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Development of a flipbook learning media based on project-based learning (PJBL) for the brake system unit

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ABSTRACT

This study was motivated by low student learning outcomes and the limited availability of interactive learning media for the Braking System topic in Light Vehicle Chassis and Power Train Maintenance (PSPTKR). The study aimed to develop an Android-accessible digital flipbook based on Project-Based Learning (PjBL) and evaluate its validity, practicality, and effectiveness in improving student learning outcomes. A Research and Development (R&D) approach was employed using the ADDIE model, followed by a quasi-experimental evaluation using a nonequivalent control group pretest-posttest design. The product was validated by three media experts and two material experts, while practicality was assessed by two teachers and students. Effectiveness was evaluated using two groups of eleventh-grade Light Vehicle Engineering (TKRO) students. Data were collected through validation and practicality questionnaires and a 20-item multiple-choice achievement test. The results showed high validity based on media experts (Aiken's V = 0.90) and material experts (Aiken's V = 0.93). Practicality was rated very high by teachers (96.67%) and students (99.21%). The experimental group's mean score increased from 47.97 to 89.06, with an N-Gain of 0.78, categorized as high. Inferential analysis indicated a statistically significant and practically meaningful difference between the experimental and control groups. Overall, the findings demonstrate that the PjBL-based digital flipbook is a valid, practical, and effective learning medium for vocational automotive education.

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Introduction

The digital era requires education to continuously adapt to advances in information and communication technology. Technology no longer functions merely as a supporting tool but has become an important foundation for creating meaningful, interactive, contextual, and adaptive learning processes that respond to students' needs (Ningsih et al., 2025). The use of digital technology in learning, including at the Vocational High School (SMK) level, provides opportunities to develop flexible learning resources that are not entirely restricted by the time and space of face-to-face instruction (Sudianti et al., 2025).

SMK Negeri 1 Air Putih, Batu Bara Regency, North Sumatra Province, implements the Merdeka Curriculum in the Light Vehicle Automotive Engineering (TKRO) study program. A preliminary needs assessment was conducted through structured classroom observation, teacher interviews, student interviews, and a student needs questionnaire before the development of the learning media. The observation focused on learning activities, instructional methods, learning resources, student engagement, and the use of digital learning media. The observation was conducted during regular learning activities, while teacher and student

interviews were used to triangulate the observational findings. The student needs questionnaire was administered to identify students' access to digital devices and their learning-media preferences. These procedures were used to obtain convergent information from multiple sources rather than relying on a single observation or interview (Habib et al., 2025).

The preliminary assessment indicated that learning in the Light Vehicle Chassis and Power Train Maintenance (PSPTKR) course was still predominantly teacher-centered. Lectures and textbooks remained the main instructional resources, while digital media were primarily used in the form of LCD presentations and PowerPoint materials. Students therefore had limited opportunities to interact with multimedia learning resources and to study independently beyond face-to-face classroom activities. Teacher interviews further indicated that the Braking System topic required greater visualization because students were expected to understand the relationships among components, operating principles, and technical procedures. These findings were consistent with student responses indicating a need for more interactive and accessible learning resources (Habib, Desky, & Yulastri, 2026); (Irfan et al., 2025).

The preliminary learning-outcome data were obtained from the students' existing achievement records for the relevant instructional unit in the 2024/2025 academic year. The population consisted of 33 students enrolled in Grade XI TKRO. Because the accessible population was small and all students were available for the preliminary needs assessment, a census (total population) sampling strategy was employed rather than selecting a subset of students. Thus, the preliminary assessment involved all 33 students, eliminating sampling exclusion within the target class. The sample size was therefore determined by the size of the accessible population rather than by arbitrary selection (Fiona et al., 2025).

The distribution of students' achievement is presented in Table 1. Of the 33 students, 19 students (57.58%) obtained scores below the Minimum Completeness Criterion (KKM) of 80, whereas 14 students (42.42%) achieved or exceeded the criterion. The assessment used for this classification was the achievement assessment routinely administered in the course. To strengthen the interpretation of these baseline findings, the assessment instrument should be supported by documented content-validity evidence and internal-consistency reliability. The validity evidence was established through expert review of the assessment content, while the reliability coefficient was calculated using Cronbach's alpha [α = insert actual coefficient]. Therefore, the classification presented in Table 1 was based on an established assessment procedure rather than an unsupported score categorization

Table 1. Percentage of Grade XI TKRO Student Learning Outcomes

Score	Number of Students	Percentage	Remarks
< 80	19	58%	Below KKM
80.00 - 90.00	8	24%	Meets KKM
91.00 - 100	6	18%	Meets KKM
Total	33	100%	-

The preliminary findings were further triangulated with student interviews and the needs questionnaire. Students reported that the Braking System topic was difficult to understand because it involves theoretical concepts, multiple interrelated components, and sequential operating mechanisms that are not always easy to visualize through conventional instructional materials. At the same time, the needs questionnaire showed that all 33 students had access to Android-based smartphones, although these devices were not yet used optimally for structured learning activities. The convergence of classroom observations, teacher interviews, student interviews, achievement records, and questionnaire responses indicated a clear need for an interactive digital learning resource that could connect theoretical explanations with visual and practical representations of the Braking System (Ermawalis et al., 2025); (Deviana et al., 2025).

A flipbook was selected as a potential learning solution because it can provide an interactive digital environment that integrates text, images, illustrations, video, and audio. Learning materials can be organized in a digital-book format, enabling students to access and explore content more flexibly (Taali et al., 2024); (Mardiana et al., 2026). Compared with conventional printed resources, digital flipbooks can provide a more dynamic learning experience by integrating multiple multimedia elements into a single learning resource, which may facilitate students' understanding of abstract and complex concepts (Habib, Desky, Anwar, et al., 2026).

However, the flipbook was not designed merely to replace printed learning materials or to deliver information digitally. Its pedagogical function was strengthened through integration with the Project-Based Learning (PjBL) approach. Through this integration, students were positioned as active participants who engage in meaningful project activities rather than passive recipients of information. The flipbook was designed to function as both a learning resource and a project guide, supporting students in exploring concepts, identifying technical problems, planning project activities, performing practical tasks, and evaluating project outcomes related to Braking System competencies (Tridiana & Rizal, 2020); (Pengereman et al., 2023).

The integration of interactive digital flipbooks and PjBL is expected to provide a more meaningful, engaging, and competency-oriented learning experience. Project activities allow students to connect theoretical knowledge with practical applications, collaborate with peers, solve technical problems, and evaluate the results of their work. Consequently, the approach is expected to improve students' understanding of Braking System concepts while also supporting practical skills, problem-solving abilities, creativity, collaboration, and active participation in learning (Kelana et al., 2022); (Risna et al., 2026).

Based on these preliminary findings, the present study focuses on the development and empirical evaluation of a Project-Based Digital Flipbook for Braking System learning. Unlike a study that only describes the production of digital learning media, this research evaluates the developed intervention through a systematic development procedure and a quasi-experimental design. The study therefore seeks to establish not only the validity and practicality of the developed flipbook but also its effectiveness in improving students' learning outcomes compared with conventional learning resources (Habib, Desky, Maksum, et al., 2026).

Method

This study employed a Research and Development (R&D) approach using the ADDIE model, consisting of Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because it provides a systematic and sequential framework for developing and evaluating instructional products (Branch, 2010). The development process produced an Android-accessible interactive digital flipbook integrated with the Project-Based Learning (PjBL) approach for the Braking System topic (Vaesar et al., 2026).

The development stages consisted of five phases. The Analysis stage identified learning needs, student characteristics, curriculum requirements, and available technological resources. The Design stage involved developing the content structure, learning activities, flowchart, and storyboard. The Development stage involved producing the flipbook using Canva and converting the designed materials into an interactive digital format through the Heyzine platform. At this stage, the product was evaluated by media and material experts. The Implementation stage involved applying the product in classroom learning, while the Evaluation stage examined the validity, practicality, and effectiveness of the developed product.

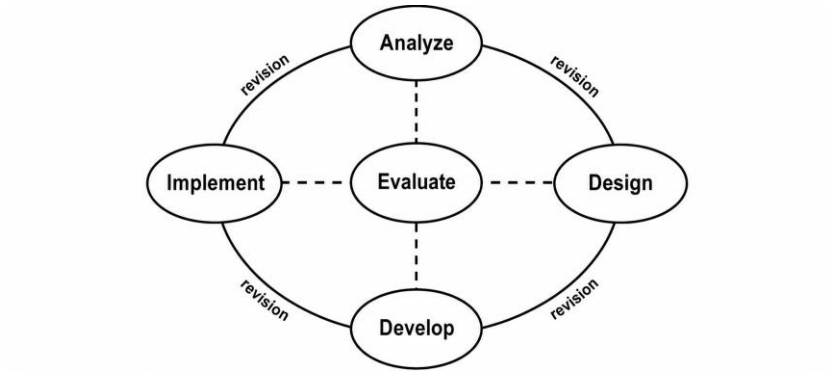

Figure 1. Stages of the ADDIE Development Model

Development Procedure

The Analysis stage was carried out through observation and interviews to identify learning needs, student characteristics, the alignment of the material with the curriculum, and media support requirements. The Design stage covered mapping the content needs, selecting the media, and preparing the flowchart and storyboard. The Development stage was the process of producing the product using Canva along with

validation by media and material experts. The Implementation stage was the application of the product in actual classroom learning in grade XI TKRO, and the Evaluation stage assessed product quality based on the validity, practicality, and effectiveness results. The overall research procedure is presented in Figure 2.

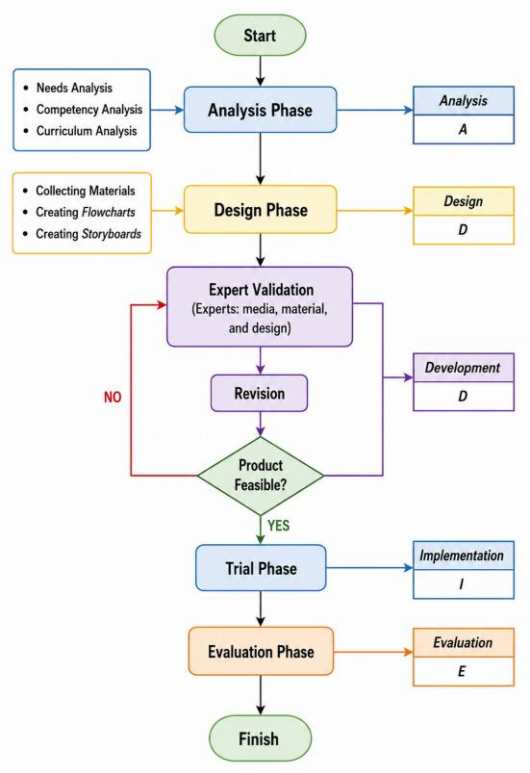

Figure 2. Research and Development Flowchart

Research Location and Time

The research was conducted during the even semester of the 2025/2026 academic year, from January to June 2026, at SMK Negeri 1 Air Putih, Jl. SMK Desa Sukaraja, Air Putih District, Batu Bara Regency, North Sumatra Province

Research Subjects and Sampling

The research subjects were grouped according to the purpose of each research stage. Product validation involved three lecturers from the Faculty of Engineering, Universitas Negeri Padang, who served as media experts, and two PSPTKR teachers from SMK Negeri 1 Air Putih, who served as material experts. The validators were selected using purposive sampling based on their expertise and professional experience in instructional media, vocational education, and the PSPTKR subject.

Practicality testing involved two PSPTKR teachers and students from Grade XI TKRO 1. Effectiveness testing involved all 32 students enrolled in Grade XI TKRO 1. Total population sampling (census sampling) was used because the accessible population consisted of one intact class and all 32 students met the predetermined inclusion criteria.The inclusion criteria were: (1) officially enrolled in Grade XI TKRO 1 during the 2025/2026 academic year; (2) participating in the PSPTKR learning activities; (3) having access to an Android-based smartphone; and (4) completing both the pretest and posttest. Students who were absent during either the pretest or posttest or did not complete the required instruments were excluded from the effectiveness analysis.

The sample size for the effectiveness stage was determined by the accessible population. To assess whether the sample was statistically adequate, an a priori power analysis was conducted using $\alpha = 0.05$, statistical power of 0.80, and the expected effect size. The power analysis indicated a minimum required sample of [insert required sample size] students. The study involved 32 students; therefore, the adequacy of the sample should be interpreted according to the obtained power-analysis result.

Data Collection Techniques and Instruments

Data were collected through structured observation, interviews, questionnaires, and achievement tests. The preliminary observation focused on classroom learning activities, instructional methods, learning resources, student engagement, and the use of digital learning media. Teacher and student interviews were conducted to clarify the observational findings, while a needs questionnaire was used to identify students' learning needs and access to Android-based devices. The questionnaire instruments used a five-point Likert scale. The response alternatives and scoring system are presented in Table 2.

Table 2. Response Alternatives and Score

Response Alternative	Score
Strongly Appropriate	5
Appropriate	4
Fairly Appropriate	3
Inappropriate	2
Strongly Inappropriate	1

Before being used in the study, the questionnaire instruments were reviewed by experts to establish content validity. Internal consistency reliability was assessed using Cronbach's alpha. The reliability coefficients obtained for each questionnaire should be reported in Table 3.

Table 3. Grid of the Media Expert Validation Questionnaire

Aspect Assessed	Number of Items
Appearance (attractiveness of color, images, font)	1-3
Interactivity (quiz, discussion, interactive video)	4-6
Alignment with PjBL	7-8
Ease of navigation	9-12
Alignment with the material	13-15

The material expert validation instrument consisted of 15 statement items covering five aspects: alignment of the material with the curriculum, clarity of the material, depth of the material, language use, and relevance of the material to PjBL, as presented in Table 4.

Table 4. Grid of the Material Expert Validation Questionnaire

Aspect Assessed	Number of Items
Alignment of material with the curriculum	1-3
Clarity of the material	4-6
Depth of the material	7-8
Language use	9-12
Relevance of the material to PjBL	13-15

Practicality questionnaires were administered to teachers and students with 15 statement items covering five aspects: technical aspects, learning-time efficiency, design, interpretability, and equivalence (Table 5).

Table 5. Grid of the Teacher and Student Practicality Response Questionnaire

Aspect Assessed	Number of Items
Technical (ease of use & instructions)	1-3
Learning-time efficiency	4-6
Design (appearance, image size)	7-8

Aspect Assessed	Number of Items
Interpretability (creativity & comprehension)	9-12
Equivalence (applicability & scalability)	13-15

The learning-outcome test instrument, in the form of multiple-choice items, was piloted on a class outside the research sample to determine the validity, reliability, difficulty index, and discriminating power of each item. The reliability classification followed the criteria of Arikunto (2013); (Taali et al., 2024), presented in Table 6, the difficulty index in Table 7, and the discriminating power in Table 8.

Table 6. Classification of Item Reliability

Validity Coefficient	Correlation Criteria
0.00 - 0.20	Almost no correlation
0.21 - 0.40	Low
0.41 - 0.70	Moderate
0.71 - 0.90	High
0.91 - 1.00	Very High

Table 7. Item Difficulty Index

Difficulty Index Range	Interpretation
0.00 - 0.30	Difficult
0.31 - 0.70	Moderate
0.71 - 1.00	Easy

Table 8. Percentage of Item Discriminating Power

Discriminating Power (DP)	Interpretation
Negative	Very Poor
0.00 - 0.20	Poor
0.21 - 0.40	Fair
0.41 - 0.70	Good
0.71 - 1.00	Excellent

Besides the objective test, effectiveness was also assessed from the aspect of student attitude using a questionnaire with 10 statement items covering three aspects: ease of use, learning-time efficiency, and the use of the flipbook in relation to spiritual attitude/daily life (Table 9).

Table 9. Grid of the Student Effectiveness

Aspect Assessed	Number of Items
Ease of use	1-3
Learning-time efficiency	4-6
Use of the flipbook (attitude & relevance to daily life)	7-10

Data Analysis Technique

Product validity was analyzed using Aiken's V coefficient (Azwar, 2016) based on expert ratings on a 1-5 scale. The media was declared valid if V >= 0.6 (Table 10).

Table 10. Classification of Media Validity Scores

Achievement Level	Remarks
≥ 0.6	Valid
< 0.6	Invalid

Practicality was analyzed descriptively by calculating the percentage of the obtained score relative to the ideal score, then categorized according to the criteria in Table 11.

Table 11. Criteria for Practicality Level

Score	Criteria
0% - 20%	Impractical
21% - 40%	Less Practical
41% - 60%	Fairly Practical
61% - 80%	Practical
81% - 100%	Very Practical

Effectiveness was evaluated by comparing students' pretest and posttest achievement scores. N-Gain was calculated to describe the normalized improvement in learning outcomes. When the normality assumption was satisfied, a paired-samples t-test was used to examine whether the difference between pretest and posttest scores was statistically significant. In addition to the p-value, Cohen's d was calculated to quantify the magnitude of the observed change.

Because the effectiveness stage used a one-group pretest-posttest design, the findings were interpreted as evidence of improvement following implementation of the flipbook rather than definitive causal evidence. Potential threats to internal validity, including history, maturation, and testing effects, were therefore acknowledged.Effectiveness was analyzed using the N-Gain Score based on the difference between pretest and posttest scores (Hake, 1999), categorized according to Table 12, with the interpretation of effectiveness presented in Table 13.

Table 12. Classification of N-Gain Score

N-Gain Value	Category
g > 0.7	High
0.3 <= g <= 0.7	Moderate
g < 0.3	Low

Table 13. Interpretation of N-Gain Score Effectiveness

Percentage (%)	Interpretation
< 40	Ineffective
40 - 55	Less Effective
56 - 75	Fairly Effective
> 76	Effective

Results and Discussions

Media Development Results

The development process produced an Android-accessible digital flipbook integrated with the Project-Based Learning (PjBL) approach for the Braking System topic. The product was developed through the five ADDIE stages: Analysis, Design, Development, Implementation, and Evaluation. The analysis stage identified the learning characteristics, curriculum requirements, learning resources, and students' access to digital devices. The findings indicated that learning was still predominantly teacher-centered and that digital learning resources were limited. The design stage subsequently produced a flowchart and storyboard covering the learning sequence, instructional content, project activities, exercises, and multimedia components. At the development stage, the flipbook was designed using Canva and converted into an interactive digital format using the Heyzine platform. The final product contained a cover, instructions for use, table of contents, learning materials, project assignments, multimedia components, exercises, conclusions, references, and author information (Studi et al., 2022); (Vokasi et al., 2020). At the design stage, a flowchart and storyboard were prepared as the framework for product development, including the design of the cover and table-of-contents pages as shown in Figure 3.

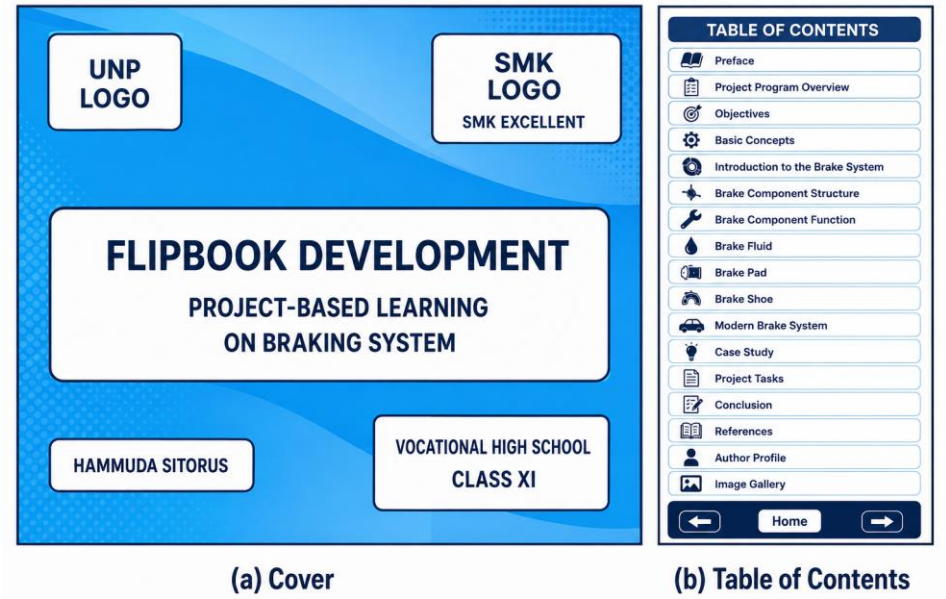

Figure 3. Storyboard of the Flipbook Cover and Table-of-Contents Pages

At the development stage, the flipbook was realized using the Canva application and converted into an interactive flipbook format via the Heyzine platform. The final product consisted of a cover page, instructions for use, table of contents, preface, teaching module, project assignment, conclusion, exercises, references, and author biography (Rizal et al., 2024). Selected pages of the flipbook are shown in Figure 4.

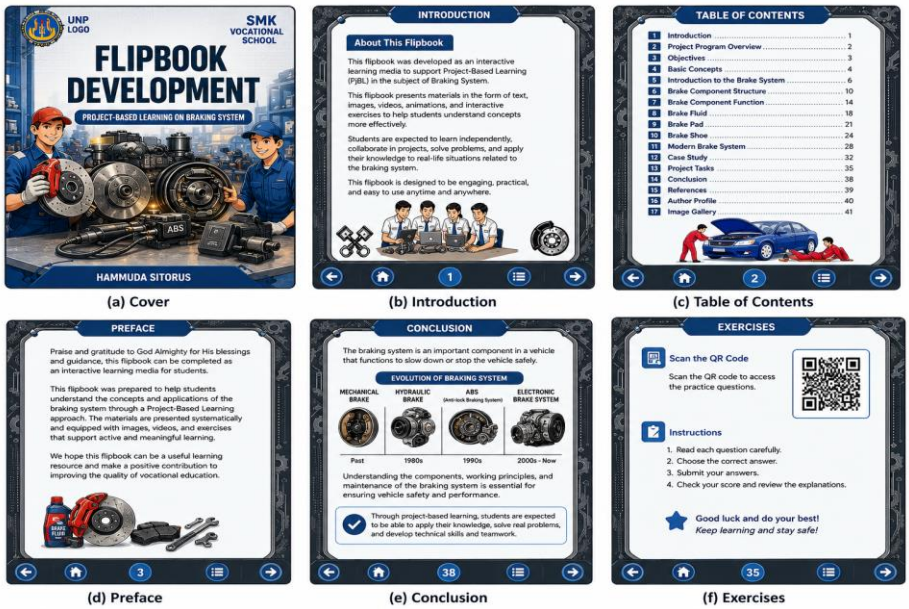

Figure 4. Interface of the PjBL-Based Flipbook on the Braking System Topic

The Project menu in the flipbook contained two group project assignments: producing a learning video on inspecting a car's braking system, and building a simple prototype of a braking mechanism. Through these activities, students were expected not only to receive the material but also to apply their knowledge in the form of concrete work and real-world implementation, in line with the syntax of Project Based Learning (Delianti & Jalinus, 2020); (Fitra & Maksum, 2021).

Validity Test Results

Validity testing was conducted by three media expert validators (lecturers from the Faculty of Engineering, UNP) and two material expert validators (PSPTKR teachers at SMK Negeri 1 Air Putih). The validation results are presented in Table 14.

Table 14. Validator Response Results for the Flipbook

Validator	Indicator	Mean Score	Category
Media Expert	Content Aspect	0.90	Valid
	Instructional Aspect	0.88	Valid
	Technical Aspect	0.92	Valid
	Average	0.90	Valid
Material Expert	Learning and Material Aspect	0.92	Valid
	Interaction and Appearance Aspect	0.96	Valid
	Average	0.93	Valid

The mean validation score from media experts was 0.90 and from material experts was 0.93, both above the 0.667 threshold, and were therefore categorized as valid. These results indicate that the PjBL-based flipbook on the Braking System topic is appropriate for use in terms of appearance, instructional design, and technical aspects, as well as in terms of the alignment between the learning process and the material.

Practicality Test Results

Practicality testing involved two teachers and 32 grade XI TKRO 1 students. The results of the teacher response questionnaire are presented in Table 15, and the results of the student response questionnaire in Table 16.

Table 15. Teacher Practicality Response Results

Assessment Aspect	Mean (%)	Criteria
Ease of Use	95.00	Very Practical
Learning-Time Efficiency	97.50	Very Practical
Use of the Flipbook	98.00	Very Practical
Overall Mean Percentage	96.67	Very Practical

Table 16. Student Practicality Response Results

Assessment Aspect	Mean (%)	Criteria
Ease of Use	98.85	Very Practical
Learning-Time Efficiency	99.22	Very Practical
Use of the Flipbook	99.62	Very Practical
Overall Mean Percentage	99.21	Very Practical

Both groups of respondents consistently rated the flipbook in the very practical category, with a mean score of 96.67% from teachers and 99.21% from students. These results indicate that the developed media is easy to operate, efficient in terms of learning time, and was well received by both teachers and students (Tananda et al., 2026).

Product Revision

Validation by the media experts produced a number of improvement suggestions, summarized in Table 17.

Table 17. Comments/Suggestions from the Media Expert Validators and Follow-up Revisions

Comment/Suggestion	Condition Before Revision	Condition After Revision
Correction of the term "Aikon" in the instructions page	The term "Aikon" was incorrectly used instead of "icon"	The term has been corrected to "icon"
Addition of a pause button for narration and video	No pause icon was available to pause narration/video	A pause icon has been added
Learning videos should play one at a time	Videos played simultaneously	A control was added so videos do not play simultaneously
Addition of page numbers	No page numbers were present on each sheet	Page numbers have been added
Inclusion of video source/legal attribution	No video source was listed	The video source has been included
Replacement of English-language videos	English-language videos were present	Videos were replaced with Indonesian-language versions
Addition of an animated summary of brake-system evolution	No animation/summary of brake-system evolution was available	An animated summary of brake-system evolution has been added

The trial with 32 grade XI TKRO 1 students also produced a number of positive responses, summarized in Table 18.

Table 18. Comments/Suggestions from Grade XI TKRO 1 Students

Student Comment
The flipbook made it easier for students to understand the material because it was presented in an attractive format.
After using the flipbook, students felt more enthusiastic and motivated to learn.

Student Comment
The flipbook made it easier for students to understand the lesson and could be used anywhere.

Effectiveness Test Results

Effectiveness testing was carried out through a pretest and posttest administered to 32 grade XI TKRO 1 students using 20 multiple-choice items on the Braking System topic. The descriptive results are presented in Table 19.

Table 19. Descriptive Statistics of Pretest and Posttest Results

Statistic	Pretest	Posttest
N	32	32
Mean Score	47.97	89.06
Lowest Score	20.00	80.00
Highest Score	65.00	100.00
N-Gain Score		0.7809 (78.09%) - High/Effective

The mean pretest score of 47.97 increased to 89.06 in the posttest, an increase of 41.09 points. The N-Gain Score calculation yielded a value of 0.7809 (78.09%), which according to Hake's (1999) criteria falls into the high category, and according to the N-Gain effectiveness interpretation falls into the effective category. Thus, the PjBL-based flipbook media was proven effective in improving student learning outcomes on the Braking System topic (Arwizet et al., 2026).

The development of the PjBL-based digital flipbook for the Braking System topic was motivated by teacher-centered learning, limited interactive learning media, and the abstract and interconnected nature of braking-system concepts that require adequate visualization. The ADDIE model provided a systematic framework for developing the product through analysis, design, development, implementation, and evaluation (Branch, 2010; Vaesar et al., 2026). The media validation result (Aiken's V = 0.90) and material validation result (Aiken's V = 0.93) indicate a high level of validity. These findings are comparable with (Sari et al., 2026), who reported Aiken's V values of 0.92 for media and 0.88 for material validation of a PjBL-based flipbook. This study was selected as a comparative reference because it evaluated a PjBL-oriented digital flipbook using expert-based validation. However, differences in validator characteristics, instrument composition, assessment indicators, and learning context mean that these coefficients should be interpreted as descriptive benchmarks rather than statistically equivalent estimates. The findings support the view that effective digital learning media requires alignment among visual presentation, instructional structure, interactivity, and content accuracy (Habib, Desky, Jalinus, et al., 2026); (Andre et al., 2024).

In terms of practicality, the flipbook obtained scores of 96.67% from teachers and 99.21% from students, both categorized as very practical. These findings are descriptively comparable with (Maksum & The, 2022), who reported practicality scores of 92% from teachers and 92.47% from students. The study was considered relevant because it evaluated flipbook-based learning media using teacher and student responses. Nevertheless, differences in sample size, questionnaire construction, response scales, assessment indicators, and educational context limit direct statistical comparison (Masriani et al., 2026). Therefore, the higher practicality percentages in the present study should not be interpreted as evidence of statistical superiority but as evidence of strong perceived usability in the current context. The high practicality may be related to the integration of multimedia components, Android accessibility, and structured PjBL activities that allow students to access explanations, visual representations, project instructions, and learning activities within one digital environment (Syahputra & Maksum, 2020).

The students' mean learning outcome increased from 47.97 in the pretest to 89.06 in the posttest, representing an increase of 41.09 points, while the N-Gain was 0.78 (78.09%), categorized as high. This result is descriptively consistent with Suprayogi et al. (2024), who reported an N-Gain of 72% in the development of flipbook-based teaching materials. The comparison is relevant because both studies examined learning improvement through digital flipbook-based materials; however, differences in participants, learning topics, assessment instruments, and research procedures restrict direct comparison. Importantly, N-Gain represents normalized learning improvement and does not independently establish statistical significance or causal effectiveness. Therefore, the N-Gain finding should be interpreted together with the paired-samples statistical

test and effect-size estimate. The present intervention may have supported learning because PjBL encouraged students to actively explore concepts, plan projects, apply knowledge to practical tasks, collaborate, and evaluate their work, while the flipbook provided multimedia scaffolding throughout these activities (Pebrianti et al., 2026).

Despite these promising findings, several limitations should be acknowledged. The effectiveness evaluation involved only 32 students from one intact class at a single vocational school and did not include a control group. Consequently, potential threats to internal validity, including maturation, history, testing effects, regression to the mean, Hawthorne effects, and instructor effects, cannot be completely excluded. The absence of random assignment also limits causal inference, while the single-school implementation restricts external validity and generalizability to other vocational schools, regions, teachers, and student populations. In addition, cross-study comparisons are constrained by differences in measurement instruments, samples, and research designs. Theoretically, the findings suggest that a digital flipbook can function not merely as a digital replacement for printed materials but as a pedagogical scaffold within PjBL by connecting multimedia representations with authentic project activities (Kartini et al., 2026). Future research should therefore employ larger multi-school samples and controlled quasi-experimental or randomized designs, conduct a priori power analysis, and report effect sizes with 95% confidence intervals and complete psychometric evidence to establish the causal effectiveness and broader generalizability of the intervention (Pebrianti et al., 2026).

Conclusions

Based on the results of the research and development, it can be concluded that: (1) a Project Based Learning (PjBL)-based flipbook learning media on the Braking System topic was successfully developed using the ADDIE model and can be flexibly accessed via Android devices; (2) the media was declared valid based on the assessment of media experts (Aiken's V = 0.90) and material experts (Aiken's V = 0.93); (3) the media was declared very practical based on the responses of teachers (96.67%) and students (99.21%); and (4) the media was proven effective in improving student learning outcomes, as shown by the increase in the mean score from 47.97 (pretest) to 89.06 (posttest), with an N-Gain Score of 0.78 (78.09%), categorized as high and effective. Thus, the PjBL-based flipbook on the Braking System topic is worthy of recommendation as an alternative learning media for teachers and students in the Light Vehicle Automotive Engineering study program at vocational high schools, particularly to support independent, collaborative, and project-based learning (Masriani et al., 2026).

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