classes. The results of the homogeneity test indicated that all classes had homogeneous variances, making them suitable for inclusion as research samples. The next stage involved randomly selecting two classes using a lottery technique, which resulted in classes XC and XD as the sample classes. A second lottery was then conducted to assign the roles of the experimental and control groups, resulting in class XC as the experimental class and class XD as the control class. This selection process was conducted without any specific academic considerations, thereby minimizing potential bias in group assignment.

The data collection technique used in this study was a measurement technique employing a learning outcomes test as the research instrument. The test was used to assess students'

conceptual understanding of electron configuration and the periodic system of elements. Measurements were conducted twice: before the treatment (pretest) to determine students' initial abilities and after the treatment (posttest) to identify improvements in learning outcomes.

The test instrument consisted of 10 multiple-choice questions developed based on the competency achievement indicators for the topics of electron configuration and the periodic system of elements. The questions were designed to measure students' conceptual understanding, including their ability to determine electron configurations, understand electron-filling rules, and relate electron configurations to the positions of elements in the periodic table. Prior to its use in the study, the test instrument underwent validity and reliability testing to ensure that the items were appropriate, consistent, and capable of measuring the intended constructs.

The data analysis technique employed was inferential analysis using IBM SPSS Statistics version 27. Before hypothesis testing, prerequisite analyses were conducted, including normality and homogeneity tests. The normality test used the Kolmogorov–Smirnov test, with data considered normally distributed when the p-value was  $\geq 0.05$ . The homogeneity test was performed to examine the equality of variances between groups, with data considered homogeneous when the p-value was  $\geq 0.05$ .

After the prerequisite assumptions were met, an independent t-test was conducted to determine differences in learning outcomes between the experimental and control classes. In addition, effect size was calculated using Cohen's d to determine the magnitude of the impact of the PeT-Efig interactive multimedia on students' learning outcomes.

The research hypotheses were formulated as  $H_0$ : There is no significant difference in learning outcomes between students using the PeT-Efig interactive multimedia and those using a textbook.  $H_a$ : There is a significant difference in learning outcomes between students using the PeT-Efig interactive multimedia and those using a textbook.

Hypothesis testing was conducted at a significance level of  $\alpha = 0.05$ . If the p-value was less than 0.05,  $H_0$  was rejected, and it could be concluded that the use of the PeT-Efig interactive multimedia had a significant effect on students' learning outcomes (Magdalena & Angela Krisanti, 2019).

To determine the effect size of the treatment and measure the magnitude of the influence of variable A on variable B, Cohen's formula was used as follows:

$$d = \frac{\bar{X}_B - \bar{X}_A}{SD_{pooled}}$$

Notes:

d = Cohen's d value (effect size)

$\bar{X}_a$  = Mean of group A (control class)

$\bar{X}_\beta$  = Mean of group B (experimental class)

$SD_{pooled}$  = pooled standard deviation

The results of the effect size test can be interpreted as shown in Table 1.

Table 2. Effect Size Categories

Effect Size	Category
$0 \leq ES \leq 0,2$	Low
$0,2 \leq ES \leq 0,8$	Medium
$ES \geq 0,8$	High

(Cohen, 1988)

## RESULTS AND DISCUSSION

### Normality Test

The normality test was conducted to determine whether the data from the experimental class (XC) and the control class (XD) were normally distributed. The data tested included posttest scores using IBM SPSS Statistics version 27.0 with the Kolmogorov–Smirnov test. If the significance value is greater than 0.05, the data are considered normally distributed; conversely, if the significance value is less than 0.05, the data are not normally distributed. The results of the posttest normality test for the experimental and control classes are as presented in table 3.

Tabel 3. Posttest Normality Test Results

	Kelas	Kolmogorov-smirnov		
		Statistic	df	Sig.
Posttest Scores	Experimental Class	.142	36	.063
	Control Class	.143	35	.066
a. Lilliefors Significance Correction				

Based on the data above, the posttest significance values obtained were 0.063 for the experimental class and 0.066 for the control class. Since the significance values  $0.063 > 0.05$  and  $0.066 > 0.05$ , the posttest data for both classes are greater than 0.05. Therefore, according to the decision criteria previously described, it can be concluded that the posttest data for both the experimental and control classes are normally distributed.

### Homogeneity Test

The homogeneity of variance test was conducted to determine whether the variance of the data from the experimental and control classes came from a homogeneous population. This test used the posttest data from both classes and was carried out using the Homogeneity of Variance test in One-Way ANOVA, with the results shown in the table 4.

Tabel 4. Homogeneity Test Results for Posttest

	Test of Homogeneity of Variances			
	Levene Statistic	df1	df2	Sig.
posttes	3.301	1	69	.074

Based on these results, the significance value obtained for the posttest was 0.074, which is greater than 0.05. The homogeneity test using the Homogeneity of Variances in One-Way ANOVA therefore indicates that the posttest data meet the criterion of homogeneity. This means there is no significant difference in the variances of the distributions for either posttest. Thus, it can be concluded that the data from both groups have equal variances (homogeneous).

### T-Test Result

An independent t-test was conducted to determine whether there was a significant difference in students' learning outcomes between the experimental class and the control class after the implementation of the learning treatment. The results of the test are presented in the table 5.

Tabel 5. Descriptive Statistics of Posttest Results for the Experimental and Control Classes

Nilai	F	Sig.	t	df	Sig*
Equal variances assumed	3.459	.067	5.793	69	.000
Equal variances not assumed			5.768	62.365	.000

The results of the t-test showed a value of  $t = 4.058$ ,  $df = 69$ , and  $\text{Sig. (2-tailed)} < 0.000$ . Since the significance value is less than 0.05, the difference is statistically significant. If the significance value ( $\text{Sig. 2-tailed}$ ) is less than 0.05, then  $H_0$  is rejected and  $H_a$  is accepted. Thus,

it can be concluded that the mean posttest scores of the experimental and control classes differ significantly.

Based on these criteria, it can be concluded that there is a significant difference in learning outcomes between the experimental and control classes. Thus, the null hypothesis ( $H_0$ ), which states that there is no difference in learning outcomes between the two classes, is rejected, and the alternative hypothesis ( $H_a$ ) is accepted. These results indicate that the learning model or approach applied in the experimental class had a significant impact on improving students' learning outcomes compared to the method used in the control class. Therefore, it can be stated that the PeT-EFig interactive media used in the experimental class was more effective in enhancing students' understanding and learning achievement.

### Effect Size Test Result

To determine the magnitude of the instructional treatment's influence on students' learning outcomes, the effect size ( $d$ ) was calculated using Cohen's  $d$  formula as follows:

$$d = \frac{\overline{X}_B - \overline{X}_A}{SD_{pooled}}$$

$$d = \frac{78,37 - 53,71}{17,90}$$

$$d = 1,3$$

These findings indicate that the instructional treatment using PeT-EFig has a very strong influence on improving students' learning outcomes. In other words, the implementation of the PeT-EFig interactive media successfully produced a significant improvement in student achievement compared to the conventional textbook-based instruction used in the control class.

### Differences in Learning Outcomes Between the Control and Experimental Classes

The t-test results indicate a significant difference in learning outcomes between students who learned using the PeT-EFig interactive media and those who learned using textbooks. This difference suggests that PeT-EFig is more effective in helping students understand the abstract and complex concepts of electron configuration and the periodic system of elements.

The effectiveness of PeT-EFig compared to textbooks is primarily attributed to its interactive and visual characteristics. The concept of electron configuration requires students to visualize the process of electron filling into subshells and orbitals and to relate it to the position of elements in the periodic table. Textbooks typically present these concepts in the form of text and static images, which are less capable of representing the dynamic nature of electron filling processes. In contrast, PeT-EFig provides animations, simulations, and interactive visualizations that allow students to directly observe how electrons occupy orbitals based on the Aufbau principle, Hund's rule, and the Pauli exclusion principle. These visualizations help reduce students' cognitive load and minimize misconceptions in understanding abstract concepts.

In addition, the interactivity embedded in PeT-EFig enables students to actively engage in the learning process, such as exploring the content, controlling the learning flow, and receiving immediate feedback. This active engagement encourages students to construct knowledge independently rather than passively receiving information, as often occurs in textbook-based instruction. This condition aligns with constructivist theory, which emphasizes that knowledge is built through active learning experiences and direct interaction with learning resources.

The findings of this study are supported by numerous previous studies demonstrating the effectiveness of interactive multimedia in enhancing students' understanding of abstract

chemistry concepts. Waruwu & Sitinjak, (2022) reported that the use of simulation- and video-based interactive multimedia significantly improved conceptual understanding. Sijabat dkk., (2024) also stated that the presence of interactive learning media increases students' active participation in learning activities, thereby enhancing individual learning engagement. Furthermore, Bahri, (2023) showed that interactive multimedia integrating text, graphics, animations, audio, and video can improve learning outcomes more effectively than conventional presentation-based multimedia. This improvement occurs because interactivity allows students to engage in the learning process, understand the material more deeply, and enhance memory retention and conceptual comprehension.

Other studies have emphasized that visualization and animation in interactive multimedia play a crucial role in helping students understand the relationships among microscopic, symbolic, and macroscopic representations in chemistry. Fitria dkk., (2023) stated that presenting chemistry concepts through interactive multimedia can reduce misconceptions and improve students' conceptual retention. These findings are consistent with those of Rahman dkk., (2016) and Fernanda dkk., (2020), who reported that students' main difficulties in learning electron configuration stem from weak visualization skills and challenges in connecting related concepts.

The high effect size value ( $d = 1.3$ ) indicates that the impact of using PeT-EFfig is not only statistically significant but also practically meaningful. This finding confirms that the use of interactive media specifically designed to match the characteristics of the subject matter can provide more optimal learning outcomes than conventional media. Therefore, PeT-EFfig can be regarded as an effective instructional medium for helping students develop a deeper and more meaningful understanding of electron configuration and the periodic system of elements.

## CONCLUSION

The t-test results indicate a significant difference in learning outcomes between the experimental class that used the PeT-EFfig interactive media and the control class that used a textbook. A significance value of  $< 0.05$  led to the rejection of  $H_0$  and the acceptance of  $H_a$ , meaning that instruction using PeT-EFfig was more effective. This finding is supported by an effect size value of 1.3 (categorized as a large effect), demonstrating that the influence of PeT-EFfig is very strong. Thus, the PeT-EFfig interactive media has been proven to significantly enhance students' understanding and learning outcomes compared to conventional instruction.

## RECOMMENDATIONS

Considering the positive impact obtained, it is recommended that similar interactive multimedia be developed and applied to other chemistry topics that are abstract and difficult to understand, such as chemical bonding, reaction mechanisms, and thermochemistry. Future researchers are also encouraged to investigate more deeply how interactive multimedia influences specific aspects of the learning process, such as learning motivation, problem-solving skills, cognitive load, and long-term retention. These findings would provide a more comprehensive understanding of the mechanisms through which interactive multimedia enhances learning outcomes.

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