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# Digital Flipbook Ecosystem (DFE) based on Problem-based Learning (PBL) to Improve Scientific Attitudes

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**ABSTRACT** In ecosystem learning, fostering students' scientific attitudes remains a challenge in biology education, particularly when digital learning media are primarily used to support conceptual understanding rather than scientific behavior. This study aimed to develop and implement a Digital Flipbook Ecosystem (DFE) integrated with Problem-Based Learning (PBL) to support the development of students' scientific attitudes in ecosystem learning. The study employed a Research and Development (R&D) approach using the Hannafin and Peck model, which included stages of needs analysis, design, development, validation, and limited field implementation. The developed DFE underwent content and construct validation through expert judgment before classroom implementation. Students' scientific attitudes were measured using a Likert-scale questionnaire covering curiosity, open-mindedness, respect for data, cooperation, and environmental sensitivity. Data were analyzed using descriptive statistics and N-gain analysis to examine changes in students' scientific attitudes during the implementation phase. Based on the results of statistical analysis, students who learned using the PBL-based DFE demonstrated greater improvement in several dimensions of scientific attitudes, particularly curiosity, open-mindedness, and cooperation, compared to students who learned using conventional instructional materials. These findings indicate that a systematically developed digital learning medium integrated with PBL has the potential to support the development of students' scientific attitudes alongside biology content learning. The study provides pedagogical implications for the design of technology-enhanced biology learning that emphasizes not only cognitive outcomes but also the cultivation of scientific attitudes, especially in ecosystem topics.

**Keywords** Digital flipbook ecosystem; Problem-based learning; Scientific attitudes; Digital learning media; Biology learning process; Ecosystem

## 1. INTRODUCTION

In recent years, the integration of digital technology into science education has become increasingly important to address the learning needs of 21st-century students. Digital learning media are widely promoted for their potential to enhance accessibility, visualization, and student engagement in biology learning (Batubara, 2021; Hendra et al., 2023). However, many digital learning implementations remain primarily focused on supporting conceptual understanding, with limited attention to developing students' scientific attitudes. This condition highlights the need for learning media that not only deliver content effectively but also support the cultivation of scientific dispositions essential for meaningful science learning.

One form of digital learning media that has gained attention is the Digital Flipbook Ecosystem (DFE), which presents learning materials through interactive text, images, videos, and navigation features (Adikara et al., 2021; Nuha et al., 2021). Ecosystem material was selected in this study because it is closely related to students' daily experiences and local environmental issues, such as pollution, biodiversity loss, and resource management. These characteristics make ecosystem topics particularly suitable for contextual and problem-oriented learning approaches, as they allow students to explore authentic environmental problems and connect biological concepts with real-world phenomena.

To maximize the pedagogical potential of digital media, the DFE in this study was designed by integrating the Problem-Based Learning (PBL) model. PBL emphasizes student-centered learning by engaging students with real-

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world problems that require investigation, collaboration, and critical thinking (Hmelo-Silver, 2024; Widiastuti et al., 2023). Previous studies have reported that PBL can support active learning and problem-solving skills; however, evidence regarding its systematic integration within digital flipbook media and its specific influence on students' scientific attitudes remains limited. Thus, while digital media and PBL have been widely studied independently, their combined application, particularly with an explicit focus on scientific attitudes, has not been sufficiently explored.

Scientific attitudes, such as curiosity, open-mindedness, respect for evidence, perseverance, collaboration, and environmental sensitivity, are essential components of scientific literacy and scientific reasoning (Aini et al., 2021; Waruwu & Purba, 2022). Developing these attitudes is especially important in ecosystem learning, where students are expected to analyze complex environmental systems and make evidence-based decisions. Nevertheless, traditional learning resources, including printed textbooks and conventional worksheets, often provide limited opportunities for students to actively engage with contextual environmental problems (Arika & Rachmadiarti, 2025; Kamran et al., 2023).

Based on these considerations, a research gap can be identified in the limited availability of digital learning media that explicitly integrate PBL stages and are intentionally designed to support the development of students' scientific attitudes in ecosystem learning. Therefore, this study aims to examine the effect of a Digital Flipbook Ecosystem (DFE) integrated with Problem-Based Learning (PBL) on students' scientific attitudes in biology learning. The findings of this study are expected to contribute to the design of technology-enhanced biology learning that balances conceptual understanding with the cultivation of scientific attitudes.

## 2. Method

### 2.1 Research Design

This study employed a Research and Development (R&D) approach using the Hannafin and Peck model, which consists of stages of needs analysis, design, development, validation, and field implementation. As part of the field implementation stage, the developed Digital Flipbook Ecosystem (DFE), integrated with Problem-Based Learning (PBL), was piloted in two intact classes to assess its potential impact on students' scientific attitudes.

During this stage, a pretest–posttest procedure was used to describe changes in students' scientific attitudes before and after the implementation of the DFE. One class implemented the PBL-based DFE, while another class used conventional learning materials as a comparison condition. The pretest–posttest data were used to support the evaluation of the developed product during the implementation phase, rather than to claim a pure experimental design.

**Table 1** Research design

| Class | Pretest | Treatment | Posttest |
|---|---|---|---|
| Experiment | $O_1$ | $T_1$ | $O_2$ |
| Control | $O_2$ | $T_2$ | $O_2$ |

As for what is meant by $O_1$ = implementation of pretest; T = treatment; $O_2$ = implementation of posttest

Two intact classes were involved in this study and assigned as the experimental and control groups using purposive sampling, as random assignment was not feasible. Both groups were given a pretest ($O_1$) to assess baseline equivalence before the intervention. The experimental group received treatment $T_1$, which consisted of ecosystem learning using a Digital Flipbook Ecosystem (DFE) integrated with Problem-Based Learning (PBL). The control group received treatment $T_2$ through conventional instruction using printed textbooks and teacher-led explanations without structured PBL activities or interactive digital media. After the intervention, both groups were administered a posttest ($O_2$) to measure changes in students' scientific attitudes.

Based on Table 1, this study involved an experimental group and a control group. Before the intervention, students' initial scientific attitudes in both groups were measured using a pretest ($O_1$). The experimental group then received treatment $T_1$, consisting of ecosystem learning using a Digital Flipbook Ecosystem (DFE) integrated with Problem-Based Learning (PBL). In contrast, the control group received treatment $T_2$, which involved conventional biology instruction using printed textbooks and teacher-led explanations without structured PBL activities or interactive digital media. After the intervention, students in both groups completed a posttest ($O_2$). The posttest results were compared between groups, accounting for pretest scores, to assess the effectiveness of the respective treatments.

### 2.2 Data Collection Tools

The subjects of this study were class X students in the 2024/2025 academic year at SMAN 21 Jakarta, comprising two control classes (n=60) and two experimental classes (n=60), with the following details.

**Table 2** Distribution of research subjects

| Class | Treatment | Subject |
|---|---|---|
| Experiment | DFE | 30 |
| Experiment | DFE | 30 |
| Control | Kemendikbud Textbook | 30 |
| Control | Kemendikbud Textbook | 30 |

Before its implementation during the field-testing stage of this Research and Development (R&D) study, the Digital Flipbook Ecosystem (DFE) underwent content and design validation through expert judgment. The validation focused on the accuracy of ecosystem concepts, alignment with learning objectives, integration of Problem-Based Learning (PBL) stages, clarity of learning instructions, and the functionality of digital features. Revisions were made in response to experts' feedback to ensure that the developed DFE was pedagogically sound and appropriate for classroom implementation as part of the R&D process.

Following the validation process, participants were assigned to experimental and control groups based on intact classes. The experimental class consisted of two classes of students in grades X7 and X6, who were involved in the DFE implementation. The control class consisted of two classes of students in grades X2 and X3, intervening in the Ministry of Education and Culture's textbook (Kemendikbud) implementation. Tenth-grade students were selected for this study using purposive sampling, based on several considerations, including the relevance of ecosystem material to the tenth-grade curriculum, students' academic abilities, and the relative homogeneity of the student population.

### 2.3 Instrument

The scientific attitude questionnaire used in this study was adapted from established scientific attitude frameworks reported in previous studies and subsequently modified to suit the context of ecosystem learning and the characteristics of the participants. The initial instrument consisted of 60 items covering six dimensions of scientific attitudes: (1) critical thinking, (2) curiosity, (3) respect for data, (4) perseverance, (5) open-mindedness, and (6) environmental sensitivity. Responses were measured using a four-point Likert scale (4–3–2–1) to avoid neutral responses and encourage clear attitudinal tendencies.

The instrument underwent a content validity process through expert judgment, involving experts in biology education and educational measurement, to examine the relevance, clarity, and alignment of items with the intended constructs. Following this process, item validity analysis was conducted using empirical data, resulting in 35 valid items retained for further analysis. The reliability of the validated instrument was assessed using internal consistency analysis, yielding a Cronbach's alpha coefficient of 0.964, which indicates very high reliability.

### 2.4 Data Analysis Techniques

The obtained research data were then analyzed using the data prerequisite tests (normality and homogeneity), descriptive tests, feasibility tests, and effectiveness tests, with value grading (N-gain).

Data analysis in this study examined the effect of the Digital Flipbook Ecosystem (DFE) integrated with Problem-Based Learning (PBL) on students' scientific attitudes. Normality and homogeneity tests were performed to determine whether the data met the assumptions required for subsequent statistical analyses. Descriptive statistics were used to summarize students' scientific attitude scores before and after the intervention in both groups.

To examine changes in scientific attitudes, N-gain analysis was employed to measure the magnitude of improvement within each group. In addition, inferential statistical tests were conducted to compare posttest results between the experimental and control groups while considering pretest scores. These analyses were carried out to provide a comprehensive evaluation of the impact of the PBL-based DFE on students' scientific attitudes.

### 2.5 Research Procedures

This study was conducted in three stages: an initial stage involving preliminary research and needs analysis, an implementation stage, and a final stage measuring the treatment's impact. The research procedures are presented in Figure 1.

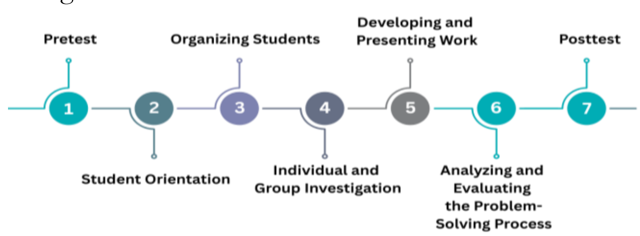


**Figure 1** Research procedures

Figure 1 presents the sequence of research procedures conducted in this study. The pretest stage involved several steps, including instrument preparation, a brief orientation for students, the administration of the scientific attitude questionnaire to both groups, and the scoring of students' responses to establish baseline equivalence. The treatment stage consisted of implementing the learning intervention, in which the experimental group learned ecosystem material using the Digital Flipbook Ecosystem (DFE) integrated with Problem-Based Learning (PBL). In contrast, the control group received conventional instruction. Learning activities in the experimental group followed the main PBL phases, including problem orientation, investigation, solution development, and reflection. The posttest stage involved re-administering the validated scientific attitude questionnaire, scoring the responses, and compiling the data for analysis. The comparison of pretest and posttest results was then used to examine changes in students' scientific attitudes resulting from the intervention.

## 3. RESULT AND DISCUSSION

This study examines the application of Digital Flipbook Ecosystem (DFE) learning media integrated with Problem-Based Learning (PBL). Before implementation, the DFE demonstrated content and design validity, as confirmed through expert judgment, indicating that the ecosystem material, digital features, and integration of PBL stages were appropriate for biology learning. During classroom implementation, the DFE functioned as intended across various digital devices, allowing students to consistently access interactive content, problem scenarios, and learning activities. The validated design of the DFE supports the credibility of the learning intervention and provides a sound basis for interpreting its effects on students' scientific attitudes.

### 3.1 Result

The Digital Flipbook Ecosystem (DFE) implemented in this study was designed to guide students through the stages of scientific learning, rather than merely presenting compiled ecosystem content. Learning activities embedded in the DFE followed inquiry-oriented processes aligned with Problem-Based Learning (PBL), including problem identification, question formulation, information exploration, evidence analysis, data interpretation, and reflection. Ecosystem topics, such as components, interactions, energy flow, and biogeochemical cycles, were presented through contextual problem scenarios that required students to observe phenomena, analyze information, and draw evidence-based conclusions. Through these structured scientific stages, the DFE functioned as a learning environment that supported the development of scientific attitudes, including curiosity, open-mindedness, respect for data, perseverance, and environmental sensitivity.


**Figure 2** a) b) Examples of the Digital Flipbook Ecosystem (DFE): (a) concept map section illustrating relationships among ecosystem concepts, and (b) content section presenting contextual ecosystem problems integrated with inquiry-oriented activities—source: Author's own documentation.

Information supporting the DFE content was collected, followed by the drafting of the DFE. This study employed a Research and Development (R&D) approach using the Hannafin and Peck model, which consists of three main stages: needs analysis, design, and development, accompanied by continuous evaluation and revision. The DFE creation phase involved several steps: first, creating the DFE cover and template; second, packaging the DFE; and third, finalizing the DFE. Each step contributed to a cohesive development process leading to material assembly. These steps formed the overall workflow for developing the DFE materials.

The preparation of the Digital Flipbook Ecosystem (DFE) in this study was not intended as a media development process following a research and development (R&D) or design-based research (DBR) framework. Instead, the DFE was structured as a learning intervention designed to support scientific learning stages aligned with Problem-Based Learning (PBL). Inquiry processes, including problem identification, the formulation of investigable questions, the exploration of information sources, the analysis of evidence, the interpretation of findings, and reflection, guided the organization of ecosystem content. Design elements such as layout, multimedia selection, and navigation were implemented to facilitate these scientific stages during learning activities, rather than serving as the study's primary focus. Through this approach, the DFE functioned as a pedagogical tool that supported students' engagement in scientific inquiry and the development of scientific attitudes.

Following the completion of the initial design stage, the Digital Flipbook Ecosystem (DFE) was developed by organizing ecosystem learning materials sourced from biology textbooks and peer-reviewed scientific literature. The selection of materials was based on conceptual accuracy, relevance to ecosystem learning objectives, and appropriate depth for senior high school students. The content was presented through a combination of text, images, and videos and integrated with Problem-Based Learning (PBL) activities designed to guide students through the stages of scientific inquiry, including problem identification, investigation, evidence analysis, and reflection.

As part of the development process, the DFE underwent content and construct validation through expert judgment, followed by revisions to improve conceptual clarity and pedagogical alignment. In addition, evaluative


a b

**Figure 3** a) Example of a product in the Digital Flipbook Ecosystem edition in the content section b) Example of a product in the Digital Flipbook Ecosystem edition in the glossary section. Source: Author's own documentation.

components, such as multiple-choice and descriptive questions, were embedded to support learning reflection and assessment.

The development of the Digital Flipbook Ecosystem (DFE) followed a Research and Development (R&D) approach using the Hannafin and Peck model, which emphasizes needs analysis, design, development, and continuous evaluation. The FlipHTML5 platform was utilized only as a technological tool to implement the designed learning media, enabling the integration of videos, hyperlinks, images, and interactive navigation in a digital book format. The use of this platform did not determine the instructional design; rather, it supported the realization of learning activities structured around the Problem-Based Learning (PBL) and scientific inquiry stages.

The learning content embedded in the DFE was derived from peer-reviewed scientific articles, biology textbooks aligned with the national curriculum, and authoritative academic references to ensure conceptual accuracy and relevance. During the development stage, the DFE underwent expert validation, including assessments of content and construct validity and media suitability. Following revisions in response to expert feedback, product trials were conducted with certified biology teachers and biology education lecturers to evaluate the practicality and instructional clarity of the developed media.

PBL-based flipbooks were used in experimental classes X-6 and X-7, while control classes X-2 and X-3 used e-books from the Ministry of Education and Culture (Kemendikbud) with a scientific approach. To compare scientific attitudes, pretests and posttests were given to each group.

Before the lesson, the teacher administered a pretest on ecosystem concepts using the Digital Flipbook Ecosystem (DFE). After the pretest, the teacher posed problem-oriented guiding questions to activate students' prior knowledge and introduce contextual ecosystem issues as part of the problem-orientation stage of Problem-Based Learning.

a b

**Figure 4** Classroom implementation of the learning intervention: (a) teacher administering the pretest and providing instructions before learning activities, and (b) students engaging with learning materials during the instructional process.

Source: Author's own documentation.

Following the pretest and initial discussion, students entered the first phase of Problem-Based Learning, namely problem orientation. In this phase, students did not merely observe photos and videos presented in the Digital Flipbook Ecosystem (DFE); rather, they engaged in guided inquiry activities embedded within the media. The DFE presented contextual photos and videos of local environmental phenomena accompanied by guiding questions and prompts that required students to identify problems, describe observable evidence, and articulate factual issues based on real situations.

Unlike the Kemendikbud textbook, which primarily presents static images and explanatory text, the DFE integrated multimedia representations with interactive prompts that encouraged students to analyze phenomena and formulate initial problem statements actively. This interactive and inquiry-oriented process distinguished the

DFE-based learning activities from conventional textbook-based instruction and supported students' engagement in the early stages of scientific inquiry.

Once the orientation phase is complete, phase 2, "Organizing Students," begins. The teacher divides students into groups. Each group member prepares the previously distributed Student Worksheets (DFE), and then the teacher distributes them to each group. Students are guided to understand the Student Worksheet, and if anything is unclear about its completion, the teacher explains the rules. Students are given 20 minutes for this process.

a b

**Figure 5** a) The Students Work on the Student Worksheet with Guidance from the Teacher. b) The Teacher Provides a Posttest

During Phase 3 of Problem-Based Learning, namely Guiding Individual and Group Investigation, students in the experimental class engaged in collaborative investigations supported by the Digital Flipbook Ecosystem (DFE). The teacher facilitated group discussions, encouraged information exchange, and guided students in completing structured worksheets embedded in the DFE. Students were prompted to analyze information, discuss evidence, and align their activities with the inquiry process. In contrast, students in the control class conducted learning activities using conventional worksheets and textbook-based discussions, which focused primarily on completing assigned tasks without structured inquiry prompts or interactive media support.

In Phase 4, Developing and Presenting Work Results, students in the experimental class presented their findings using DFE-supported materials, received peer and teacher feedback, and refined their responses through guided discussion. Meanwhile, presentations in the control class were delivered through oral explanations of textbook content, with limited use of visual or interactive support. These differences in learning processes influenced the level of student engagement and interaction observed between the two classes.

The final phase, Analyzing and Evaluating the Problem-Solving Process, involved reflection and conclusion drawing in both groups. However, the experimental class used reflective prompts embedded in the DFE to evaluate their problem-solving strategies, whereas in the control class, reflection was mainly guided verbally by the teacher. Although both classes showed improvements in scientific attitudes, the experimental class demonstrated higher average gains, as presented in Table 3.

**Table 3** Descriptive analysis

| Class | | Indicator | | | | | |
|---|---|---|---|---|---|---|---|
| | | Mean | Min | Max | SD | Gain Score | N-gain |
| Experiment | Pretest | 71.83 | 40.00 | 90.00 | 21.08 | 31.63 | 48.81% |
| | Posttest | 85.58 | 76.00 | 100.00 | 5.90 | | |
| Control | Pretest | 75.23 | 10.00 | 90.00 | 16.51 | 26.84 | 39.06% |
| | Posttest | 81.78 | 73.00 | 92.00 | 4.59 | | |

Based on Table 3, the average pretest scores of the experimental and control classes were relatively similar, indicating comparable initial levels of students' scientific attitudes. After the intervention, the experimental class showed higher average posttest scores and higher minimum and maximum scores than the control class. This result indicates a greater improvement in students' scientific attitudes in the experimental class following the implementation of the PBL-based Digital Flipbook Ecosystem, as reflected by descriptive score comparisons. The standard deviation (SD) indicates how spread out the data is from the mean. A higher SD value in the experimental group indicates that students' scientific attitude abilities were more varied than those in the control group.

The difference in students' scientific attitude abilities scores in the pretest and posttest after implementing PBL-based Flipbooks in the experimental class and using the scientific approach in the control class shows a gain score. The higher the gain score, the greater the increase in students' scientific attitude abilities. The N-gain analysis provides information on the relative magnitude of improvement in students' scientific attitudes across groups. The experimental class obtained a higher N-gain value than the control class, indicating a greater relative improvement following the learning intervention. This difference suggests that students in the experimental class benefited more from learning activities that emphasized problem-based inquiry, structured investigation, and reflection through the Digital Flipbook Ecosystem (DFE).

In contrast, the lower N-gain observed in the control class may be related to learning activities that were primarily focused on content delivery, with fewer opportunities for guided inquiry and collaborative problem-solving.

Although the N-gain results indicate a tendency toward greater improvement in the experimental class, further statistical testing would be required to confirm the significance of these differences. The N-gain value in the experimental class is greater than in the control class. The greater the N-gain value, the more effective the learning method is at improving students' scientific attitudes.

**Table 4** Normality test results

| Class | Data | α | Sig | Notes |
|---|---|---|---|---|
| Control | Pretest | 0.05 | 0.20 | Normal Data |
| | Posttest | 0.05 | 0.20 | |
| Experiment | Pretest | 0.05 | 0.17 | |
| | Posttest | 0.05 | 0.20 | |

Table 4 shows the results of the normality test. It shows that the significance values for all classes exceed the α level. It indicates that the data are normal, allowing the homogeneity test to be performed.

**Table 5** Homogeneity test results

| Data | $F_{count}$ | $F_{table}$ | Notes |
|---|---|---|---|
| Pretest | 1.62 | 3.15 | Homogen |
| Posttest | 1.65 | 3.15 | Data |

Table 5 shows the results of the homogeneity test by the F-test (Fisher) method. They indicate that both data sets have smaller Fcounts than Ftables. Therefore, both data sets are homogeneous. Based on the normality and homogeneity tests, the requirements for conducting a t-test are met.

**Table 6** Paired t-test results

| Class | Mean | | $t_{count}$ | $t_{table}$ | df | α |
|---|---|---|---|---|---|---|
| Control Class | Pretest | 75.23 | 4.58 | 0.68 | 59 | |
| | Posttest | 88.78 | | | | |
| Experiment Class | Pretest | 71.83 | 6.25 | 0.68 | 59 | |
| | Posttest | 85.58 | | | | |

Table 6 displays the results of the paired t-test, which show that both the control and experimental classes had calculated t-values greater than the t-table values for degrees of freedom (df) and the significance level (alpha). A t-value higher than the t-table indicates that the difference between the pretest and posttest averages in each group is statistically significant. That is to say, the treatment given to the group significantly impacted student learning outcomes. Therefore, it can be concluded that the applied learning model effectively improves learning outcomes in both the control and experimental groups, based on the two learning models tested.

**Table 7** Independent t-test results

| | $t_{count}$ | df | $t_{table}$ | α | Notes |
|---|---|---|---|---|---|
| Posttest control experiment | 5.11 | 118 | 1.98 | 0.05 | significant |

Table 7 shows the results of the independent t-test. Based on the table, there is a significant difference in the average posttest scores between the control and experimental groups. It is indicated by the t-count scores, which far exceed the t-table scores in both degrees of freedom (df) and significance level (alpha). Thus, the difference in posttest results between the two groups was not due to chance, but rather reflected that the learning treatment given to the experimental group led to greater improvement than in the control group. These results suggest that the learning method implemented in the experimental group is perceived as more effective in improving student achievement than that in the control group. Therefore, it can be concluded that the use of DFE in the experimental class is more effective than the use of e-books in the control class.

**Table 8** Scientific attitude analysis

| No | Data | Mean | | | | Gain Score | N-Gain |
|---|---|---|---|---|---|---|---|
| | | Pretest | SD | Posttest | SD | | |
| 1 | Critical | 77.5 | 26.46 | 89.28 | 44.03 | 11.78 | 15% |
| 2 | Curious | 64.5 | 11.80 | 87.28 | 19.77 | 22.78 | 35% |
| 3 | Respecting data | 75.43 | 15.47 | 94.56 | 25.72 | 19.13 | 25% |
| 4 | Preserving | 74.34 | 17.42 | 80.89 | 28.95 | 6.55 | 9% |
| 5 | Open-minded and teamwork oriented | 69.82 | 13.32 | 95.26 | 18.08 | 25.44 | 36% |
| 6 | Sensitive to the environment | 77.58 | 17.27 | 98.30 | 28.46 | 20.72 | 27% |

Table 8 shows varying improvements across the scientific attitude indicators. This improvement implies that the learning implemented not only focuses on cognitive aspects but also develops students' attitudes and tendencies to think critically consistently in various learning situations and everyday life.

## 3.2 Discussion

This study examined the effect of implementing a PBL-based Digital Flipbook Ecosystem (DFE) on students' scientific attitudes. Based on the descriptive analysis presented in Table 3, students in the experimental class demonstrated higher average posttest scores, as well as higher minimum and maximum scores, than those in the control class. In addition, the experimental class showed a lower standard deviation, indicating a more even distribution of scientific attitude scores among students. These findings suggest that learning activities supported by interactive digital media and structured problem-based inquiry may contribute to more consistent development of students' scientific attitudes compared to conventional instruction. However, these conclusions are based on descriptive comparisons and do not represent statistical significance (Mutiani et al., 2024; Tobin et al., 2024).

The decrease in standard deviation (SD) in the experimental group illustrates that variation in critical thinking skills among students decreased after the treatment, indicating that PBL-based flipbooks not only increase the average ability but also help students with low initial abilities develop significantly. It is supported by Nuha et al. (2021), who found that the PBL-based flipbook model is effective in improving critical thinking skills and equitable student learning outcomes, especially in the analysis, evaluation, and solution-creation indicators (Nuha et al., 2021; Song & Cai, 2024).

Based on the results of the analysis prerequisite tests shown in Tables 4 and 5, the research data meet the requirements to continue parametric statistical analysis. The Kolmogorov-Smirnov test indicated that the data were normally distributed. Furthermore, the homogeneity test using the $F_{\text{test}}$ showed that the $F_{\text{count}}$ was less than the $F_{\text{table}}$ value in both the pretest and posttest data, indicating that the variances of the two groups were homogeneous. The fulfillment of these two prerequisites is very important because it enables the use of more accurate parametric statistical tests to analyze the effectiveness of the given treatment (Novia et al., 2025; Zhou et al., 2023).

The higher N-gain value in the experimental group compared to the control group indicates that students learning with PBL-based flipbooks were more effective in improving their critical thinking skills. It is in line with a study by Muda et al. (2024), which found that the use of interactive digital media in problem-based learning can significantly increase the gain score in the subject's critical thinking, particularly in the interpretation and inference aspects (Muda et al., 2024).

Normal data distribution is a prerequisite for the validity of parametric statistical analysis. A preceding study shows that the Kolmogorov-Smirnov test is a reliable method for assessing data normality, especially in educational research with relatively small to moderate sample sizes (Marleni et al., 2024; Munadhiroh et al., 2024). Another study has also used the Shapiro-Wilk test as an alternative, which is more sensitive for small samples (Usmandi, 2020). The fulfillment of the homogeneity requirement in this study indicates that the observed differences between the experimental and control groups were due to the treatment administered, not to differences in baseline characteristics between the groups (Zhou et al., 2023).

Based on the results of the paired t-test presented in Table 6, it can be concluded that there is a significant difference between the pretest and posttest scores on scientific attitudes in both the control and experimental classes. These results imply that the learning implemented, whether using a science-based e-book or a PBL-based flipbook, is equally effective in improving students' scientific attitudes. However, the improvement in the experimental class is more pronounced, as indicated by the calculated t-value, which exceeds the t-table value for both indicators in both groups.

The paired t-test results on the use of PBL-based flipbooks show a significance value of <0.05. There is a significant difference in the average scores between students' pretest and posttest results for their critical thinking skills. It aligns with the N-gain test and paired t-test, and finds that PBL-based flipbooks, validated by media, material, and language experts, are feasible and effective for improving critical thinking (Putri & Pratiwi, 2025). This finding is consistent with previous studies that have confirmed the effectiveness of the flipbook-based PBL model in improving students' scientific attitudes.

Based on the results of the independent t-test presented in Table 7, it can be concluded that there is a significant difference in the posttest scientific attitudes between the control and experimental groups. The t-count scores for both indicators are much higher than the t-table value. It signifies that the use of PBL-based flipbooks in the experimental group, compared to the use of scientific approach-based e-books in the control group, has a greater impact on improving scientific attitudes. These results align with prior studies showing that the PBL model, assisted by flipbooks, is effective in improving literacy and student learning outcomes, with a two-sample t-test indicating significant differences between the experimental and control classes (Dwiyanti, 2025; Irvy, 2020).

Table 8 shows an increase in each indicator of students' scientific attitudes following the implementation of Problem-Based Learning (PBL) with flipbooks. This increase occurred across all dimensions of scientific attitudes: critical thinking, curiosity, respect for data, perseverance, open-mindedness, willingness to collaborate, and environmental sensitivity. It indicates that learning that not only focuses on cognitive aspects but also develops scientific attitudes and tendencies can encourage students to think critically consistently across various learning situations and daily life.

In the pretest data, several aspects of scientific attitudes, such as "critical attitude" and "environmental sensitivity," had developed significantly, while "curiosity" and "open-mindedness and willingness towards cooperation" remained moderate. After the learning process, all indicators showed increases in average scores, with the largest increases in "environmental sensitivity" and "open-mindedness and willingness towards cooperation." This improvement demonstrates that PBL-based learning is highly effective in fostering a more comprehensive scientific attitude, not only in students' critical thinking and environmental sensitivity, but also in their open-mindedness, willingness to cooperate, and curiosity.

The decrease in standard deviations across most indicators also indicates that nearly all students experienced a uniform improvement in scientific attitudes. It indicates that the implemented learning strategies were not only effective for some students but also facilitated the development of scientific attitudes in all students, both those with high and low initial abilities. This finding aligns with research by Nurhaedah et al. (2022) suggesting that indicators of scientific attitudes, such as curiosity and open-mindedness, can be developed effectively through active and collaborative learning (Nurhaedah et al., 2022).

In terms of curiosity, DFE includes activities that can stimulate questions. The students ask questions prompted by the stimulus presented during learning activities. With its engaging design and activities, DFE captures students' attention, encouraging them to be more active in the learning process (Aytekin et al., 2005; Liu et al., 2023).

Regarding respect for facts and data, applying PBL-based DFE can effectively foster students' respect for them. It is proven when students engage in DFE-centered learning activities. Table 8 shows that students in the experimental class value facts and/or data more during the learning process. With DFE, students are encouraged to engage in collaborative activities that allow them to collect, analyze, and present data accurately (Agustina & Fitrihidajati, 2020).

In relation to critical thinking, the use of PBL-based DFE can encourage students not to feel satisfied with the answers they find easily. DFL encourages students to question and explore potentially questionable statements continually. Research supports the finding that when students are confronted with new information or changes in their understanding of ecosystems, they are encouraged to inquire further, dig deeper, and not ignore data, even if it seems small or trivial. Students' enthusiasm for seeking answers is a key driver of this process, creating an engaging and inquisitive learning environment (Landina & Agustiana, 2022).

In conjunction with an open-minded and cooperative attitude, students are encouraged to collaborate in groups during PBL-based DFE practice. Students can share ideas and receive suggestions from their peers. Research has shown that students value suggestions and criticism from peers, making them more comfortable expressing their views and listening to others' perspectives (Noviani et al., 2023). Active participation in groups not only strengthens students' understanding of the material in ecosystems but also teaches the values of cooperation and mutual respect (Saragih & Purwanti, 2025).

Regarding perseverance, students in PBL-based DFE learning projects are encouraged to complete each assigned task, such as open-ended problems or case studies. If students encounter difficulties, they are encouraged to keep trying to find solutions by discussing with their group members. Yet students need to respect their peers' opinions and findings. By listening to and appreciating others' contributions, students learn that every idea has value, which can enrich group learning (Irmayanti et al., 2024; Ristanto et al., 2020).

Environmental sensitivity: PBL-based DDE advocates that students pay attention to events occurring around them, such as weather changes, the presence of flora and fauna, and the impact of human activities on ecosystems. It encourages students to be more sensitive to the surrounding environmental conditions. Furthermore, this learning model also emphasizes the importance of maintaining a clean school environment. By involving students in activities related to cleanliness and environmental preservation, students learn to be responsible and help maintain the cleanliness of their learning spaces (Lestari et al., 2023; Ramandani et al., 2023).

Other research has also presented similar findings that discussion methods and problem-based learning models can significantly improve scientific attitude indicators, such as students' open-mindedness, curiosity, and critical thinking (Anastasha & Movitaria, 2019; Golden, 2023). Consistent research confirms that implementing the PBL model increases the average scientific attitude score from adequate to excellent, with almost all students meeting the scientific attitude mastery criteria (Chand, 2023; Darling-Hammond et al., 2020).

## 4. CONCLUSION

The Problem-Based Learning (PBL) Digital Flipbook Ecosystem (DFE) has shown greater effectiveness than conventional instruction in enhancing students' scientific attitudes in the biology learning process. By integrating engaging multimedia content and real-world problem-solving scenarios, DFE not only enhances students' understanding of ecosystem concepts but also significantly fosters key scientific dispositions such as curiosity, open-mindedness, respect for data, perseverance, and environmental sensitivity. Empirical evidence shows that students using DFE as a learning model show greater improvements in scientific attitude indicators than those using conventional resources, highlighting the potential of DFE to create more dynamic, accessible, and impactful science learning experiences for 21st-century learners.

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## REFERENCES

Adikara, G. J., Kurnia, N., Adhrianti, L., Astuty, S., Wijayanto, X. A., Desiana, F., & Astuti, S. I. (2021). Aman Bermedia Digital (G. J. Adikara & N. Kurnia, Eds.; 1st ed., Vol. 1). Direktorat Jenderal Aplikasi Informatika.

Agustina, D. W., & Fitrihidajati, H. (2020). Development of Flipbook Based on Problem based Learning (PBL) In Environmental Pollution Submaterial to Train The Critical Thinking Skills of 10 Th Grades High School Students BioEdu Berkala Ilmiah Pendidikan Biologi, 9(1), 325–33. https://doi.org/10.26740/bioedu.v9n2.p325-339

Aini, K., Megawati, & Rojayanti, N. (2021). Membekalkan Pengetahuan Prosedural dan Sikap Ilmiah Kepada Siswa SMA melalui Pembelajaran Virutal Laboratory. Jurnal Program Studi Pendidikan Biologi, 11(1), 39–48.

Anastasha, D. A., & Movitaria, M. A. (2019). Constructivist Learning Approach to Improve Student Response and Outcomes. Innovation in Islamic Education: Challenges and Readiness in Society, 5, 73–78.

Aprilia Putri, F., & Ari Pratiwi, I. (2025). The Effectiveness of the Problem based Learning (PBL) Model Assisted by Flipbook Media on Improving the Learning Outcomes of Pancasila Education Grade 4 SDN 1 Datar. Taxonomy: Journal of Elementary Education Research, 5(1), 1–11. https://doi.org/10.35326/taksonomi.7057

Arika, F. Z., & Rachmadiarti, F. (2025). Pengembangan Flipbook Berbasis Problem Based Learning pada Materi Ekosistem untuk Melatihkan Literasi Sains Siswa. BioEdu: Berkala Ilmiah Pendidikan Biologi, 14(1), 123–127. https://ejournal.unesa.ac.id/index.php/bioe

Aytekin, Mehmet, Fahme, & Hatice. (2005). A New Model for the World of Instructional Design: A New Model. The Turkish Online Journal of Educational Technology-TOJET, 4(3), 1–7.

Batubara, H. H. (2021). Media Pembelajaran Digital. PT. Remaja Rosdakarya.

Chand, S. P. (2023). Constructivism in Education: Exploring the Contributions of Piaget, Vygotsky, and Bruner. International Journal of Science and Research (IJSR), 12(7), 274–278. https://doi.org/10.21275/sr23630021800

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for Educational Practice of the Science of Learning and Development. Applied Developmental Science, 24(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

Dwiyanti, P. B. (2025). E-Book based Problem based Learning to Improve Student's Critical Thinking in Science Learning in Elementary School. Jurnal Ilmiah Pendidikan Guru Sekolah Dasar, 1(1), 41–57. https://journal.unj.ac.id/unj/index.php/pgsd/

Golden, B. (2023). Enabling Critical Thinking Development in Higher Education Through the Use of a Structured Planning Tool. Irish Educational Studies, 42(4), 949–969. https://doi.org/10.1080/03323315.2023.2258497

Hendra, Afriyadi, H., Tanwir, Prakasa, Y. F., Hasibuan, R. P. A., & Asyhar, A. D. A. (2023). Media Pembelajaran Berbasis Digital (Vol. 1). PT. Sonpedia Publishing Indonesia.

Hmelo-Silver, C. E. (2024). Problem-Based Learning: What and How Do Students Learn? Educational Psychology Review, 16(3), 235–266.

Irmayanti, A., Damayanti, R., Wahyuni, A., Putra, A. P., Fajeriadi, H., Lisda, L. J., Zaini, M., Ayu, D., & Nia, A. (2024). Perbandingan penerapan metode Simulasi dan Problem-Based Instructional Untuk Meningkatkan Pemahaman Siswa Pada Materi Ekosistem. Study Program of Biology Education, 1(2), 61–65. https://doi.org/10.20527/bioco.v1i2.13822

Irvy, I. I. (2020). Understanding the Learning Models Design for Indonesian Teacher. International Journal of Asian Education, 1(2), 95–106. https://doi.org/10.46966/ijae.v1i2.40

Kamran, F., Kanwal, A., Afzal, A., & Rafiq, S. (2023). Impact of Interactive Teaching Methods on Students Learning Outcomes at University level. Journal of Positive School Psychology, 7(7), 89–105. https://www.researchgate.net/publication/372289203

Landina, I. A. P. L., & Agustiana, I. G. A. T. (2022). Meningkatkan Berpikir Kritis Siswa melalui Media Pembelajaran Flipbook berbasis Kasus pada Muatan IPA. Mimbar Ilmu, 27(3), 443–452. https://doi.org/10.23887/mi.v27i3.52555

Lestari, D. A., Wakhyudin, H., Nursyahidah, F., & Istikomah, A. (2023). Efektifitas PBL terhadap Kemampuan Pemecahan Masalah Ekosistem. Journal on Education, 05(04), 13026–13034. https://doi.org/https://doi.org/10.31004/joe.v5i4.2301

Liu, F., Wang, X., & Izadpanah, S. (2023). The Comparison of the Efficiency of the Lecture Method and Flipped Classroom Instruction Method on EFL Students' Academic Passion and Responsibility. SAGE Open, 13(2), 1–15. https://doi.org/10.1177/21582440231174355

Marleni, Rahayu, A., & Hermansah, B. (2024). The Influence of the Problem Based Learning Model on Students' Learning Outcomes. ESTEEM: Journal of English Study Programme, 7(2), 334–347.

Muda, Mhd. A. M., Siburian, J., & Musli. (2024). Improving Students' Critical Thinking Skills Using Multimedia in a Problem-Based Learning Model (PBL): A Narrative Review. Jurnal Ilmu Pendidikan (JIP) STKIP Kusuma Negara, 16, 245–265. https://doi.org/10.37640/jip.v16i2.2179

Munadhiroh, M., Elsafitri, R., Fibriana, N., & Ningsih, N. M. (2024). The Effect of Project Based Learning Assisted by Manipulative Learning Media on the Understanding of Elementary School Students. Advanced Journal of Education and Religion, 1(2), 91–101.

Mutiani, M., Syarifuddin, S., Syaharuddin, S., Hassan, M. I. bin A., Jumriani, J., & Nur'aini, F. (2024). The Effectiveness of Flipbook-Based Blanded Leaning Technology on Thinking Skills and Student Learning Outcomes. International Journal of Social Learning (IJSL), 5(1), 264–275. https://doi.org/10.47134/ijsl.v5i1.350

Novia, D., Husaeni, A., Rangga Gintara, A., Firdha Nabila, G., & Nursalman, M. (2025). Mengungkap Pentingnya Uji Normalitas dan Homogenitas dalam Penelitian: Studi Kasus dan Aplikasinya. Jurnal Pendidikan Tambusai, 9(1), 829–839.

Noviani, R., Nugraha, E., & Rustandi, A. (2023). Penerapan Model Problem Based Learning Berbantuan Flipbook Dalam Pembelajaran Membaca Pemahaman Teks Iklan Pada Peserta Didik Kelas VIII SMP Negeri 25 Kota Bandung. JISPENDIORA: Jurnal Ilmu Sosial, 2(2), 143–157. https://doi.org/10.56910/jispendiora.v2i2.665

Nuha, U., Wahyuni, S., Budiarso, A. S., Hasanah, U., & Anggraeni, N. E. (2021). The Effectiveness of Flipbook and Video to Improve Students' Critical Thinking Skills in Science Learning during the COVID-19 Pandemic. Lensa: Jurnal Kependidikan, 9(1), 32–37. https://doi.org/10.33394/j

Nurhaedah, Hartoto, & Amalia, N. I. (2022). The Effect of Problem-based Learning Model on Students' Outcomes in Learning Natural Science of 5th Grade at UPT SDN 104 Tontonan Anggeraja District, Enrekang Regency. (IJEST) International Journal of Elementary School Teacher, 2(1), 39. https://doi.org/10.5937/IJESTxxx

Ramandani, R., Lestari, N. A., Budiarto, E., Fitri, R., & Uulaa, R. (2023). Problem Based Learning Modules in Environmental Education to Improve Problem Solving Ability. International Journal of Research and Community Empowerment, 02(1), 1–13. https://doi.org/10.58706/ijorce

Ristanto, R. H., Rusdi, Mahardika, R. D., Darmawan, E., & Ismirawati, N. (2020). Digital Flipbook Imunopedia (DFI) A Development in Immune System e-Learning Media. International Journal of Interactive Mobile Technologies, 14(19), 140–162. https://doi.org/10.3991/ijim.v14i19.16795

Saragih, P. P., & Purwanti, P. D. (2025). Penerapan Media Flipbook Berbasis Problem Based Learning (PBL) Upaya Peningkatan Sikap Gotong Royong. BasicEdu, 9(1), 82–96. https://doi.org/10.31004/basicedu.v9i1.9107

Song, H., & Cai, L. (2024). Interactive learning environment as a source of critical thinking skills for college students. BMC Medical Education, 24(1). https://doi.org/10.1186/s12909-024-05247-y

Tobin, B., Farren, M., & Crotty, Y. (2024). Impacting Teaching and Learning Through Collaborative Reflective Practice. Educational Action Research. https://doi.org/10.1080/09650792.2024.2394933

Usmandi. (2020). Pengujian Persyaratan Analisis (Uji Homogenitas dan Uji Normalitas). Inovasi Pendidikan, 7, 50–62.

Waruwu, Y., & Purba, F. J. (2022). Upaya Meningkatkan Sikap Ilmiah Siswa pada Pembelajaran dengan Menggunakan Model Pembelajaran. ChemER, 02(02), 70–79.

Widiastuti, I. A. M. S., Mantra, I. B. N., Utami, I. L. P., Sukanadi, N. L., & Susrawan, I. N. A. (2023). Implementing Problem-based Learning to Develop Students' Critical and Creative Thinking Skills. JPI (Jurnal Pendidikan Indonesia), 12(4), 658–667. https://doi.org/10.23887/jpiundiksha.v12i4.63588

Zhou, Y., Zhu, Y., & Wong, W. K. (2023). Statistical Tests for Homogeneity of Variance for Clinical Trials and Recommendations. Contemporary Clinical Trials Communications, 33, 1–11. https://doi.org/10.1016/j.conctc.2023.101119