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Innovating 3D Learning Media through Experiential Learning: A Strategy to Improve Students' Motivation and Critical Thinking in Science Learning

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Abstract: This study aims to investigate the effectiveness of 3D media based on experiential learning in enhancing students' learning motivation and critical thinking skills on the topic of the human respiratory system. The media was developed using the ADDIE model and tested through a quasi-experimental design involving eighth-grade students divided into control and experimental groups. Data were collected through pretest, posttest, questionnaires, observation, and interviews. The experimental group used 3D web-based media, while the control group received conventional instruction. Results showed a significant increase in the experimental group's motivation, especially in interest, effort, persistence, and self-confidence. Critical thinking also improved, particularly in argumentation and implementation. Welch's t-test showed a significance value of 0.000, and n-gain analysis revealed higher effectiveness in the experimental group, with learning motivation categorized as high (n-gain = 0.7) and critical thinking as moderate (n-gain = 0.5), compared to low in the control group (n-gain = 0.3). The integration of interactive 3D visualization with experiential learning allowed students to better connect theoretical concepts to real-life applications. These findings suggest that experiential learning-based 3D media is a powerful tool to improve motivation and critical thinking in science education.

Keywords: Critical thinking; Experiential learning; Learning motivation; Respiratory system

Introduction

Educators urgently integrate technology into education in the rapidly advancing digital era (Krinawati & Prabowo, 2025). As supportive learning media, educational websites offer flexible access and interactive content delivery. They facilitate online learning, reaching students from diverse backgrounds, enhancing interaction, and enriching the learning experience Shehzadi et al., 2021; Kumi-Yeboah et al., 2022. Researchers have proven that the shift towards digital technology in learning supports a more effective learning process, especially in the context of distance education, which expanded significantly during the COVID-19 pandemic (Mhlanga & Moloi, 2020).

Teachers use learning media in science education to engage students. Therefore, they must be tailored to the complexity of the learning material and students' perceptions (Amarta et al., 2023). This aligns with the objectives of science education, which emphasize active understanding of concepts and real-world issues (Purwasih et al., 2022). However, although learning media are designed to support student engagement and experience, challenges remain.

A science teacher at SMP Negeri 31 Semarang revealed in an interview that students struggle to relate

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the respiratory system material to their daily lives. The teacher identified this issue based on the average score of 74, which falls below the minimum mastery criteria. Therefore, there is a need for an instructional approach that connects abstract concepts with real-life experiences, while also fostering understanding and critical thinking. Several studies have also demonstrated a positive correlation between conceptual knowledge and students' critical thinking skills (Wulandari, 2018; Az-Zahra et al., 2021; Amanda et al., 2022; Nugraha et al., 2022;).

Critical thinking is essential in science learning, as students are expected to analyze and draw conclusions from scientific phenomena. However, the challenges posed by adaptive learning environments require teachers to present relevant and meaningful content (Kahfi & Srirahayu, 2021). Moreover, learning motivation is key in engaging students in science (Libao et al., 2016; Usman & Adhellya, 2021).

The experiential learning model introduced by Kolb (2014) is considered a practical instructional approach. It engages students directly through four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. This approach has been shown to enhance students' learning motivation (Sahlan et al., 2023; Zannatunna'imah et al., 2021) and critical thinking skills (Adi & Lestari, 2022; Susanti et al., 2022) while promoting the contextual and meaningful application of knowledge in real-life situations (Xu et al., 2023). The success of this model is also highly influenced by the learning media employed during instruction.

Interactive media has been proven to enhance teaching effectiveness, facilitate concept comprehension, and promote cognitive engagement and active learning (Afrina et al., 2023; Asela et al., 2020; Jafnihirda et al., 2023; Ratumbuisang & Ratumbuisang, 2023). In the context of learning about the human respiratory system, experiential learning can be implemented by developing interactive 3D-based web media. This approach allows students to concretely visualize the respiratory organs' structure and function while fostering critical thinking skills through simulations and learning scenarios (Mulyani, 2022; Morris, 2020).

Previously developed web-based learning media generally included features such as illustrated materials, animations, videos, simulations, and curriculum-based assessments (Irawan et al., 2018; Said et al., 2023). Some platforms offered admin and user access and interactive menus supporting active and independent learning. Fatonah and Isdaryanti, 2024 developed media using Google Sites, which is easily accessible. Sina et al. (2023) demonstrated the effectiveness of website-based media in improving conceptual understanding in physics learning. Gusal et al. (2023) highlighted the importance of responsive web design to ensure compatibility across various devices. However, certain limitations remain, such as assessments being limited to simple quizzes and lacking effectiveness data in remedial contexts (Akram & Maryam, 2021; Irawan et al., 2018).

The novelty of this study lies in the development of 3D-based learning media using an experiential learning approach, designed to support in-depth exploration and active interaction. Previous studies have primarily focused on presenting content through images, videos, animations, or basic simulations, but have yet to integrate interactive 3D visualizations that allow students to manipulate models of the respiratory system organs directly.

Based on this background, integrating digital technology and the experiential learning approach has become increasingly relevant in supporting interactive and meaningful science learning. Therefore, this study aims to investigate the effects of developing 3D learning media based on experiential learning through a website on students' learning motivation and critical thinking skills in the topic of the human respiratory system.

Method

The researchers developed this study using the ADDIE model and conducted the implementation stage of the 3D learning media through an experiment employing a Pretest-Posttest Control Group Design. The research began with administering a pretest to two eighth-grade classes at SMP Negeri 31 Semarang in April 2025, each consisting of 30 students and divided into a control group and an experimental group. The experimental group used the 3D learning media, while the control group was taught using conventional methods. The study concluded with a posttest to determine the outcomes. Before data analysis, normality and homogeneity tests were conducted to ensure the data met the requirements for parametric statistical analysis.

Data was collected through observation, interviews, and documentation involving science teachers and eighth-grade students. The aim was to explore learning needs so that the development of the 3D learning media based on experiential learning would align with the students' context. The improvements in students' learning motivation and critical thinking skills were analyzed by comparing the pretest and posttest results and learning motivation questionnaires administered before and after the intervention in both groups. The results indicated a significant increase in learning motivation and critical thinking skills among students in the experimental group after using the 3D

learning media, compared to the control group that received conventional instruction. The detailed stages of the research process are presented in Figure 1.

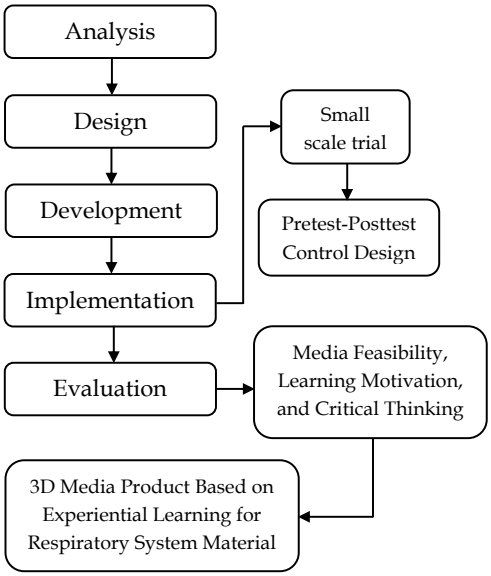

Figure 1. Research Flow

Parametric Prerequisite Test

The collected data were analyzed using normality and homogeneity tests to determine whether the data were normally distributed and had homogeneous variances. The normality test results for the learning motivation data showed significance values of 0.328 for the control group's pre-questionnaire, 0.691 for the control group's post-questionnaire, 0.600 for the experimental group's pre-questionnaire, and 0.209 for the experimental group's post-questionnaire. Meanwhile, the normality test for the critical thinking data yielded significance values of 0.239 for the control group's pretest, 0.287 for the posttest, 0.091 for the experimental group's pretest, and 0.479 for the posttest. Since all significance values were greater than 0.05, it can be concluded that the data in both groups were normally distributed.

The homogeneity test results indicated differing variance characteristics between the two data types. The learning motivation data showed a significance value of 0.000, below the 0.05 threshold, indicating non-homogeneous variance. In contrast, the critical thinking data yielded a significance value of 0.575, exceeding 0.05, which suggests homogeneous variance. Therefore, the data that met the assumptions of normal distribution and appropriate variance characteristics were deemed suitable for further analysis using statistical techniques aligned with the nature of each dataset.

Data Analysis

Based on the prerequisite analysis results, the learning motivation questionnaire data were normally distributed but did not meet the assumption of variance homogeneity. Therefore, differences between the experimental and control groups were analyzed using Welch's t-test via SPSS, which is appropriate when the assumption of equal variances is violated (Kim, 2019). The hypothesis testing followed the criteria that the null hypothesis (H_0) would be accepted if there was no significant difference between the two groups ($p > 0.05$), and the alternative hypothesis (H_1) would be accepted if a significant difference was found ($p < 0.05$). Additionally, the improvement in learning motivation was analyzed descriptively using percentages and categorized into four levels: very high, high, moderate, and low.

The researchers analyzed the critical thinking skills data using an Independent Sample t-test in SPSS, as the data met both normality and homogeneity of variance assumptions. Hypothesis testing followed the same criteria, where the null hypothesis (H_0) was accepted if no significant difference was found between the experimental and control groups ($p > 0.05$), and the alternative hypothesis (H_1) was accepted if a significant difference existed ($p < 0.05$). Improvements in students' critical thinking skills were also analyzed descriptively by calculating percentages and categorizing them into five levels: very low, low, moderate, high, and very high. To assess the effectiveness of the 3D learning media on students' learning motivation and critical thinking skills, the study employed N-gain analysis with score interpretation based on Hake's criteria (1999). Thus, the analytical methods were tailored to the data characteristics to ensure valid, reliable, and accurate findings.

Result and Discussion

The analysis results from the experimental and control classes showed improvements in learning motivation and critical thinking skills following the implementation of the 3D media based on experiential learning. The effectiveness of the media was examined by measuring the increase in students' learning motivation and critical thinking skills after using the press. The data were collected from a limited trial and analyzed using quantitative and qualitative approaches to understand the media's impact on learning and outcomes comprehensively.

Improvement in Students' Learning Motivation

In the experimental and control classes, students who completed the initial questionnaire showed

differences in scores compared to the final questionnaire after the learning process. The score differences are illustrated in Figure 2.

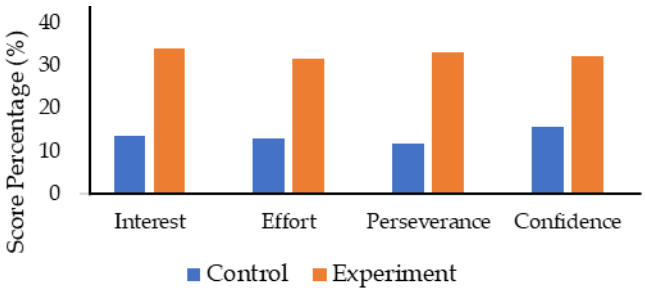

Figure 2. Diagram of Improvement in Learning Motivation of Experimental and Control Classes

The experimental class experienced a higher increase across all aspects of motivation than the control class. The highest improvement occurred in the interest aspect, which increased by 34%, followed by persistence (33%), self-confidence (32.3%), and effort (31.6%). On the other hand, the control class showed relatively low improvement, with the highest in self-confidence (15.8%) and the weakest in persistence (11.9%). Based on the percentage increase categories, the improvement in learning motivation in the experimental class falls into the high category (70.8%–85%), while the control class falls into the low category (40.8%–55%). The t-Welch test analysis supports increased learning motivation in experimental and control classes.

The Welch's t-test, used to analyze differences in students' learning motivation between the two groups, yielded a significance value (Sig. 2-tailed) of 0.000 with degrees of freedom (df) of 57.05. Welch's t-test was chosen because it does not assume equal variances between groups, making it more appropriate for data with non-homogeneous variances. The obtained significance value is below the threshold of 0.05, indicating a statistically significant difference in students' learning motivation between the two groups. The analysis was then followed by calculating the normalized gain (n-gain) to determine the effectiveness of the 3D media based on experiential learning in improving students' learning motivation. The results of the n-gain analysis are presented in Table 2.

Tabel 2. N-gain of Learning Motivation

	N-gain	(%)	Category
Control	0.3	27	Low
Experiment	0.7	70	High

In the control class, the n-gain scores ranged from 0.0 to 0.6, with an average of 0.3. This corresponds to a 27% increase and falls into the low category. This indicates that the learning approach used in the control class had a minimal impact on improving students' learning motivation. In contrast, the experimental class showed higher n-gain scores, ranging from 0.5 to 0.9, with an average of 0.7. The percentage increase reached 70%, which is categorized as high. This suggests that the treatment or learning model applied in the experimental class enhanced students' learning motivation more than the control class. Therefore, the learning model implemented in the experimental class significantly improved students' learning motivation.

Improved Critical Thinking Ability

The researchers measured students' critical thinking skills through pretest and posttest assessments to determine the effect of the 3D media based on experiential learning provided to the experimental group. The results of this measurement are presented in Figure 3, which compares scores between the control and experimental groups based on five indicators of critical thinking skills: Argumentation, Analyzing arguments, Defending facts, Evaluation, and Implementation.

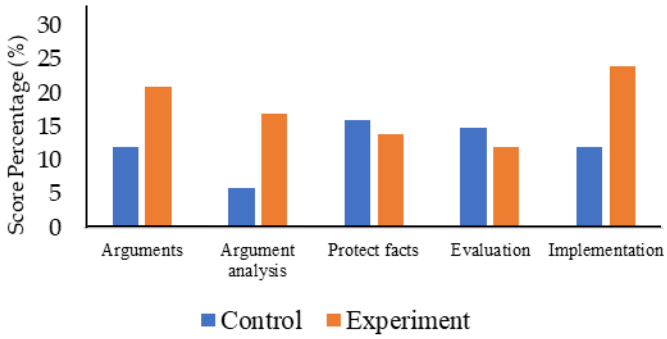

Figure 3. Diagram of Critical Thinking Improvement of Experimental and Control Classes

The percentage increase in critical thinking skills shows that, for the Argumentation indicator, the control class improved by 12% while the experimental class improved by 21%. For Analyzing Arguments, the control class increased by 6% and the experimental class by 17%. In Defending Facts, the control class saw a 16% increase compared to 14% in the experimental class. For Evaluation, the control class improved by 15% and the experimental class by 12%. Lastly, in implementation, the control class increased by 12%, whereas the experimental class showed the highest improvement at 24%. These findings are also supported by the results of the t-test analysis of students' critical thinking skills.

The significance value (Sig. 2-tailed) was 0.000 with degrees of freedom (df) of 58. This significance value is below the 0.05 threshold, indicating a statistically significant difference between the two groups. In other words, using 3D media based on experiential learning

has a real impact on improving students' critical thinking skills compared to the teaching methods used in the control group. The next step in the analysis was to calculate the n-gain scores to assess the effectiveness of the 3D media based on experiential learning in enhancing students' critical thinking abilities. The results of the n-gain calculation are presented in Table 3.

Table 3. N-gain of Critical Thinking Ability

	N-gain	(%)	Category
Control	0.3	33	Low
Experiment	0.5	50	Moderate

In the control class, the n-gain scores ranged from 0.3 to 0.5, with an average of 0.3. The percentage increase achieved was 33%, which falls into the low category. This indicates that the conventional teaching method in the control class only slightly improved students' critical thinking skills. Meanwhile, the experimental class showed better results, with n-gain scores ranging from 0.3 to 0.8 and an average of 0.5. The percentage increase reached 50%, which is categorized as moderate. These results demonstrate that using 3D media based on experiential learning has a greater impact on enhancing students' critical thinking abilities than the teaching methods used in the control class.

Discussion

The aspects of learning motivation (interest, effort, persistence, and self-confidence) showed significant improvement in the experimental group. The interest aspect increased by 34%, indicating that the 3D media based on experiential learning enhanced students' enthusiasm, independence, readiness, and interest through engaging visualizations and an enjoyable learning environment. Whereas students typically learned in classrooms or laboratories, they now use the 3D experiential learning media via a website in the computer lab, creating a new atmosphere that motivates them to engage more deeply with the material (Pratama et al., 2024). Previously, body organs were only viewed as 2D images in textbooks. Still, with 3D visualization, students demonstrated greater interest, which aligns with Teplá et al. (2022), who found that 3D models and animations significantly increase intrinsic motivation, especially regarding interest and learning effort.

The effort aspect was evident in the learning process, where students had to complete problem-solving questions for each subtopic before accessing the full content in the 3D experiential learning media. This aligns with Ningsih et al. (2019), who stated that gradual problem-solving can enhance motivation, particularly in effort. Regarding persistence, students studied the respiratory system material sequentially and completed quizzes for each subchapter, which demanded focus and consistency. This is consistent with Dayanti et al. (2023), who found that interactive media encourages persistence because students feel challenged to complete each task stage. Self-confidence in learning was observed when students worked in groups to create simple models of respiratory system teaching aids, which they then presented in front of the class. According to Susanti et al. (2022), visual media and project-based activities in science learning increase students' self-confidence and active participation by giving them control over the learning process.

Implementing 3D media based on experiential learning also impacted various aspects of students' critical thinking skills. The argumentation aspect emerged when students responded to problems presented in the narrative of the respiratory system subtopics, stimulating crucial thinking through identification, analysis, and problem-solving. This aligns with Amelia and Kurniawan (2024), who stated that argumentative texts within problem contexts enhance students' critical skills by encouraging the construction of fact- and logic-based arguments. Defending facts was observed during learning as students accessed materials through the 3D experiential learning media. While studying the organs, mechanisms, and disorders of the respiratory system via this media, students not only identified facts (such as organs and their functions) but also understood real-world issues like air pollution. This is consistent with Adiputra and Hidayah (2025), who found that this approach strengthens critical thinking by linking respiratory system facts with visual evidence through 3D media.

Students completed quizzes to assess their understanding of the respiratory system's organs, mechanisms, and disorders in the evaluation aspect. They demonstrated critical thinking evaluation skills by selecting logical answers using the 3D media. This aligns with Kusum et al. (2022), who stated that teachers evaluate students' understanding through questions or short tests after exploring the material. Figure 3 shows that the control class experienced a higher increase than the experimental class. The greater improvement in the control class was influenced by the variety of learning resources, such as the internet and supplementary books, compared to the experimental class, which only used 3D media and educational videos on the respiratory system. This affected the evaluation stage, where the experimental class experienced greater overall improvement. This occurred because students in the control class sought information from various sources during learning, giving them more comprehensive information to answer questions accurately.

The implementation aspect was observed when students applied their understanding of the organs and functions of the respiratory system by collaboratively creating teaching aid models, transforming theory into practical experience. This aligns with Wafi et al. (2022), who stated that model-making strengthens critical thinking as students actively reconstruct and test their understanding in concrete contexts. The treatment given to the experimental group significantly improved critical thinking compared to the control group. Although experiential learning builds knowledge through experience, argument analysis skills must be strengthened. Baumtrog (2015) highlighted the necessity of guided instruction in argument analysis, while Jalmo et al. (2023) emphasized the importance of additional strategies to enhance more abstract cognitive aspects optimally.

Conclusion

The use of 3D media based on experiential learning has been proven effective in increasing students' learning motivation, particularly in the aspect of Interest and critical thinking skills in the Implementation indicator. This effectiveness is supported by the Welch's t-test results, which showed a significance value of 0.000 and a higher average n-gain in the experimental group, indicating better improvement in learning motivation after using the media. The t-test results also revealed a significant difference in critical thinking skills between the experimental and control groups, with the experimental group's n-gain categorized as "moderate" and the control group's as "low".

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Author Contributions
Conceptualization, methodology, investigation, formal analysis, data curation, writing—original draft preparation, writing—review and editing, F.N.R. and supervision A.W. and E. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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