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DEEP LEARNING INTEGRATED TOURISM CONTEXTUALIZED MATRIX DIGITAL WORKSHEETS FOR ENHANCING VOCATIONAL STUDENTS CRITICAL THINKING SKILLS

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ABSTRACT

This study aims to develop a valid, practical, and effective interactive E-Worksheets on matrix concepts contextualized within a tourism travel framework through a Deep Learning approach to enhance students' critical thinking skills. Employing a Research and Development (R&D) design based on the ADDIE model, the research involved Phase F students at SMK Dirgantara Putra Bangsa. Data were collected using expert validation sheets, student usability questionnaires, and critical thinking pretest-posttest instruments, then analyzed via paired-sample t-tests and normalized gain (N-Gain). The results demonstrated that the E-Worksheets achieved high validity, with expert scores reaching 71.00 for subject matter and 103.00 for media (Very Valid category). The practicality assessment yielded a mean score of 72.6 (Practical category). Furthermore, the intervention significantly improved students' critical thinking skills, increasing the mean score from 55.57 to 86.20 ($t(29) = 27.50, p < .001$) with an average N-Gain of 0.69 (moderate-to-high level). In conclusion, the interactive tourism-contextualized E-Worksheets effectively optimizes smartphone utilization and transforms vocational mathematics learning into a meaningful, critical-thinking-driven experience.

Keywords: Interactive E-Worksheets; ADDIE model; Critical thinking; Deep Learning; Matrix

Abstrak

Penelitian ini bertujuan untuk menghasilkan E-LKPD interaktif materi matriks berkonteks perjalanan wisata melalui pendekatan *Deep Learning* yang valid, praktis, dan efektif untuk meningkatkan kemampuan berpikir kritis siswa. Menggunakan metode *Research and Development* (R&D) dengan model ADDIE, penelitian ini melibatkan siswa Fase F SMK Dirgantara Putra Bangsa. Data dikumpulkan melalui lembar validasi ahli, angket respons siswa, serta tes awal (*pretest*) dan tes akhir (*posttest*), lalu dianalisis menggunakan uji *paired-sample t-test* dan perhitungan *normalized gain* (N-Gain). Hasil penelitian menunjukkan bahwa E-LKPD memiliki kevalidan yang sangat tinggi, dengan skor rata-rata ahli materi sebesar 71,00 dan ahli media sebesar 103,00 (kategori Sangat Valid). Kepraktisan media memperoleh skor rata-rata 72,6 (kategori Praktis). Selain itu, penggunaan E-LKPD terbukti efektif meningkatkan kemampuan berpikir kritis siswa secara signifikan, ditunjukkan oleh peningkatan rerata nilai dari 55,57 menjadi 86,20 ($t(29) = 27,50; p < 0,001$) dengan N-gain sebesar 0,69 (kategori sedang-tinggi). Kesimpulannya, E-LKPD interaktif berkonteks perjalanan wisata ini efektif mengoptimalkan penggunaan gawai dan meningkatkan kemampuan berpikir kritis siswa SMK dalam pembelajaran matematika.

Kata Kunci: E-LKPD interaktif, Model ADDIE, Berpikir kritis, *Deep Learning*, Matriks

1. INTRODUCTION

Vocational High School (SMK) education in the Merdeka Curriculum era is required to equip students with 21st-century skills, particularly critical thinking skills, which serve as the primary foundation for solving complex problems in the workplace [1]. Vocational mathematics is no longer viewed as merely a collection of mechanical formulas, but rather as a tool for analytical reasoning to resolve real-world industry challenges [2]. To achieve these competencies, the learning process requires a Deep Learning approach that encourages students to shift their cognitive focus from surface learning toward a deep, integrated, and solution-oriented construction of meaning [3]. The Deep Learning approach emphasizes meaningful, mindful, and joyful learning activities, enabling students to independently and critically analyze, evaluate, and synthesize mathematical information.

Nevertheless, the actual conditions of mathematics instruction in the field reveal a significant gap from this ideal state. Initial observations and needs analysis at SMK Dirgantara Putra Bangsa demonstrated that instructional practices for Grade XI (Phase F) students were heavily dominated by expository lecture methods at 50% and the use of conventional printed Worksheets at 66% [4]. This passive and rote-based learning pattern directly contributed to a high rate of student conceptual errors, with the matrix topic representing the largest source of errors at 57%. Students experienced substantial difficulties when confronted with matrix operations, determinant and inverse calculations, and the translation of contextual problems into accurate mathematical models [5]. These cognitive hurdles indicate that the abstract nature of matrix concepts has not been effectively accommodated by existing learning materials.

On the other hand, there is unexploited digital potential within the school environment that has yet to be converted into productive learning tools. Initial survey data confirmed that 90% of students at SMK Dirgantara Putra Bangsa owned personal smartphones; however, their utilization to support mathematics learning reached only 10%, with the vast majority of usage dominated by non-educational activities such as communication and gaming. The imbalance between personal technology infrastructure availability and its classroom utilization creates a digital divide that undermines students' learning potential [6]. Therefore, a transformation of learning materials from static printed formats to an interactive E-Worksheets easily accessible via students' smartphones is necessary to shift digital media consumption behaviors from passive consumption to active-educational engagement [7].

To optimize the effectiveness of the interactive E-Worksheets in alignment with the Deep Learning approach, matrix concepts need to be integrated into a tourism travel context relevant to vocational education. Matrix topics naturally possess strong connections to practical applications such as shortest travel route processing, tour budget calculations, and participant allocation [8]. By embedding real-world problems from the tourism domain, abstract matrix concepts are transformed into concrete and meaningful objects of study for students [9]. Integrating this vocational context not only enhances students' intrinsic motivation and active engagement, but also stimulates critical thinking indicators, such as identifying assumptions, analyzing tourism operational data, and logically evaluating the accuracy of calculations.

The design and development process of this digital interactive E-Worksheets requires a structured and proven instructional design framework, namely the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) [10]. Through the ADDIE stages, the E-Worksheets is systematically constructed starting from analytical needs mapping, visual interface design in PowerPoint converted into an interactive flipbook via the FlipHTML5 platform, to validity, practicality, and effectiveness testing phases [11]. The integration of FlipHTML5 technology enables interactive features such as audiovisual navigation, direct task links, and digital feedback that support Deep Learning workflows by facilitating students' independent exploration [12]. Consequently, the resulting E-Worksheets is not only theoretically valid and operationally practical, but also progressively constructs students' critical reasoning skills.

Based on the theoretical and empirical urgency outlined above, the development of an interactive matrix E-Worksheets within a tourism travel context serves as an urgent and innovative solution to address students' low critical thinking skills and high conceptual error rates in vocational mathematics. The synergy of an applicable tourism context, a Deep Learning approach focusing on profound understanding, and a measurable ADDIE development model is believed to transform students' smartphones into effective learning instruments in the classroom [13]. Implementing learning supported by this interactive E-Worksheets is expected to cultivate interactive, contextual, and impactful learning experiences that elevate the mathematical competencies of vocational students.

2. LITERATURE REVIEW

2.1. Interactive E-Worksheets

The evolution of modern educational technology has catalyzed a paradigm shift from traditional paper-based learning materials to interactive E-Worksheets. Conventional static Worksheets often restrict students to passive reading and mechanical drill exercises, leading to low cognitive engagement, rapid mental fatigue, and limited conceptual retention [14]. In contrast, interactive digital Worksheets leverage multimedia integration such as dynamic visual navigation, embedded audio-visual resources, interactive flipbook formats, and direct digital submission features to establish a multi-sensory learning environment [15]. This digital transformation effectively lowers extraneous cognitive load while heightening learner stimulation, allowing students to transition from passive consumers of static content into active, self-directed learners who construct mathematical knowledge through self-paced exploration.

Within vocational education settings, the strategic deployment of mobile-compatible E-Worksheets addresses the pervasive disparity between high personal device ownership and low educational device utilization [16]. By converting mobile devices from classroom distractions into purposeful learning instruments, interactive E-Worksheets enhance material accessibility, visual presentation quality, and intrinsic learner motivation [17]. Furthermore, the real-time interactive feedback mechanisms embedded in platforms like FlipHTML5 facilitate immediate self-assessment, enabling vocational students to identify procedural errors instantly, revise their mathematical reasoning, and sustain autonomous problem-solving workflows.

2.2. ADDIE Instructional Design Model

Developing rigorous, high-quality digital instructional materials requires a systematic design architecture, with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) standing as one of the most widely validated global standards [18]. The structured sequence of ADDIE ensures that learning materials are constructed upon verified diagnostic field needs rather than intuitive assumptions, systematically bridging the gap between pedagogical theory and digital software execution [19]. Through its iterative stages, instructional developers can systematically align core curriculum learning outcomes, contextual problem scenarios, user interface aesthetics, and critical thinking assessment rubrics into a unified, high-performing learning ecosystem.

In the domain of mathematics education research, the ADDIE framework provides rigorous, multi-stage quality control checkpoints for content validity, instructional coherence, and operational practicality [20]. Subject-matter and media expert validation during the development phase minimizes conceptual inaccuracies and structural flaws prior to classroom deployment, ensuring that the digital media satisfies stringent standards of internal consistency [21]. Subsequent implementation and evaluation phases allow researchers to capture empirical field data through pretest-posttest designs, normality verifications, paired-sample inferential testing, and normalized gain metrics, establishing a robust foundation for instructional scalability and evidence-based publication.

2.3. Critical Thinking Skills in Mathematics

Critical thinking skills represent an essential 21st-century core competency required for vocational high school graduates seeking to navigate complex, automated industrial environments [22]. In mathematics education, critical thinking extends far beyond procedural fluency and formula memorization; it encompasses the higher-order ability to analyze contextual assumptions, evaluate mathematical arguments, translate unstructured real-world challenges into precise algebraic models, and synthesize logical, verified solutions [23]. Students equipped with advanced mathematical reasoning demonstrate higher cognitive flexibility, enabling them to deconstruct multi-step operational problems commonly encountered in professional technical fields.

Despite its strategic importance, traditional expository instruction frequently suppresses critical reasoning by prioritizing rote calculation over conceptual inquiry, leaving students helpless when confronted with non-routine problem formulations [24]. Fostering authentic critical thinking requires learner-centered instructional environments that intentionally introduce cognitive disequilibrium through realistic, industry-relevant problem scenarios [25]. When contextual digital Worksheets actively prompt learners to justify their analytical steps, evaluate alternative solution paths, and verify the logical validity of their final outputs, student cognitive performance demonstrates a marked structural progression from surface-level recall to high-level analytical mastery.

2.4. Deep Learning Approach in Education

The Deep Learning approach in contemporary pedagogy advocates for meaningful, mindful, and joyful learning experiences that shift student focus away from surface-level memorization toward profound conceptual construction [26]. While surface learning limits students to reproducing isolated algorithms for immediate assessment, Deep Learning empowers learners to integrate new information into pre-existing cognitive schemas, analyze underlying structural patterns, and transfer abstract concepts to novel real-world situations [27]. Cultivating Deep Learning demands instructional strategies that stimulate active inquiry, metacognitive reflection, and collaborative problem-solving, thereby converting abstract academic requirements into personally meaningful intellectual achievements.

Integrating Deep Learning principles into digital instructional media provides the necessary cognitive scaffolding for self-regulated knowledge construction [28]. Interactive digital platforms empower students to navigate complex mathematical ideas autonomously, manipulate visual variables, and continuously connect abstract symbolic operations to familiar practical context representations [29]. Consequently, embedding a Deep Learning framework within mobile-based digital Worksheets directly mitigates persistent conceptual error rates, enhances cognitive engagement, and cultivates sustained intellectual agency among vocational high school learners.

2.5. Matrix Material in Vocational Contexts

Matrix algebra is a fundamental mathematical topic within Grade XI (Phase F) vocational curricula, providing indispensable analytical tools for structuring linear systems, processing data transformations, and solving multi-variable optimization problems [30]. However, empirical diagnostic surveys consistently reveal that matrices represent one of the most prominent sources of student conceptual errors, particularly regarding matrix multiplication rules, determinant evaluations, inverse calculations, and word-problem model formulations [31]. These persistent cognitive hurdles stem largely from traditional, overly abstract instructional modes that detach formal matrix operations from functional, real-world applications.

To bridge this conceptual gap, matrix instruction in vocational schools benefits significantly from anchoring abstract algebraic structures within authentic vocational contexts, such as tourism travel planning [32]. Applied scenarios including travel route optimization, tour group budgeting, bus seating capacity allocations, and multi-tier pricing matrices transform abstract numerical arrays into concrete decision-making instruments [33]. By embedding matrix operations directly into professional industry workflows, contextual digital learning materials elevate intrinsic student motivation, eliminate procedural misconceptions, and provide a direct catalyst for strengthening mathematical critical thinking capabilities.

3. METHOD

This study is a Research and Development (R&D) project aimed at producing an E-Worksheets on matrix concepts contextualized within a tourism travel framework, integrated with a Deep Learning approach through the Problem-Based Learning (PBL) model to enhance the mathematical thinking skills of Phase F students at SMK Dirgantara Putra Bangsa. The development model utilized was the ADDIE model, which comprises five stages: analysis, design, development, implementation, and evaluation [10]. In the analysis phase, a preliminary study was conducted through classroom observations and teacher interviews to identify instructional conditions, student characteristics, and curriculum alignment with the Merdeka Curriculum. The design phase involved structuring the E-Worksheets around a tourism travel context and drafting research instruments, including expert validity questionnaires, student response questionnaires, and critical thinking test items.

The initial product was drafted using Microsoft PowerPoint and subsequently converted into a digital flipbook via the FlipHTML5 platform to enhance interactivity and engagement. The research subjects were Phase F students at SMK Dirgantara Putra Bangsa who participated in instruction over two learning sessions. During the implementation phase, a limited trial was conducted by administering a pretest to determine students' baseline abilities, followed by instruction utilizing the E-Worksheets, and concluding with a posttest to measure improvements in critical thinking skills. Additionally, students completed response questionnaires to evaluate the practicality of the product. The collected data were analyzed quantitatively using normality tests and paired-sample t-tests with SPSS 25 software to determine significant differences between pretest and posttest scores [34]. Furthermore, the effectiveness of student competency improvements was analyzed

using normalized gain (N-Gain) calculations [35]. The analysis results were used to evaluate the validity, practicality, and effectiveness of the developed E-Worksheets in mathematics instruction.

4. RESULTS

4.1. Analysis Phase

This study produced an E-Worksheets on matrix topics within a tourism travel context using the ADDIE model. Initial observations and interviews with the Grade XI mathematics teacher at SMK Dirgantara Putra Bangsa revealed that instructional practices relied heavily on conventional, paper-based Worksheets containing brief summaries and rote exercises, offering minimal interactive or contextual engagement. The matrix topic spans core conceptual definitions, matrix operations, determinants, matrix inverses, and applications (e.g., travel route processing, budget planning, participant allocation). Although the full curriculum allocates 44 instructional hours to matrices, this development focused on a targeted 16-hour subset to ensure focused, contextual execution for Phase F students. Instruction occurred over two 90-minute sessions per week. Diagnostic surveys indicated persistent student errors regarding matrix operations and contextual problem formulations.

Table 1. Initial Survey Results

Dimension	Category/ Sub-item	Percentage (%)
Instructional Methods	Lecture/ Expository	50%
	Project-based	31%
	Questioning	16%
	Culture-based	3%
Common Conceptual Errors	Matrices	57%
	Absolute Value	33%
	Composite Functions	10%
Use of Learning Materials	Printed LKPD (Worksheets)	66%
	Modules	12%
	Comics	10%
	Handouts	9%
	Textbooks	3%
Smartphone Ownership	Personal	90%
	Shared with Parents	10%
Smartphone Usage Purpose	Communication	44%
	Gaming	33%
	Video Streaming	13%
	Learning/ Education	10%

As shown in Table 1, instruction was dominated by lectures (50%) and lacked student-centered activities, while matrices represented the largest source of conceptual error (57%). Although printed Worksheets were the primary medium (66%) and personal smartphone ownership was high (90%), educational mobile usage remained low (10%). These findings confirmed the need for an interactive, digitally contextualized E-Worksheets.

4.2. Design Phase

The design phase involved organizing the matrix content around travel contexts, drafting validation rubrics, constructing critical thinking items, laying out initial media templates in PowerPoint, and structuring pages before digital conversion into flipbook format. Initial layouts included.

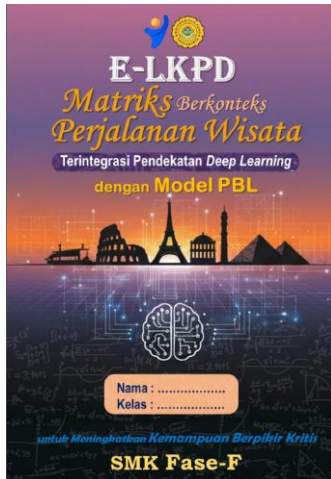


Figure 1. Cover

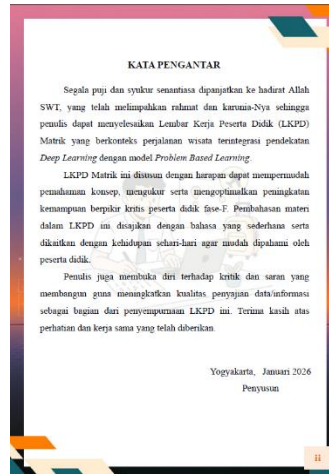


Figure 2. Introduction

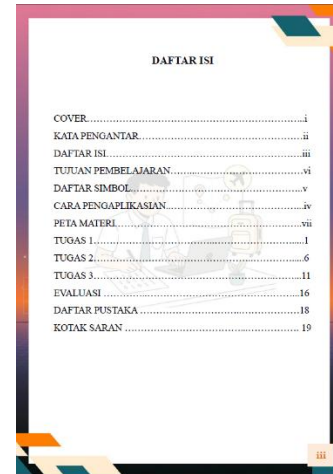


Figure 3. Table of Contents

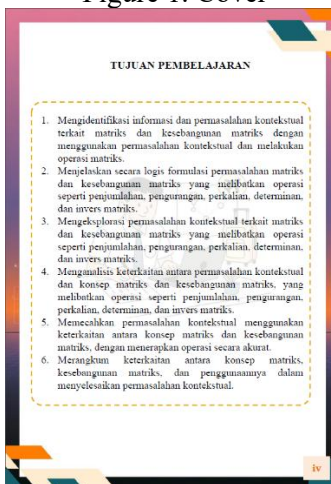


Figure 4. Learning Objectives



Figure 5. List of Symbols

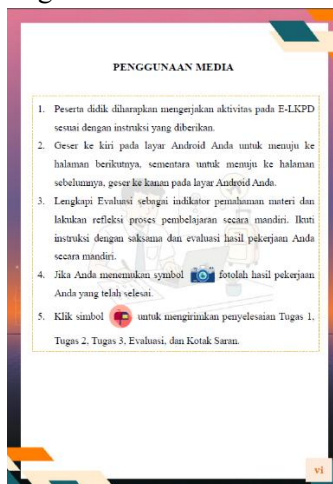


Figure 6. Instructions for Use

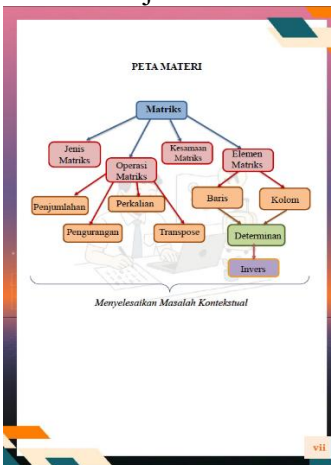


Figure 7. Content Map

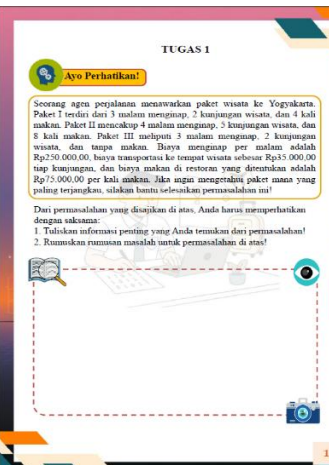


Figure 8. Task 1



Figure 9. Task 2

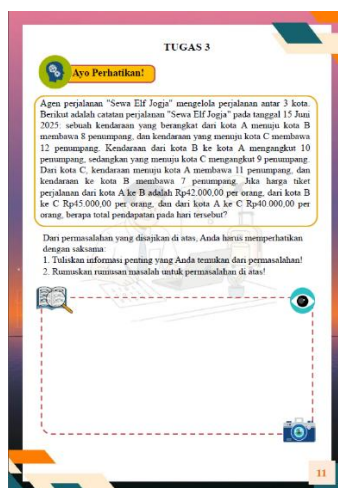


Figure 10. Task 3

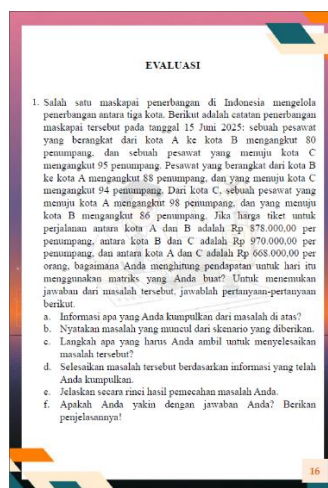


Figure 11. Evaluation



Figure 12. References

During implementation, Phase F students participated in a baseline pretest in session one, engaged with the E-Worksheets, completed a posttest in session two, and provided usability feedback via questionnaires.

4.3. Development Phase

The LKPD drafted using PowerPoint was subsequently converted into PDF format and uploaded to the FlipHTML5 platform to be developed into a more interactive and engaging digital flipbook. Following this development phase, the E-Worksheets underwent a validation process conducted by subject-matter and media experts. This validation aimed to evaluate the appropriateness and validity of the E-Worksheets in terms of both content substance and media presentation. The assessment was carried out through an evaluation process referencing predetermined criteria and percentage thresholds established in the research methodology.

The subject-matter expert validation instrument was structured around three main dimensions: Content Appropriateness, Language Precision, and Presentation Quality, adhering to established standards (Depdiknas, 2008). The Content Appropriateness dimension comprised 15 items used to evaluate the alignment of the material with the curriculum and intended learning objectives. Furthermore, the Language Precision dimension consisted of 5 items focusing on clarity of language, accuracy of terminology, and ease of comprehension for students. Similarly, the Presentation Quality dimension contained 5 items assessing the systematic organization of content, coherence between sections, and overall readability of the module. Each item carried a maximum score of 5, yielding a maximum total score of 75 across all statements. The assessment results from the subject-matter experts are presented in Table 2 below.

Table 2. Subject-Matter Expert Validation

Evaluation Dimension	Expert I	Expert II	Expert III
Content Appropriateness	22	23	24
Language Precision	25	24	23
Presentation Quality	25	23	23
Total Score	72	70	70
Mean Score	71		

Media validation evaluated Content (5 items), Presentation (5 items), and Graphic Design Quality (12 items) (Max score = 110).

Table 3. Media Expert Validation

Evaluation Dimension	Expert I	Expert II	Expert III
Content Appropriateness	24	23	23
Presentation Quality	23	23	22
Graphic / Visual Quality	58	57	55
Total Score	105	103	100
Mean Score	103		

As shown in Table 2 and Table 3, average expert scores reached 71.00 (subject matter) and 103.00 (media), categorizing the E-Worksheets as Very Valid. Formative expert feedback was incorporated to refine the media prior to field implementation.

4.4. Implementation Phase

After the E-Worksheets was declared valid based on the evaluation results from subject-matter and media experts, the product was implemented in classroom instructional activities. This implementation phase aimed to directly observe how the E-Worksheets was utilized by students during the learning process and to determine the extent to which the media effectively supported mathematics learning. Additionally, evaluations were conducted at this stage to measure the practicality and effectiveness of the E-Worksheets in assisting students' comprehension of the instructional material. The practicality of the E-Worksheets was assessed through student responses following their use of the media throughout the instructional sessions.

Student responses were collected via a questionnaire administered to Phase F students at SMK Dirgantara Putra Bangsa upon completion of the entire instructional series. The questionnaire comprised 17 items covering four primary dimensions: usability (ease of use), material clarity, media aesthetic quality, and the instructional benefit of the E-Worksheets in supporting learning. Each item carried a maximum score of 5, enabling a more objective and measurable assessment of the E-Worksheets's practicality level. The processed data from the student response questionnaire are detailed in Table 4 below.

Evaluated Dimension	Average Total Score per Dimension
Student Interest	12.2
Material Clarity	17.1
Language Accessibility	17.3
Presentation Quality	26.0
Overall Mean Score	72.6 (Practical)

The average student response score of 72.6 indicates that the developed E-Worksheets met the threshold for the Practical category, demonstrating high usability and readability in classroom settings.

4.5. Evaluation Phase

The evaluation phase constitutes the final stage in research applying the ADDIE model, aimed at ensuring that the developed E-Worksheets possesses optimal quality and is suitable for instructional use. In this phase, the evaluation process commenced with administering a pretest to students prior to using the E-Worksheets, aiming to identify and measure students' baseline critical thinking skills before engaging in instruction with the E-Worksheets on the target material. Following the pretest, the participating students were subsequently administered a posttest to evaluate the progression of their learning outcomes after learning with the E-Worksheets.

To determine the effectiveness level of the E-Worksheets, an analysis was performed by comparing pretest and posttest results using a paired-sample t-test. Prior to this analysis, the data underwent normality testing using SPSS 25 software to ensure that the obtained dataset was normally distributed. The findings from this overall analysis then served as the basis for concluding whether the developed E-Worksheets was effective in enhancing students' learning outcomes and critical thinking skills.

Assessment	Kolmogorov-Smirnov Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
Pretest	0.128	29	.199*	0.962	29	0.341
Posttest	0.115	29	.200*	0.971	29	0.563

* Lower bound of true significance. a Lilliefors Significance Correction

Because Shapiro-Wilk significance values ($p = 0.341$ for pretest, $p = 0.563$ for posttest) exceeded 0.05, the data satisfied normality assumptions. Subsequently, a paired sample t-test was conducted.

Table 6. Paired Samples Test Results

Pair	Paired Differences Mean	Std. Dev.	Std. Error Mean	95% CI (Lower)	95% CI (Upper)	t	df	Sig. (2-tailed)
Pretest-Posttest	30.36	6.10	1.11	28.36	32.90	27.50	29	.000

The t-test yielded $t(29) = 27.50, p < 0.001$, rejecting H_0 and demonstrating a statistically significant improvement in student critical thinking skills post-intervention. The normalized gain ($N\text{-Gain}$) was calculated as follows:

$$N\text{-Gain} \langle g \rangle = \frac{S_{\text{post}} - S_{\text{pre}}}{S_{\text{max}} - S_{\text{pre}}} = \frac{86.20 - 55.57}{100 - 55.57} = \frac{30.63}{44.43} = 0.69$$

Based on these calculations, the pretest and posttest analysis yielded an average normalized gain ($N\text{-gain}$) score of 0.69, falling into the moderate-to-high category. This score demonstrates a clear enhancement in student abilities following instruction using the E-Worksheets. This improvement is depicted more clearly in the following figure.

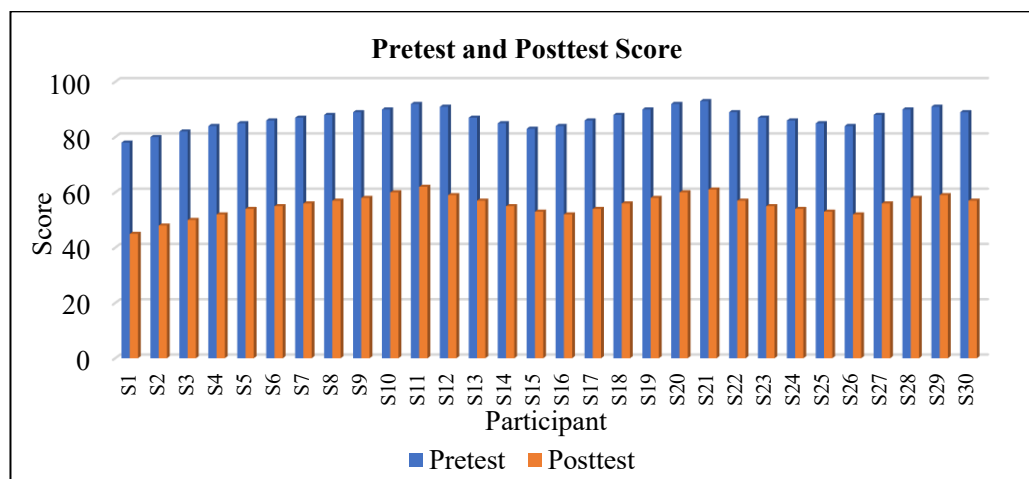


Figure 13. Peningkatan Skor Pretest ke Posttest

As illustrated in the figure above, students' pretest scores yielded a mean of 55.57, a median of approximately 56, and a mode of 57, indicating that students' baseline ability remained in the moderate category. Meanwhile, posttest scores demonstrated a significant improvement, with a mean of 86.20, a median of 87, and a mode of 87, reflecting that the majority of students achieved a high level of material mastery. Considering the difference in mean scores between the posttest and pretest, there was an overall increase of 30.63 points, demonstrating that the use of the E-Worksheets was effective in enhancing students' critical thinking skills.

4.6. Discussion

The diagnostic findings in the analysis phase highlighted a critical structural barrier to Deep Learning in vocational high school (SMK) mathematics instruction. At SMK Dirgantara Putra Bangsa, learning was heavily dominated by expository lectures (50) and static printed Worksheets (66%), despite 90% of Grade XI students owning personal smartphones of which a mere 10% were utilized for educational purposes. This technological misalignment directly correlated with severe learning hurdles, as evidenced by 57% of students exhibiting persistent conceptual errors in matrix operations. Within the Deep Learning framework, traditional lecture-heavy methods trap students in surface learning, where mathematical procedures are passively memorized without conceptual understanding or real-world connections [36]. These baseline empirical findings align with research by Wijaya et al. [37], who demonstrated that abstract mathematical topics taught via rote instruction fail to cultivate higher-order cognitive processing. Furthermore, the high error rate in matrix operations mirrors observations by Kurniati & Wiyani [38], who noted that vocational students

struggle with problem formulation when topics are presented without authentic, industry-relevant contextual anchoring.

During the design phase, contextualizing matrix topics within a tourism travel framework served as a fundamental pedagogical catalyst for Deep Learning. By embedding core matrix concepts such as matrix operations, determinants, inverses, and systems of linear equations into authentic vocational scenarios like travel route optimization, tour budgeting, and participant allocation, the E-Worksheets transformed abstract algebraic structures into meaningful objects of inquiry. In Deep Learning theory, connecting academic content to students' lived experiences and vocational profiles triggers mindful engagement and facilitates cognitive schema integration [39]. This approach reflects the core principles of Realistic Mathematics Education (RME) and Contextual Teaching and Learning (CTL), which assert that mathematical competencies are acquired most effectively when learners construct solutions within familiar real-world environments [40], [41], [42]. Previous investigations in vocational education corroborate that situating mathematical tasks within professional domains, such as tourism, substantially enhances student engagement, conceptual retention, and analytical agency [43].

In the development phase, compiling the PowerPoint layouts into an interactive digital flipbook via FlipHTML5 produced an instructional media that satisfied rigorous criteria for validity and Deep Learning readiness. Evaluation by subject-matter experts yielded an average score of 71.00 (out of 75), while media validation reached an average score of 103.00 (out of 110), placing the developed E-Worksheets firmly in the Very Valid category. High ratings in content appropriateness, language precision, and graphic presentation confirm that the media possessed strong internal consistency and instructional coherence. According to [44], [45], validity framework, high expert validity is a prerequisite for fostering Deep Learning environments, as flawed or poorly structured media can induce extraneous cognitive load and hinder deep conceptual processing. These results corroborate recent findings [46], who reported that expert-validated digital flipbooks effectively organize complex mathematical information, allowing learners to focus on higher-order cognitive tasks rather than struggling with media navigation.

The implementation phase demonstrated that the E-Worksheets was highly practical and seamlessly integrated into classroom instruction, directly supporting the mindful and engaging dimensions of Deep Learning. The student usability response questionnaire yielded an overall mean score of 72.6, categorizing the media as Practical, with notable positive ratings in presentation quality (26.0), language accessibility (17.3), and material clarity (17.1). By capitalizing on the high rate of personal smartphone ownership (90%), the interactive flipbook successfully redirected student mobile device usage from passive entertainment toward goal-directed educational inquiry. This transition is essential in Deep Learning environments, where interactive, student-centered media empower learners to control their learning pace and engage deeply with instructional tasks [47], [48]. These empirical results are consistent with Ningrum et al. [49], who found that interactive digital Worksheets significantly boost learner autonomy, ease of navigation, and task motivation compared to static paper materials in vocational classrooms.

The evaluation phase provided robust empirical evidence regarding the instructional effectiveness of the E-Worksheets in promoting Deep Learning and enhancing critical thinking skills. Inferential statistical testing using a paired-sample t-test revealed a highly significant improvement in student performance post-intervention ($t(29) = 27.50, p < .001$), leading to the rejection of the null hypothesis. The average score increased substantially from a pretest mean of 55.57 (moderate baseline ability) to a posttest mean of 86.20 (high mastery level), representing a mean score difference of 30.63 points. This cognitive gain indicates a structural shift from surface memorization to deep analytical reasoning, directly mitigating the initial 57% matrix conceptual error rate observed during the diagnostic survey. These findings strongly resonate with research by Ramdani et al. [50], Siswanto et al. [51] and Janah et al. [52], who observed that context-rich digital Worksheets cultivate critical thinking skills by requiring students to analyze, evaluate, and synthesize complex mathematical data rather than perform routine calculations.

Quantifying overall student learning gains yielded a normalized gain (N-Gain) score of 0.69, placing the instructional impact in the upper boundary of the moderate-to-high gain category. According to Hake [35] normalized gain classification criteria, an N-Gain value approaching 0.70 signifies an exceptionally effective instructional intervention capable of closing cognitive gaps in applied mathematics. Within the Deep Learning framework, such a substantial yield confirms that students did not merely memorize matrix operational rules, but internalized concepts deeply enough to apply them to novel contextual problems. This

outcome aligns with broader meta-analytic evidence by Ansari et al. [53] and Saputra et al. [39], which demonstrates that technology-assisted contextual instruction consistently outperforms conventional expository teaching in fostering higher-order mathematical competencies. Furthermore, these results reinforce the conclusions of Nurazi et al. [54] and Oktapia & Siregar [55], who emphasized that mobile-compatible contextual Worksheets provide the scaffolding necessary to sustain self-paced, deep cognitive restructuring in vocational education.

In conclusion, the systematic development of the tourism-contextualized E-Worksheets through the ADDIE model offers a powerful framework for advancing Deep Learning in vocational high schools. By converting ubiquitous mobile technology from a classroom distraction into an interactive Deep Learning medium, this study successfully resolved the discrepancy between high device ownership (90%) and low educational usage (10%). The integration of authentic tourism scenarios transformed matrix operations from abstract, error-prone procedures into practical decision-making tools, yielding validated media quality (71.00 subject matter, 103.00 media), high practicality (72.6), and marked cognitive improvement (N-Gain = 0.69, $p < .001$). Ultimately, these findings demonstrate that embedding Deep Learning principles within interactive, contextualized digital media provides a scalable and effective strategy for transforming vocational mathematics education and cultivating the critical thinking skills required in the modern workforce.

5. CONCLUSION

Based on the empirical findings, it can be concluded that the interactive matrix E-Worksheets contextualized within a tourism travel framework and developed via the ADDIE model is exceptionally valid (expert scores of 71.00 for subject matter and 103.00 for media), highly practical (student usability score of 72.6), and remarkably effective in elevating the critical thinking skills of Grade XI students at SMK Dirgantara Putra Bangsa, as evidenced by a statistically significant mean score increase from 55.57 to 86.20 ($t(29) = 27.50, p < .001$) and an average normalized gain (N-Gain) of 0.69. Based on these conclusions, it is recommended that vocational mathematics educators integrate contextual, mobile-compatible digital Worksheets to productively transform student smartphone usage into active learning engagement, while future researchers are encouraged to expand this Deep Learning-based framework to other mathematical topics, larger student cohorts, and diverse vocational disciplines to assess its broader generalizability and long-term instructional efficacy.

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