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The Effectiveness of Interactive Biology Learning Media Assisted by 3D PageFlip Professional Software in Improving High School Students' Conceptual Understanding

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Abstract: Conceptual understanding is an essential learning outcome in biology because it enables students to explain biological phenomena, connect related concepts, and apply scientific knowledge in different contexts. This study aimed to examine the descriptive improvement in high school students' conceptual understanding after learning with interactive biology learning media assisted by 3D PageFlip Professional software. The study employed a pre-experimental one-group pretest–posttest design involving 35 Grade XI students at SMAN 1 Keruak. The interactive media were integrated into discovery learning activities. Data were collected using a 21-item multiple-choice conceptual-understanding test covering the C1–C6 cognitive levels of the revised Bloom's Taxonomy. The data were analyzed descriptively by comparing pretest and posttest scores and calculating normalized gain. The students' mean score increased from 29.39 on the pretest to 76.87 on the posttest, with improvement across all cognitive levels. The normalized gain was 0.67, classified as moderate, and the N-gain percentage was 67.45%, categorized as moderately effective according to the adopted criterion. The highest gains occurred at C1 and C3, whereas C6 showed the lowest gain. These results indicate a descriptive improvement in conceptual understanding; however, because the study used a single-group design and did not report inferential testing, the findings should not be interpreted as evidence of statistical significance or causal effectiveness.

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INTRODUCTION

Biology learning requires students not only to memorize facts, terms, and definitions, but also to understand relationships among concepts, explain biological processes, interpret scientific information, and apply concepts in different situations. These abilities reflect conceptual understanding, which provides a foundation for meaningful learning and the development of scientific thinking skills. However, many biology topics are abstract, complex, dynamic, and cannot always be observed directly. Presenting material solely through verbal explanations and static learning resources may make it difficult for students to connect the concepts they are learning. Previous studies have shown that digital learning media can improve biology learning outcomes when they are aligned with the characteristics of the subject matter and students' needs (Hafzah et al., 2020; Surata et al., 2020).

Conceptual understanding is reflected not only in students' ability to state definitions, but also in their ability to explain, compare, classify, provide examples, draw conclusions, and use concepts to solve problems. Conceptual understanding can develop when students actively organize information and connect prior knowledge with new information. Activities such as self-explaining, summarizing, mapping, and interpreting representations can strengthen relationships among concepts within students' cognitive structures (Fiorella & Mayer, 2016). Active learning also produces better achievement than instruction that positions students merely as recipients of information (Deslauriers et al., 2019).

One alternative for increasing students' engagement and conceptual understanding is the use of interactive digital learning media. Such media can integrate text, images, diagrams, animations, audio, video, exercises, hyperlinks, navigation, and feedback within a single learning environment. Integrating multiple forms of representation allows students to learn concepts through verbal and visual information simultaneously. Educational technology can also enhance student engagement when interactive features are used to support cognitive activities that are relevant to the learning objectives (Bond et al., 2020). According to multimedia learning principles, well-organized words and visuals can help students select, process, and integrate information into a more coherent mental model (Mayer, 2017).

Nevertheless, the presence of multimedia elements does not automatically guarantee improved learning outcomes. Excessive information, irrelevant decorative elements, or confusing navigation can increase students' cognitive load. Interactive media should therefore apply principles such as coherence, segmentation, signaling, learner control, and feedback. Feedback in computer-based learning environments can help students identify errors and improve their understanding when it is specific and informative (van der Kleij et al., 2015). Instructional videos can also have a positive effect when used as part of structured learning activities (Noetel et al., 2021), while mobile devices can increase flexibility of access and opportunities to review learning materials (Sung et al., 2016).

Visual representations are particularly relevant to biology learning because many biological processes are microscopic, dynamic, and difficult to observe directly. Digital visualizations can help students understand cell structures, physiological processes, energy flow, population changes, and interactions within ecosystems. Research on augmented reality indicates that visual technologies can support conceptual understanding by connecting abstract information with observable objects (Akçayır & Akçayır, 2017; Ibáñez & Delgado-Kloos, 2018). Meta-analytic evidence also shows that interactive visual technologies can positively affect students' learning gains (Garzón & Acevedo, 2019).

However, greater technological sophistication and immersion do not necessarily lead to better learning outcomes. The benefits of virtual environments depend strongly on instructional design, the form of interaction, and the activities performed by students (Radianti et al., 2020). More immersive environments may even impose greater cognitive load and reduce learning achievement despite increasing interest and the sense of presence (Makransky et al., 2019). Technology should therefore be positioned as a tool that supports instruction. Hillmayr et al. (2020) showed that digital tools positively affect science learning in secondary schools when they are combined with appropriate teaching strategies and teacher guidance.

One form of interactive digital media is the e-book or flipbook, which combines reading materials with images, animations, videos, and hyperlinks. E-books can improve learning outcomes when the media design, duration of use, and instructional strategy are appropriate for students' characteristics (Wijaya et al., 2022). One software application that can be used to develop interactive flipbooks is 3D PageFlip Professional. This software allows material to be presented in a digital-book format with page-flipping effects and various multimedia components.

Several studies have shown that 3D PageFlip Professional can be used to produce learning media that are feasible, engaging, and accessible. Diani and Hartati (2018) developed a 3D PageFlip Professional-assisted flipbook that met media-feasibility criteria.

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Ferdianto et al. (2019) reported that the medium could support students' representational ability. Kurniawan et al. (2021) used the software to address limitations in science learning resources, whereas Lestari and Fitria (2023) developed an e-book that integrated instructional stages with digital information resources. The use of 3D PageFlip Professional media has also been reported to produce better cognitive learning outcomes than conventional presentation media (Abdjul et al., 2023).

In science learning, interactive media allow students to observe relationships among variables and repeatedly explore a process. Interactive simulations have been shown to support conceptual understanding because students can connect their observations with theoretical concepts (Inayah & Masruroh, 2021). These characteristics are relevant to 3D PageFlip Professional-assisted media, which can integrate text, visualizations, videos, exercises, and interactive navigation into a single learning product.

In the context of biology learning, Arifin (2024a) developed a mini virtual aquatic-ecosystem learning medium assisted by 3D PageFlip Professional. The medium digitally presented components and interactions within aquatic ecosystems and was rated practical based on teacher and student responses and the implementation of learning activities. These findings indicate that 3D PageFlip Professional can be used to visualize complex ecosystem concepts that are difficult to observe directly.

The development of this type of media has also been supported by learning tools based on the Culturally Responsive Transformative Teaching model with a Socio-Scientific Issues approach. The learning tools developed by Arifin et al. (2024b) were found to be valid and practical for connecting ecosystem concepts with cultural contexts and socio-scientific issues. Subsequently, Arifin et al. (2024c) developed a 3D PageFlip Professional-assisted ecosystem e-module that met validity criteria in terms of content, language, presentation, and media design.

Although previous studies have shown that these media and learning tools are valid, practical, and engaging, such evidence does not directly demonstrate their effectiveness in improving students' conceptual understanding. Validity reflects the appropriateness of the content and media design, whereas practicality reflects ease of use. A medium that is valid and practical does not necessarily produce a meaningful improvement in conceptual understanding. Previous studies involving 3D PageFlip Professional have also focused primarily on development, feasibility, validity, practicality, user responses, and general learning outcomes (Diani & Hartati, 2018; Kurniawan et al., 2021; Abdjul et al., 2023; Arifin, 2024a; Arifin et al., 2024b, 2024c). Therefore, research is needed to specifically examine changes in high school students' conceptual understanding after using the medium.

Changes in conceptual understanding after the use of the medium can be described by comparing scores before and after instruction. The pretest is used to describe students' initial conceptual understanding, while the posttest describes their achievement after instruction. The magnitude of relative improvement can be analyzed using normalized gain (N-gain), which compares the actual score increase with the maximum possible increase. N-gain should still be interpreted proportionally because its value can be influenced by initial scores and the distribution of the data (Nissen et al., 2018).

Based on this rationale, interactive biology learning media assisted by 3D PageFlip Professional have the potential to support conceptual understanding through the integration of text, visualizations, video, navigation, and interactive activities. However, changes in conceptual understanding after using the media need to be examined empirically. Therefore, this study aimed to analyze changes in high school students' conceptual understanding after learning with interactive biology media assisted by 3D PageFlip Professional by comparing pretest, posttest, and N-gain scores.

RESEARCH METHOD

This study evaluated changes in students' conceptual understanding after learning with interactive biology media assisted by 3D PageFlip Professional and integrated into discovery learning activities. The analysis focused on comparing conceptual-understanding scores before and after instruction and on the N-gain value.

Implementation Procedure

The study employed a pre-experimental one-group pretest–posttest design. One group of students completed a pretest (O1), participated in learning activities using interactive biology learning media assisted by 3D PageFlip Professional (X1), and then completed a posttest (O2). Because the study did not include a control group, it was not categorized as quasi-experimental. The research design is presented in Table 1 (Sugiyono, 2017).

Table 1. Research design

Pretest	Treatment	*Posttest*
O_1	X_1	O_2

Notes:
O1: Pretest administered to the experimental group before the treatment
O2: Posttest administered to the experimental group after the treatment
X1: Learning using interactive biology media assisted by 3D PageFlip Professional

The study was conducted at SMAN 1 Keruak during the 2024/2025 academic year and involved 35 Grade XI students in a single study group. All students completed the pretest, participated in learning using interactive biology media assisted by 3D PageFlip Professional integrated into discovery learning activities, and completed the posttest.

Data Collection Technique

Data on conceptual understanding were collected using a 21-item multiple-choice written test. The items were developed based on the learning objectives and covered the six cognitive-process levels of the revised Bloom's Taxonomy: C1 remembering, C2 understanding, C3 applying, C4 analyzing, C5 evaluating, and C6 creating (Anderson & Krathwohl, 2001). The same instrument was administered as both the pretest and posttest to describe changes in conceptual understanding.

Data Analysis Technique

The data were analyzed descriptively using the following procedure:

N-gain Analysis

Conceptual-understanding data were analyzed descriptively using the mean, standard deviation, and pretest–posttest score comparisons. Score improvement was analyzed using normalized gain (N-gain), which compares the actual score increase with the maximum possible increase. This analysis was used to describe the magnitude of improvement rather than to establish statistical significance.

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N-gain scores were calculated from pretest and posttest scores and interpreted using the criteria presented in Table 2 (Hake, 1999). N-gain percentages were interpreted using the effectiveness categories in Table 3. The analysis was limited to descriptive statistics and N-gain; inferential tests and effect sizes were not reported.

Table 2. N-gain criteria

Range	Category
$g < 0.3$	Low
$0.7 > g \geq 0.3$	Moderate
$g \geq 0.7$	High

(Source: Hake, 1999)

Table 3. Interpretation categories for N-gain effectiveness

Percentage (%)	Interpretation Category
<40	Ineffective
40–55	Less Effective
56–75	Moderately Effective
>75	Effective

(Sugiyono, 2017)

RESULT AND DISCUSSION

The evaluation of learning outcomes focused on changes in the conceptual understanding of Grade XI students at SMAN 1 Keruak (N = 35) after using interactive biology learning media assisted by 3D PageFlip Professional. The analysis was descriptive and based on pretest–posttest score comparisons and N-gain.

Conceptual-Understanding Pretest and Posttest Data

Conceptual understanding was measured using a 21-item multiple-choice written test developed according to the learning objectives and indicators of conceptual understanding. Descriptive statistics for the pretest and posttest scores are presented in Table 4.

Table 4. Comparison of conceptual-understanding pretest and posttest results

Conceptual Understanding	Pretest	Posttest
Mean	29.39	76.87
Standard Deviation	6.39	6.15
N (Number of Students)	35	35

Table 4 compares students' conceptual-understanding scores before and after instruction. The mean score increased from 29.39 on the pretest to 76.87 on the posttest, representing a descriptive increase of 47.48 points. Because this study did not report an inferential test, this change is interpreted as a descriptive improvement and is not claimed to be statistically significant.

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Table 5. Comparison of conceptual-understanding pretest and posttest results by indicator

Conceptual-Understanding Indicator	Pretest	Posttest
C1	57.86	92.86
C2	10.71	63.57
C3	15	81.43
C4	25	72.14
C5	33.33	78.10
C6	41.43	70
Mean	30.55	76.35
Standard Deviation	16.01	9.33
N (Number of Students)	35	35

Table 5 presents the pretest and posttest results for conceptual understanding across the six cognitive levels of the revised Bloom's Taxonomy. All indicators showed descriptive improvement. C1 increased from 57.86 to 92.86; C2 from 10.71 to 63.57; C3 from 15.00 to 81.43; C4 from 25.00 to 72.14; C5 (evaluating) from 33.33 to 78.10; and C6 (creating) from 41.43 to 70.00. The mean across all indicators increased from 30.55 to 76.35.

N-gain Analysis Results for Conceptual Understanding

N-gain was used to describe the relative improvement in conceptual-understanding scores before and after learning with interactive biology media assisted by 3D PageFlip Professional. It was calculated by comparing the actual score increase with the maximum increase that remained possible based on the pretest score. The N-gain results for conceptual understanding are presented in Table 6.

Table 6. Summary of N-gain results for conceptual understanding

No.	Component	Result	Category
1	N-gain	0.67	Moderate
2	N-gain effectiveness interpretation	67.45 %	Moderately Effective

As shown in Table 6, the N-gain for conceptual understanding was 0.67, which was classified as moderate. The N-gain percentage of 67.45% fell within the moderately effective category according to the criterion used in this study. This result describes a relative increase in scores after instruction, but it does not by itself demonstrate statistical significance or a causal relationship.

Table 7. N-gain Analysis of Conceptual Understanding for Each Indicator

Indicator	Posttest	Pretest	Post - Pretest	Ideal Score	N-gain Score	Category N-gain	(%)	N-gain Effectiveness
C1	92.86	57.86	35	42.14	0.831	High	83.06	Effective
C2	63.57	10.71	52.86	89.29	0.592	Moderate	59.20	Moderately Effective
C3	81.43	15	66.43	85	0.782	High	78.15	Effective

Indicator	Posttest	Pretest	Post - Pretest	Ideal Score	N-gain Score	Category N-gain	(%)	N-gain Effectiveness
C4	72.14	25	47.14	75	0.629	Moderate	62.85	Moderately Effective
C5	78.10	33.33	44.77	66.67	0.672	Moderate	67.15	Moderately Effective
C6	70	41.43	28.57	58.57	0.488	Moderate	48.78	Less Effective

As shown in Table 7, N-gain values differed across indicators. C1 and C3 had the highest N-gain values, 0.831 and 0.782, respectively, both in the high category. C5 had an N-gain of 0.672, followed by C4 at 0.629, C2 at 0.592, and C6 at 0.488, all in the moderate category. This variation indicates that descriptive improvement was stronger for some indicators than for others, with C6 showing the lowest relative improvement.

Discussion

Conceptual understanding was measured using 21 multiple-choice items covering C1–C6 of the revised Bloom's Taxonomy: remembering, understanding, applying, analyzing, evaluating, and creating (Anderson & Krathwohl, 2001). After instruction with interactive media assisted by 3D PageFlip Professional, the mean score increased descriptively from 29.39 to 76.87.

This increase is consistent with literature indicating that digital media can support learning when text, visualizations, video, and navigation are purposefully integrated. Multimedia learning principles emphasize that an appropriate combination of verbal and visual representations can support the selection, organization, and integration of information (Mayer, 2017). Meta-analytic findings also show that digital tools can support science learning when they are used in conjunction with appropriate teaching strategies (Hillmayr et al., 2020).

At the lower cognitive levels, both C1 and C2 improved, with C1 showing the highest posttest achievement. Improvements in C3 and C4 indicate that students not only remembered information but were also better able to apply and analyze concepts. These findings are consistent with studies of interactive media and simulations that reported support for conceptual understanding and application through visual representations and exploratory activities (Inayah & Masruroh, 2021; Abdjul et al., 2023).

The use of interactive media within discovery learning activities provided opportunities for students to explore information, observe representations, and connect new information with their existing concepts. However, the benefits of discovery learning are strongly influenced by the quality of guidance. Meta-analytic evidence indicates that discovery- and inquiry-based learning produce better outcomes when adequate guidance is provided (Lazonder & Harmsen, 2016).

Differences in improvement across indicators should be interpreted cautiously. C5 and C6 represent higher-order cognitive processes in the revised Bloom's Taxonomy. C5 refers to the ability to evaluate based on criteria, whereas C6 refers to the ability to create or develop a new product or solution (Anderson & Krathwohl, 2001). In this study, C6 had the lowest N-gain (0.488), suggesting that creating requires greater support, more time, and more complex learning activities than lower-level cognitive processes.

The N-gain analysis yielded a value of 0.67 (moderate category), with a percentage of 67.45%. N-gain is useful for describing score changes relative to the available room for

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improvement, but it should be interpreted proportionally because it may be influenced by initial scores and the distribution of the data (Nissen et al., 2018). Accordingly, the N-gain result in this study is treated as descriptive evidence of improved conceptual understanding.

The findings support the potential of 3D PageFlip Professional media as an interactive learning resource. Previous research has shown that 3D PageFlip media can produce better learning outcomes than conventional presentation media (Abdjul et al., 2023), while the development of similar media has shown that the platform can integrate text, visuals, and multimedia resources in an accessible format (Diani & Hartati, 2018; Kurniawan et al., 2021). Nevertheless, because this study involved only one group without a control group and did not report inferential testing, the findings cannot be used to establish causality or statistical significance.

CONCLUSION

Interactive biology learning media assisted by 3D PageFlip Professional were associated with a descriptive improvement in high school students' conceptual understanding in this one-group pre-experimental study. The mean score increased from 29.39 on the pretest to 76.87 on the posttest. The N-gain of 0.67 was classified as moderate, with a percentage of 67.45%, categorized as moderately effective according to the criterion used. Improvement occurred across all C1–C6 indicators, with the highest N-gain values for C1 and C3 and the lowest for C6. Because the study did not include a control group or report inferential analysis, these findings are interpreted as descriptive evidence of improved conceptual understanding rather than evidence of statistical significance or a causal relationship.

RECOMMENDATIONS

Teachers may use interactive biology learning media assisted by 3D PageFlip Professional as an alternative learning resource, particularly for biological concepts that require visual and interactive representations. Learning activities should be accompanied by sufficient guidance and practice to support higher-order cognitive processes, especially evaluating (C5) and creating (C6). Future research should employ a stronger experimental design with a comparison or control group, larger and more diverse samples, and appropriate inferential analyses and effect-size reporting. Future studies should also report complete evidence of instrument validity and reliability, scoring procedures, and the distribution of test items across the C1–C6 indicators.

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