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The Application of Flash Media "Storyboard Chemistry" as an Interactive E-Module in Learning B3 Concepts at Queen Al-Falah High School

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Abstract:

Penelitian ini bertujuan untuk mengkaji efektivitas media e-module interaktif "Storyboard Chemistry" dalam meningkatkan pemahaman konsep Bahan Berbahaya dan Beracun (B3) pada siswa SMA Queen Al-Falah. Penelitian ini menggunakan metode kuasi eksperimen dengan desain one-group pretest-posttest yang melibatkan 32 siswa. Data dikumpulkan melalui tes pretest dan posttest serta angket respon siswa. Hasil penelitian menunjukkan adanya peningkatan signifikan pada hasil belajar siswa, dengan rata-rata nilai meningkat dari 56,30 pada pretest menjadi 83,40 pada posttest. Analisis statistik menggunakan uji t berpasangan menunjukkan adanya perbedaan yang signifikan ($p < 0,05$), yang menandakan bahwa penggunaan media memberikan pengaruh positif terhadap pemahaman konsep siswa. Selain itu, analisis N-Gain menunjukkan peningkatan pada kategori sedang hingga tinggi. Respon siswa terhadap penggunaan media juga menunjukkan hasil yang positif, ditandai dengan meningkatnya motivasi, keterlibatan, serta kemudahan dalam memahami materi. Integrasi elemen visual, animasi, dan pendekatan storytelling dalam e-module mampu mengubah konsep kimia yang abstrak menjadi lebih konkret dan bermakna. Dengan demikian, media "Storyboard Chemistry" dapat menjadi alternatif inovatif.

This study seeks to evaluate the efficacy of the interactive e-module "Storyboard Chemistry" in enhancing students' comprehension of Hazardous and Toxic Substances (B3) concepts at SMA Queen Al-Falah. The study utilized a quasiexperimental approach with a one-group pretest-posttest design, comprising 32 students. Data were gathered via pretest and posttest evaluations, along with student reaction surveys. The findings indicated a notable enhancement in students' academic performance, as the average score rose from 56.30 in the pretest to 83.40 in the posttest. Statistical investigation employing a paired sample t-test revealed a significant difference ($p < 0.05$), affirming that media utilization positively influenced students' conceptual comprehension. The N-Gain study indicated a moderate to substantial degree of enhancement. The students' reactions to the media were largely favorable, reflecting heightened motivation, engagement, and comprehension of the topic. The incorporation of visual components, animation, and narrative in the emodule effectively converted abstract chemistry principles into tangible and significant learning experiences. Consequently, "Storyboard Chemistry" is regarded

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as an excellent and unique educational tool that can improve the quality of chemical instruction.
Keywords: *e-module* interaktif, *storyboard chemistry*, konsep B3, hasil belajar, teknologi pendidikan

INTRODUCTION

Chemistry education at the Senior High School (SMA) level plays an important role in developing students' science literacy, especially in understanding concepts that are directly related to everyday life. One of the highly urgent topics is the concept of Hazardous and Toxic Materials (B3) (Elvania, 2024), which requires students to understand the chemical properties, hazard classification, and their impact on the environment (Wicaksono et al., 2025). Mastery of this material is not only academically important but also contributes to shaping students' awareness of safety, health, and environmental responsibility (Iyamuremye et al., 2024). In the context of increasing environmental challenges and the need for risk literacy in the 21st century, understanding hazardous materials is becoming increasingly relevant. Nevertheless, students' understanding of the B3 concept is still relatively low. One of the main causes is the abstract nature of chemistry material, which requires students to integrate symbolic, conceptual, and contextual representations simultaneously (Ketaren & Nasution, 2025; Musa et al., 2023). In classroom learning practices, the material is still largely delivered through a teacher-centered and text-based approach, which emphasises the delivery of information rather than the construction of conceptual understanding (Iqbal et al., 2026; Sandria et al., 2022; Semaranatha et al., 2016). As a result, students tend to have fragmented understanding and low levels of engagement, which ultimately affects learning outcomes. Although various studies show that the use of multimedia and interactive learning media can enhance motivation and understanding, this approach has not consistently resulted in deep conceptual understanding (Nurdyansyah, 2018).

One of the limitations in previous research is the tendency to emphasise the presence of technological features such as animations, simulations, or interactivity without thoroughly examining how the structure of material presentation in these media affects students' cognitive processes. Visualisation has indeed been recognised as an important factor in aiding the understanding of abstract chemistry concepts, yet many digital media still present information in a disjointed and non-sequential manner. This condition allows students to interact with the media, but they still struggle to build a complete understanding. This indicates a fundamental limitation in previous research, namely the lack of explanation on how specifically structured instructional design contributes to the formation of a comprehensive conceptual understanding. This shows that the main issue is not just the availability of digital media, but rather the lack of instructional design that can support cognitive processing in a structured and meaningful way.

More specifically, there is still limited empirical evidence examining how narrative-based approaches, such as the use of storyboards, can support the learning of abstract chemistry concepts, particularly in B3 material (Imbar et al., 2021). Previous research rarely highlights how the integration of visualisation, interactivity, and a structured narrative flow can reduce concept fragmentation and produce consistent learning outcomes in students with varying initial abilities. This gap indicates the need for research that not only focuses on the use of technology but also

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on the pedagogical mechanisms underlying the effectiveness of digital learning (Mubaidilla, n.d, 2025)

In response to this gap, *Storyboard Chemistry* media was developed as an alternative learning approach that integrates visualisation, interactivity, and narrative flow within a structured framework (Câmara Olim et al., 2024; Iyamuremye et al., 2024). Unlike conventional e-modules that tend to present information separately, this media organises B3 material in the form of a coherent storyline, allowing students to understand concepts gradually and contextually. This approach has the potential to reduce cognitive fragmentation, provide scaffolding in a sequential manner, and support the development of a deeper conceptual understanding (Damanik et al., 2025; Wiedbusch et al., 2026).

Based on this gap, this study aims to examine the effectiveness of using Storyboard Chemistry media in enhancing students' understanding of the B3 concept. Specifically, this research focuses on two main questions as follows. First, to what extent can the use of Storyboard Chemistry media improve students' learning outcomes on B3 material at Queen Al-Falah High School? Second, how do students respond to the use of this media in terms of engagement and learning experience?

This research contributes to the field of Educational Technology by presenting empirical evidence regarding the role of storyboard-based instructional design in chemistry learning. More specifically, this research examines how the integration of visualisation, interactivity, and a structured narrative flow can reduce conceptual fragmentation and produce significant and consistent improvements in learning outcomes. The main contribution of this research is to provide empirical explanations of how storyboard-based learning structures function as pedagogical mechanisms in enhancing conceptual understanding, rather than merely as variations in the use of digital media. Thus, this research not only emphasises the importance of using technology in learning but also highlights that the effectiveness of learning is greatly determined by the quality of the instructional design used, especially in teaching complex and abstract subjects like chemistry.

METHODOLOGY

Research Design

This research uses a quantitative approach with a quasi-experimental research type. The selection of this method is based on field conditions that do not allow the researcher to fully randomize the subjects, but still strive to control the variables that affect the research outcomes. Quasi-experimentation is used to determine the effect of using the "Storyboard Chemistry" learning media on students' understanding of B3 concepts. The research design used is a pretestposttest. In this design, students are given an initial test (pretest) before the treatment to determine their initial ability related to B3 concepts. Subsequently, students are given treatment in the form of learning using the interactive e-module media "Storyboard Chemistry." After the learning process is completed, students are given a final test (posttest) to measure the improvement in their understanding. By comparing the pretest and posttest results, the researcher can determine the effectiveness of the media used in improving students' learning outcomes.

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Research Variable

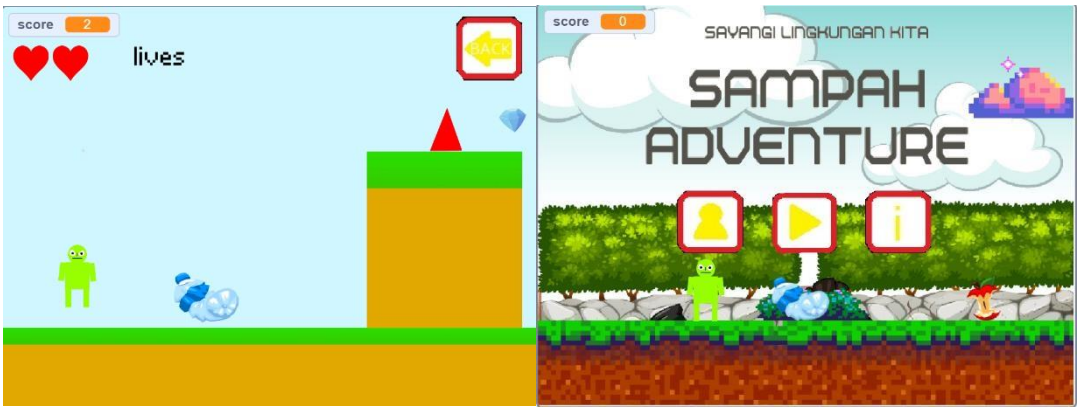

Figure 1.Story Board Chemstry Interface
Source: https://scratch.mit.edu/projects/808434284/

This study involves two types of variables, namely independent variables and dependent variables. The independent variable in this study is the use of the learning media "Storyboard Chemistry," an interactive flash-based e-module designed to help students understand B3 concepts thru a visual and interactive approach. Meanwhile, the dependent variable in this study is the students' understanding of B3 concepts. This understanding is measured thru test results given before and after the treatment. Indicators of conceptual understanding include students' ability to identify types of hazardous waste, understand their properties and impacts, and apply the concepts in everyday life contexts.

Sample

The subjects in this study are the students of Queen Al-Falah High School who are taking chemistry lessons on Hazardous and Toxic Materials (B3). The selection of subjects was carried out by considering the suitability of the material taught and the students' readiness to participate in technology-based learning. Therefore, the sampling technique used is purposive sampling, which is the selection of samples based on specific criteria relevant to the research objectives. This technique does not involve a randomisation process but emphasises the alignment of the subject's characteristics with the research needs. Thus, the sample obtained is expected to provide relevant and representative data regarding the phenomenon being studied.

Data Collection

Data collection in this study was conducted thru two main techniques, namely tests and questionnaires. Tests were used to measure students' conceptual understanding of B3 material. The tests used consisted of pretests and posttests with question formats adjusted to the learning indicators. The pretest aimed to determine students' initial abilities, while the posttest was used to measure the improvement in understanding after the use of learning media.

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In addition to tests, questionnaires were also used to collect data on students' responses to the use of the "Storyboard Chemistry" media. The questionnaire was structured in the form of a Likert scale, covering aspects of learning motivation, interest, ease of use of the media, and students' perceptions of the media's effectiveness in aiding material comprehension. Data from this questionnaire is used to complement the research results from the affective aspect and students' perceptions of learning.

Data Analysis

The data acquired in this investigation were examined utilizing several analytical methods. The N-Gain test is employed to assess the extent of enhancement in students' comprehension prior to and following the intervention. The N-Gain score is determined by the difference between the normalized pretest and posttest values, so reflecting the level of progress (low, medium, or high).

The t-test is employed to assess the significance of the difference between pretest and posttest outcomes. This test seeks to ascertain the statistical significance of the observed improvement. The t-test is employed when the data satisfies the criteria of normality and homogeneity. Furthermore, descriptive analysis is employed to elucidate the comprehensive research findings derived from both test data and questionnaires. This analysis include the computation of averages, percentages, and the interpretation of data in narrative format. By integrating these analytical methodologies, the research aims to deliver a thorough assessment of the efficacy of "Storyboard Chemistry" media in instructing the B3 concept.

RESULTS

According to the findings in Table 1, all students in the experimental group demonstrated a uniform enhancement in learning outcomes following the application of the "Storyboard Chemistry" media. The enhancement is apparent from the comparison of pre-test and post-test results, which exhibit a consistent difference ranging from ±26 to 28 points. This continuous disparity signifies that the employed learning media is effective not only for certain students but also exerts a uniform influence on all learners indiscriminately. The average pre-test score of 56.3 signifies that students' initial comprehension of Hazardous and Toxic Materials (B3) remains in the low to moderate range. This indicates that prior to the learning process, the majority of students lacked a robust comprehension of the subject, specifically regarding the identification of hazardous and poisonous substances (B3), their properties and effects, and the application of these concepts to real-life situations. This situation corresponds with the attributes of chemical material, which is typically abstract and frequently challenging to comprehend without suitable educational resources.

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Table 1. Descriptive Statistic

Remark	Pre-Test	Post-Test
1. Average	56.3	
2. Maximum Score	61	83.4 88
3. Minimum Score	52	78
Gain	**-**	**27.1**

Following the implementation of the interactive e-module "Storyboard Chemistry," there was a notable enhancement in students' post-test results, averaging 83.4. This score categorizes as high, signifying that the majority of students have comprehended the B3 topic effectively. This enhancement is manifest not only in the overall comprehension of the subject but also in the students' capacity to evaluate concepts, assess straightforward cases, and apply information in contextual scenarios. The mean difference of 27.1 points between the pre-test and post-test signifies a considerable enhancement in student learning outcomes. The consistent improvement across all students indicates that the "Storyboard Chemistry" media is highly effective in facilitating the learning process. The media can integrate several learning elements, including visualization, animation, and interactivity, facilitating students' comprehension of previously abstract topics, rendering them more tangible.

Consequently, it can be inferred that the implementation of "Storyboard Chemistry" medium markedly enhances students' academic performance and exerts a consistent effect on all learners. The findings suggest that interactive digital learning tools possess significant potential to enhance the quality of chemistry instruction at the high school level, especially for intricate subjects like B3.

Table 2. Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pre-Test	56.30	32	2.87	0.51
Post-Test	83.40	32	2.90	0.51

Based on Table 2 Paired Samples Statistics, there is a clear difference between the students' pre-test and post-test scores. The average pre-test score of 56.30 indicates that the students' initial abilities were still classified as low to moderate. After the learning process using the "Storyboard Chemistry" media, the average post-test score increased to 83.40, which falls into the high category. The standard deviation of the pre-test (2.87) and post-test (2.90) is relatively small and almost the same, indicating that the students' abilities are quite uniform. Additionally, the standard error mean value of 0.51 on both tests indicates that the data obtained is quite accurate.

Table 3. Paired Samples Test

Paired Differences	Mean	Std. Deviation	Std. Error Mean	95% CI Lower	95% CI Upper	t	df	Sig 2 (tailed)
Pre – Post	-27.10	1.20	0.21	-27.53	-26.67	-129.00	31	0.000

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The findings of the paired samples t-test in Table 3 reveal a highly significant difference between the pre-test and post-test scores of students following the use of the "Storyboard Chemistry" media. This` test was performed to ascertain if there were statistically significant alterations in students' learning outcomes prior to and during the treatment. The mean difference of -27.10 signifies an increase of 27.10 points in scores from pre-test to post-test. The negative sign on this value signifies the direction of the comparison (pre-test minus post-test), indicating that the post-test score exceeds the pre-test score. The extent of this difference signifies that the enhancement is not merely minor but additionally very significant regarding learning outcomes.

A standard deviation of 1.20 signifies that the variability in score disparities across pupils is rather minimal. This indicates that the enhancement is notably uniform across all students. In summary, nearly all students demonstrated improvement within a range that was not markedly different. This condition corroborates the observation that the learning media employed exerts a consistent impact on all pupils. The standard error mean value of 0.21 signifies a little measurement error, hence the average difference estimate can be regarded as precise and typical. A smaller score corresponds to a greater level of trust in the analysis results.

The 95% confidence interval is from -27.53 to -26.67. This range does not intersect zero, indicating that the difference between the pre-test and post-test is statistically significant. The narrow interval signifies that the estimation of the mean difference possesses a high degree of precision. The computed t-value of -129.00 with 31 degrees of freedom (df) signifies a substantial difference between the two data groups. The substantial absolute t-value signifies that the observed difference is attributable to the treatment administered, specifically the utilization of the "Storyboard Chemistry" media, rather than random chance.

The significance value (Sig. (2-tailed)) of 0.000 ($p < 0.05$) verifies that the findings of this investigation are statistically significant. Consequently, the null hypothesis (H_0), which posits no difference between the pre-test and post-test, is rejected, while the alternative hypothesis (H_1) is accepted. This indicates a substantial disparity in learning outcomes pre- and post-treatment. The findings of this test demonstrate that the "Storyboard Chemistry" media significantly enhances students' comprehension of Hazardous and Toxic Materials (B3). The substantial, constant, and statistically significant increase indicates that this interactive emodule-based learning medium is beneficial in facilitating students' comprehension of previously challenging topics. These findings further affirm that the incorporation of technology in education, especially through interactive media that merges visuals and narrative, can substantially improve the quality of learning. Consequently, the "Storyboard Chemistry" media is endorsed as a novel alternative in secondary school chemistry education.

DISCUSSION

Based on the research results presented in the previous section, it can be concluded that the use of the *"Storyboard Chemistry"* learning media has a significant impact on the improvement of understanding the concept of Hazardous and Toxic Materials (B3) among students at Queen Al-Falah High School (Elvania, 2024). The research results show a significant increase in the understanding of the concept of Hazardous and Toxic Materials (B3) after the use of the *"Storyboard Chemistry"* media. However, this improvement cannot be simply described as *"effective,"* but rather needs to be analysed from the perspective of the underlying learning

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mechanisms (Alya & Dwiningsih, 2024; Yati, 2024). One of the factors most likely explaining the improvement is how this media presents information in a multimodal and structured manner. The integration of text, visuals, and animations allows students to process information through two cognitive channels simultaneously, thereby reducing the processing load on a single channel. Additionally, presenting material in the form of a storyboard helps organise information more systematically, making it easier for students to build connections between concepts. Thus, the improvement in learning outcomes is not only due to the use of digital media but also to the way the media manages the structure of information and the cognitive processes of students.

The consistency of score improvement among students also needs to be interpreted more cautiously. Data shows that the score differences are relatively uniform, indicating that this media has the potential to provide a fairly even impact. This can be explained through the media design that provides self-navigation, immediate feedback, and gradual presentation, allowing students with different initial abilities to keep up with the learning flow (Tafonao, 2018). However, without further analysis based on initial ability categories, the claim that this media is fully inclusive should be limited to an indication, not an absolute conclusion. In other words, these findings are better understood as a tendency for the media to facilitate various levels of ability, although it has not yet been able to ensure the same effectiveness for each group specifically.

From the perspective of learning engagement, the improvement that occurs can be attributed to the interactive characteristics of the media. Interactivity allows students not only to receive information but also to engage in exploration, decision-making, and self-evaluation through features like quizzes and simulations (Studies et al., 2023). These activities encourage deeper cognitive engagement compared to passive learning. Moreover, the use of storytelling provides a context that is closer to real life, thereby helping students relate abstract concepts to concrete situations (Palupi, 2023). This mechanism is important because, in chemistry learning, the main difficulty often lies in students' inability to visualise concepts that are not directly observable. Therefore, the improvement in understanding in this study is more accurately explained as a result of a combination of concrete visualisation and active engagement, rather than solely due to the use of technology.

If compared to previous research, the main contribution of this study lies in the integration of the storytelling approach into interactive e-modules. Most previous research tends to focus on the use of animations, simulations, or digital e-modules without emphasising the narrative structure as the main framework for delivering the material (Hairishah & Nurjayadi, 2024; Okterina et al., 2025). In this study, the storyboard not only serves as an additional element but also as a structure that organises the entire learning flow. This allows information to be presented sequentially and contextually, thereby helping students build a more coherent understanding. Moreover, this research also shows that the combination of storytelling and interactivity can result in relatively consistent improvements among students, which has rarely been explicitly discussed in previous studies (Balili, 2025). Thus, the contribution of this research is not only in the use of digital media but also in how the media is pedagogically designed.

Nevertheless, the results of this study need to be interpreted with consideration of the limitations of the research design. The use of a pretest-posttest design without a control group

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makes it impossible to fully attribute the improvement in learning outcomes to the use of media. Other factors such as the practice effect, familiarity with the questions, or the learning process outside the treatment also have the potential to influence the results (Gurses et al., 2015; Heydemans et al., 2025). Therefore, even though the data shows a significant improvement, the interpretation of the media's effectiveness should be done proportionally. Further research with a stronger experimental design, such as the use of control groups, is needed to strengthen the validity of the findings (Poya, 2026).

Overall, the findings of this study indicate that the effectiveness of *"Storyboard Chemistry"* lies not only in the technological aspect but also in the learning design that combines visualisation, interactivity, and narrative structure. This combination allows students to build understanding in a more organised and contextual manner. Thus, the use of this media can be considered as one of the alternatives in chemistry learning, especially for abstract materials such as B3, while still taking into account the existing limitations (Câmara Olim et al., 2024; Shao et al., 2026).

CONCLUSION

The research findings and discussions indicate that the interactive learning media "Storyboard Chemistry" significantly enhances students' comprehension of Hazardous and Toxic Materials (B3) at Queen Al-Falah High School. The "Storyboard Chemistry" media can be effectively utilized in the classroom learning process. This medium facilitates enhanced interactive, contextual, and learner-centered education. Students can engage in independent learning through e-modules that utilize a visual and narrative methodology, while educators serve as facilitators in the learning process. The incorporation of technology in education can improve the quality of interaction and student involvement.

Moreover, regarding learning outcomes, there was a notable enhancement in the students' pretest and post-test scores. The average score elevated from the low-medium category to the high category following the utilization of media. The statistical test findings indicate that the difference is statistically significant. This demonstrates that the "Storyboard Chemistry" media is helpful in facilitating students' comprehension of the B3 concept, which was once regarded as challenging and abstract. Third, regarding student replies, the majority provided favorable feedback on the utilization of this educational resource. Students perceive that learning becomes more engaging, comprehensible, and less tedious. Interactive elements, imagery, and narrative presentation of content can augment students' motivation and engagement in learning. Consequently, all research inquiries in this study have been addressed. The "Storyboard Chemistry" medium is not only effectively implementable but also demonstrably enhances conceptual understanding and elicits favorable responses from pupils.

Limitation

1. This study has several limitations that need to be considered as a basis for interpreting the results and for the development of future research.
2. This study was conducted only on one experimental group without a control group. This results in limitations in comparing the effectiveness of the media more comprehensively with other learning methods.

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3. The number of research subjects is limited to 32 students in one school, namely SMA Queen Al-Falah. Therefore, the generalization of the research results to a broader population needs to be done with caution.
4. The material used in this study only focuses on the concept of Hazardous and Toxic Materials (B3). The effectiveness of the media on other chemistry materials has not yet been determined and requires further research.
5. The use of digital media still depends on the availability of devices and technical conditions, such as access to devices and students' ability to operate technology. This can affect the smooth implementation in some school contexts.

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