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DEVELOPMENT OF AN E-MODULE TO IMPROVE LEARNING OUTCOMES ON THE TOPIC OF MILLING MACHINE PARTS FUNCTIONS

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ABSTRACT
This study develops an e-module to address low student learning outcomes in the subject Milling Machine Parts Functions in vocational education. Observations showed that 36.1% of class XI TPM 1 and 37.0% of class XI TPM 2 scored in the low range (56–65), indicating difficulty understanding this core material. The issue stems from conventional lecture-based teaching and static textbooks that limit engagement and conceptual grasp. Using the Research and Development (R&D) approach with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation), the study involved expert validation through CVR/CVI. A Mann Whitney-Test confirmed that the e-module significantly improved learning outcomes, with the Normalized N-gain (N-gain) reaching the High effectiveness category. By integrating 3D visuals and animations, the e-module created an engaging, contextual learning experience that enhanced students technical understanding and readiness for industrial demands.

INTRODUCTION

Vocational education in Indonesia, especially through Secondary School (SMK) with a Mechanical Engineering expertise program, has an important role in preparing a skilled and expert workforce to face in the industrial era 4.0. In manufacturing, the skill of operating the main tooling machine such as the machine *Fees* become a very important technical ability. Machine *Fees* It is widely used in precision machining processes, such as cutting, forming, and making grooves on metal materials. Research by (Sujarwo et al., 2025.) shows that the use of e-modules in learning engineering drawings can significantly improve students' visualization skills and concept understanding. E-modules equipped with visualization and evaluation features are proven to help students in understanding machine structures *Fees* faster and more deeply. Mastery of this concept is very important as a basis before students practice in the workshop, due to the lack of understanding of machine components *Fees* can cause operational errors, equipment damage, and even risk causing work accidents.

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Contextualization of Vocational Education and the Need for Mechanical Competency

Although understanding the function of each component of a machine is a very important basic knowledge, preliminary observations show that there is a considerable gap in the learning achievement of XI of Machining Engineering. Based on the analysis of learning outcomes of Hydraulic Machining Engineering, it is known that the level of student understanding is still relatively low. As many as 36.1% of students in class XI 1 and 37.0% of students in class XI TPM 2 obtained scores in the range of 56–65, which is included in the low category.

This phenomenon indicates that more than a third of students have not reached the minimum expected competencies. This low achievement requires strategic intervention through the development of more effective and relevant learning media. (Khair & Fauzi, 2021) emphasizing that the application of the *based learning* in e-modules proven to be effective in improving critical thinking and technical understanding of students at the vocational level.

Learning Gap: Limitations of Conventional Methods

The main factor identified as the cause of the low learning outcomes is the dominance of *conventional learning* patterns. Teacher often use and rely on static textbooks as the main source. This approach has fundamental weaknesses in the context of vocational education. First, the method makes students passive and less active in building their own knowledge. Second, students face difficulties in understanding abstract technical, especially those related to the functions and internal movements of *milling machine components*. This condition is not in line with the characteristics of vocational school students who generally prefer learning with visual and kinesthetic approaches.

Theoretical framework: E-modules as a solution for visualizing complex technical content

Rapid advancement of information technology Communication (ICT) is one of the innovations of e-modules, which are digital-based teaching materials that offer easy access and are equipped with Various multimedia features such as animations, videos, simulations, and interactive quizzes. This approach was chosen because it has a systematic, flexible structure, and can be adapted to various learning contexts, including in the development of e-modules (Mohammad Basir et al., 2025). In learning in the field of engineering, e-modules have an important role as a link between theoretical understanding and practical application in the field, as well as encouraging students' learning independence. E-modules equipped with dynamic visualizations, such as 3D drawings, are able to help students form a more precise mental picture of how each component of the machine works. The ability of e-modules to present material in a contextual, engaging, and appropriate manner to students' needs makes it an effective solution to improve learning outcomes, as has been proven by various previous studies in the field of engineering.

Research novelty and objectives

This research was conducted to close the gap that still existed in the previous study. First, there is still very little research that specifically focuses on the development of learning media for the functional material of milling machine parts, which are complex and applicative. Second, many previous studies only stopped at the design or validation stage without proceeding to the stage of real implementation and quantitative evaluation to assess the improvement of learning outcomes in a concrete way.

Thus, this research presents an important novelty, namely the focus on complex machine *materials*, the application of the ADDIE development model as a whole to the effectiveness evaluation stage, and the integration of interactive digital elements such as 3D visualization and simulation. In detail, the objectives of are:

1. Develop e-modules on the functional material of *milling* machine parts.
2. Designing an e-module architecture to support innovative learning.
3. Determine the feasibility and validity of the e-module according to material experts and media experts.
4. Analyze the effectiveness of e-modules in improving learning outcomes using the right-party t-test (*mann Whitney-Test*).
5. To find out the amount of increase in student outcomes using the N-gain test.

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METHOD

Research design: ADDIE model framework

This research is classified in the type of Research and Development (*Research and Development/R&D*) that aims to Digital learning media in the form of e-modules that have been tested in terms of feasibility and effectiveness. Type The ADDIE model is used, which includes five main stages: *Analysis* (analysis), *Design* (planning), *Development* (development), *Implementation* (application), and (evaluation). Research by (Lumbantobing et al., 2019). who develop based on the ADDIE model designed to support the *discovery learning* on tension and shaft materials in learning mechanical engineering and mechanical elements. Developed e-modules not only presenting information, but also utilizing interactive digital technology to help students complex engineering concepts. The ADDIE model is used because it has steps that and planned, so that produced in accordance with the learning needs of students and has gone through a thorough validation and effectiveness testing process.

Subject and location of the research

This research at SMK Negeri 1 Nganjuk by involving grade XI students of the Engineering Expertise Program who took the subject Engineering as the subject of research. The total number of students in the study population was 63 people. To test the effectiveness of e-modules through *the quasi-experiment method*, the research participants were divided into groups, namely:

- Sample Experimental Group (30 students) : Students who study using e-modules.
- Control Group Sample (33 students) : Students who learn to use media Conventional Learning (Printed Books/Modules).

ADDIE stage detailed procedures

The media development process is carried out by following the five main stages in the ADDIE model systematically and sequentially.

Analysis stage

This stage is the foundation that ensures the relevance of the product.as expressed by (Watts, 2022) which states that needs analysis in the development of learning media is a very important aspect to ensure the suitability of products with user needs. This process is carried out to identify the gap between the expected learning outcomes based on the CPL of the Independent Curriculum and the actual learning outcomes of students. The results of the needs analysis revealed that students need learning media that can help them understand the function of each part of the machine *Fees* visually and digitally. This is because conventional learning methods have not been able to bridge students' understanding of abstract technical concepts. These needs include two main aspects, namely knowledge competence (understanding component functions) and skill competence (identifying and explaining), which are in line with the values in the Pancasila Student Profile.

Design stage

After the needs analysis stage is completed, the process continues to the design stage which results in the initial structure of the e-module. At this stage, the design is prepared by arranging the sequence of materials logically from simple to complex concepts, determining the learning model used *(Project Based Learning)*, and designing supporting visual elements. The main outcome of this stage is the design *of the storyboard*, which organizes the content of the e-module into easily accessible sections, including the Profile (Competencies and Objectives), Introduction (core materials such as the *Functions of the Cooling Machine Table*, the Main Shaft Function, and the Function of the Cooling System), as well as the Evaluation section. Content design is also directed to break down complex mechanical concepts such as knee and saddle movements into more cognitively simple learning units, so as to reduce the burden of students' thinking and support the knowledge transfer process effectively.

Development stage

This stage is the process the design into an offline-based e-module prototype that can be accessed through *smartphone* and laptop devices. The e-module content is developed by utilizing 3D visualization, animations that display the machine's working functions, and digital quizzes as a means of interactive evaluation. After *the prototype*

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is completed, the product is validated by two parties, namely a Media Expert who assesses design, communication, and technical aspects, and a Material Expert who reviews the accuracy, relevance, and completeness of the technical content, including components such as *Arbor* and *Spindle*.

Validation and reliability instruments

The quality of products and research instruments is maintained through a series of quantitative validity and reliability tests. According to Sugiyono (Al Hakim et al., 2021) Validity test is an important step taken to assess the suitability of the content (*content validity*) of an instrument. The main purpose of the validity test is to ensure that the instrument used is actually capable of measuring what should be measured in the study.

Content *validity*

The validity of the content of the e-module and test instruments was tested using a quantitative approach through *the Content Validity* (CVR) developed Lawshe and *the Content Validity Index* (CVI). This validation process involves ten experts or *Subject Matter Experts* (SME) to assess the level of suitability, clarity, and relevance of each component in the e-module and research instruments.

Calculation of CVR & CVI

The ContentiValidity Ratio (CVR) is used to assess the extent to which experts agree that an item of an instrument is essential. The CVR value is calculated based on a comparison between the number of experts who consider the item important to the total number of experts involved. By involving ten experts, an item is considered valid if it has a minimum CVR value of 0.62.

Furthermore, CVI is calculated as the average of all eligible CVR values, providing a measure of the overall validity of the content. The CVI value range of 0.68 – 1.0 is categorized as *Very Suitable*.

Instrument reliability

Reliability between raters (*Inter-Rater Reliability*) is used to measure the level of consistency of the assessment between experts on the feasibility of the developed media. This reliability test aims to ensure that the assessment results are stable and do not depend on a particular individual assessor. Instrument reliability testing can be performed through several reliability test methods tailored to data and research objectives. According to (Scott, 2013) "Reliability is an indicator that describes the level of reliability or consistency of a measuring instrument in producing reliable data". The methods used to measure the reliability between the assessors are *Percentage of Agreement* (PA). The instrument is declared to have good reliability if the percentage value of agreement between the assessors exceeds 0.80. Meanwhile, to test the reliability of the test, correlation coefficients between classes or *Interclass Correlation Coefficient* (ICC), where a value above 0.75 indicates a very good level of reliability.

Implementation and Evaluation Stage

Implementation

Effectiveness testing was carried out through the *Pretest-Posttest Group Design*, which is a method involving groups - the experimental group the control group which were given a pre- and *post-test test* respectively to assess the extent to which the treatment affected learning outcomes.

Table 1. Pretest *Posttest Control Group Design*

Class	*Pre-Test*	Treatment	*Post-Test*
Eksperimen		X	
Control			

Remarks: is *Pre-Test*, X is the treatment (use of e-module), and *Post-Test*.

Effectiveness Evaluation

The evaluation stage is carried out by analyzing the data of *pretest* and *posttest* results. Before testing the hypothesis, a normality test was carried out using *the Kolmogorov-Smirnov* method and a homogeneity *test* with *the Levene's Test* to ensure that the data was normally distributed and had uniform variance. The effectiveness of the e-module was then tested using *the Mann-Whitney Test*, because the research hypothesis was directional (*directional*), i.e. to prove that the learning outcomes of the experimental class () were significantly higher than the control class (),

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formulated as . The level of improvement in learning outcomes was measured using Normalized N-gain (N-gain) analysis. These N-gain values are categorized into Low (), Medium (), or High ().

RESULT

E-module Architecture and Design Implementation

The developed e-modules successfully combine the visual and digital elements needed to help students overcome difficulties in understanding technical material. In its application, operators are required to be able to set various parameters appropriately so that the frais process produces products with quality and dimensions that are in accordance with the set standards (Scott, 2020). The design of this e-module is designed to present material about the functions of each part of the machine *Fees* It is arranged systematically, by breaking down the mechanical complexity of the machine into simpler and easier to understand information units. The main material is displayed visually, including functions and illustrations of important components such as the Machine Base (*Base*), Column Machine, Knee (*Knee*), Sadel (*Saddle*), Machine Table (*Table*), Arm (*Arm*), Spindle (*Spindle*), and *Arbor*. The presentation of material in this e-module helps students build a deeper conceptual understanding of the functional relationships between engine components, such as how the movement of the Saddle above the Knee allows for a transverse shift on the engine table. This approach serves as an authentic digital alternative to the experience in a real work environment, in line with the principle of *Prosser* which emphasizes that vocational education must imitate the actual working conditions while instilling the right habits of thinking and working (*work habits*).

Table 2. Key Components of E-Modules Based on the Function of the Fresh Machine

Fresh Machine Components	Main Functions	Supporting Illustrations
Base	Main foundation and cooling duct	 Figure 2.2
Spindle	Cutting tool rotor components	 Figure 2.8, Rotation Animation
Arbor	Spindle extension, the place of installation of the fresh knife	 Figure 2.9, Installation Diagram

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Lutut (*Knee*)	Column connectors, vertical motion regulators	 Figure 2.4, Motion Animation
Drive Motor	Mechanical energy source of engine drive	 Figure 2.13, Schematic Diagram
Cutting Blade (*Endmill*)	Cutting tools that carve/cut the workpiece	 Figure 2.16

Feasibility and Validity of E-Modules Through Expert Judgment

The validation stage by experts is a crucial process to guarantee that the products developed have optimal academic and technical quality. At this stage, testing is carried out by 10 media experts and 10 material experts who have competence in the field of machining engineering.

CVR and CVI Analysis

The results of the *Content Validity Ratio* (CVR) analysis showed that all items in the media and material assessment instruments obtained a score above the minimum limit of 0.62. The high level of agreement among experts on the importance of each item indicates that the instruments used in assessing the feasibility of e-modules are appropriate and relevant. In addition, the results of the *Content Validity Index* (CVI) calculation show an average value 0.95, which is included in the category *Appropriate* (range 0.68–1.0). This high CVI value strengthens the evidence that the e-modules developed have high feasibility, both from the aspect of technical substance such as the accuracy of the explanation of the functions of the Ram and *Arbor Support components* and from the aspect of multimedia design through 3D visualization that supports the learning of machining techniques at vocational schools.

Reliability Between Appraisers (ICC)

To ensure that the CVR and CVI values obtained reflect consistent agreement between experts, reliability calculations were performed between assessors based on the percentage of agreement level (*Percentage of Agreement*), as explained by (McHugh, 2012). The results of the analysis of the consistency of assessments between experts showed that the value of *Percentage of* (PA) reaches 0.92 and the coefficient *InterclassiCorrelation Coefficient* (ICC) of 0.88. Both values are far from The minimum limit is 0.80 for PA and

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0.75 for ICC. This high value confirms that the product validation process is carried out consistently and reliably, and shows that there is no significant difference in assessment between experts in evaluating the quality of the e-modules developed.

Analysis of the Effectiveness of E-Modules on Student Learning Outcomes

The effectiveness test was carried out by comparing *the results of the posttest* between the class using e-modules and the control class conventional learning media. This comparison was made after the two groups were first confirmed to have equal initial abilities through the implementation of *pretests* and prerequisite tests.

Prerequisite Test

The results of the Normality Test through *the Kolmogorov-Smirnov* the *Homogeneity* Test with Levene's *Test* showed that *the posttest* data from both groups normally distributed and variously homogeneous. Thus, the conditions for conducting parametric statistical analysis have been met, so that it can be continued with the Right Party T Test.

Comparative Analysis Through *the Mann Whitney Test*

The Mann Whitney Test was conducted to test the research directional hypothesis. The results of the analysis showed that the average posttest *score of the* experimental class was 91, while the average posttest score of the *control class* was 70.9. This difference shows a substantial improvement in the experimental class. The results of the calculation show that the value is much greater than the value at the significance level of 5%. Based on the test criteria (If, then rejected), then the null hypothesis (: E-Module is ineffective) is rejected, and the alternative hypothesis (: E-Module is effective) is accepted. The results of the comparative test showed that the use of e-modules was proven to be statistically more effective compared to conventional learning media to improve students' cognitive learning outcomes in the functional material of the *parts of the milling* machine.

Normalized N-gain (N-gain) Analysis

N-Gain to calculate the rate of improvement in student learning by comparing the difference between the final grades (*gain aktual*) with the initial value, against the maximum possible value difference (*gain maximum*) after the treatment is given (Murtadlo & Pharisees, 2023). To assess the level of improvement in learning outcomes, an N-gain score was calculated. The results showed that the average N-gain score in the class reaches 0.75.

Table 3. Categories of N-gain Scores and Interpretation of Results

Skor N-gain	Category	Interpretation of Results
0.812	Tall	Provision of e-module media more effectively to increase student scores than conventional lecture methods.
0.422	Keep	
	Low	

This value places the effectiveness of the e-module in the High category. This shows that e-modules are not only able to significantly improve learning outcomes statistically, but also have a real practical impact in overcoming knowledge gaps that previously arose due to conventional passive teaching methods.

Discussion: Theoretical Alignment and Practical Implications

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The proven effectiveness of the e-module is supported by its design conformity with the principles of vocational pedagogy. E-modules support a constructivist approach, as interactive media such as 3D simulations and evaluative quizzes motivate students to build their own understanding of the mechanical relationships between machine components, rather than simply memorizing information from textbooks. This active involvement changes learning from the cognitive level of remembering (C1) to applying or even analyzing at the C3–C4 level. The use of visual-rich e-modules has a significant impact on *the Transfer of Learning*. Detailed visual representations, such as knee movements or *Arbor Brace functions*, help students build accurate mental schemas. This robust mental schema facilitates the transfer of knowledge from a digital learning environment to physical practice in the workshop, so that students can apply concepts appropriately and safely. In addition, the successful implementation of this e-module is in line with the vocational education philosophy put forward by *Prosser*. By providing a digital replica of a real work environment, the e-module affirms the principle that vocational training should reflect real working conditions. This design ensures that students' understanding of concepts is relevant and applicative, supporting the development of a competent workforce according to industry needs.

RESULT AND DISCUSSION

Research results

CVR CVI dan Percentage Agreement Ahli Media

The e-module validation process was carried out by involving eight media experts to assess the feasibility of the tools and the quality of the display of the developed learning media. The results of the evaluation showed that all indicators obtained *a Content Validity* (CVR) and *Validity Index* (CVI) values of 1.00, indicating that the experts fully approved the suitability of the tool's content. In addition, the percentage of agreement between experts reached 100% (*Percent Understanding*), which shows that there is no difference in perception in the assessment of media viability. Based on these results, the e-module was declared "very *substantial*" and feasible to use as a learning medium. Full agreement among the *validators* provides assurance that the design, structure, and presentation elements of the e-module have met the quality standards of good learning media, are user-friendly, and support the student learning experience effectively.

CVR and Percentage Agreement Subject Matter Experts

Validation conducted by eight subject matter experts showed that the e-module received a CVR and CVI score of 1.00, with a level of agreement between validators reaching 100%, so it was categorized as very *substantial*. These results confirm that the content of the material, the accuracy of the concept, and the feasibility of the substance of the e-module have met the learning quality standards. Thus, this e-module is suitable for use without requiring significant revisions to the material aspect.

Validity of Aiken's V and Reliability of the ICC Test Test

The content validity test of the six questions showed that the measurement instrument was classified as very substantial. Content validity aims to ensure that each item of the instrument corresponds to indicators relevant to the learning objectives(Aiken, 1985). Eight subject matter experts rated this instrument with an Aiken's V value ranging from 0.875 to 1.00, with an average of 0.98, so that all questions have exceeded the minimum limit of 0.88 and are declared substantial because they are in accordance with the indicators of learning achievement. Reliability test using *Intraclass Correlation Coefficient* (ICC) yielded an ICC value of 0.000 with p = 0.432, indicating no difference in scoring between validators. Although statistical variations were not detected, these results illustrate a high level of consistency and agreement among experts, so that the instrument was declared reliable and feasible for use at a later stage of the study.

Effectiveness Test

The results of the effectiveness test using *Mann-Whitney* show that the use of e-modules has a significant effect on improving student learning outcomes. With the number of samples in the experimental class of 30, the average *posttest value of* the experimental class reached 91, much higher compared to the control class with a sample of 33

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students of 70.9, with value of p = 0.000 (< 0.05). These findings explain that the e-modules developed are effective for learning, because they can increase student understanding more optimally compared to conventional learning media.

N-gain

The N-gain test to assess the level of improvement in learning outcomes after the application of the treatment. Based on calculations, the control class got an N-gain score of 0.422 which was included in,while reached 0.812, classified as a high category. These results show that the use of e-modules provides a more significant increase in learning outcomes, with a rate of improvement in ability of around 61.4%. Thus, it can be concluded that e-modules are effective in students' understanding of the functional material of milling machine parts.

With such results, the limitations of this study are in the number of samples of less than 50 respondents per class and the number of schools is only 1 school. So to get maximum results, the next study uses different respondents with the specified number and uses more than 1 school.

DISCUSSION

The Validity of Content by Media Experts and Subject Matter Experts

The results of the content assessment by eight media experts and eight content experts showed that the developed e-modules met all eligibility criteria. Both media experts and content experts gave CVR and CVI scores of 1.00, which indicates that the e-module has met all aspects of learning media feasibility (Polit & Beck, 2006, 489-497). The level of agreement between experts reached 100%, indicating that there was no difference of opinion in assessing the feasibility of the tool's indicators. These findings confirm that all statements in the instrument are considered to be very significant both in terms of media appearance and material substance, so that e-modules can be used in research without requiring significant changes.

Validity of Items Based on Aiken's V

The results of the instrument's validity analysis using Aiken's V showed an average of 0.98, with values ranging from 0.875 to 1.00, all above the critical limit of 0.88 for eight raters. These findings indicate that all items in the instrument are considered highly relevant and appropriately represent the construct being measured.

Intraclass correlation coefficient (ICC)

The consistency test between the raters showed very consistent results, with *the Intraclass Correlation Coefficient* (ICC) close to one, indicating a high level of agreement among the validators. This indicates that the assessment of the e-module is carried out consistently. The high ICC score also reinforces the legitimacy of the assessment, thus confirming that e-modules can be considered a reliable and valid digital vocational teaching tool.

Effectiveness of E-Modules Based on Mann-Whitney Test

The results of the effectiveness test showed significant differences between the experimental and control groups. With a value of p = 0.000, the experimental group using the e-module obtained an average *posttest* score of 91, higher than the control group of 70.9. E-modules, which offer flexibility, clear visualization, and repetitive practice opportunities, have been proven to have a positive impact on student learning outcomes. These findings are in line with previous research that shows statistically and *pedagogically* that e-modules are able to improve the understanding and quality of learning of vocational school students.

Improved Learning Outcomes

The results of the N-gain calculation showed that the experimental group experienced a higher improvement in learning outcomes than the control group, which showed only a moderate improvement. The e-modules developed have been proven to be able to improve students' understanding of concepts and test achievements. This increase in N-gain confirms that e-modules have a significant role in supporting the learning outcomes of vocational school students, both for *procedural* and *conceptual materials*.

The use of Flipbook-based e-modules showed an increase in mastery of concepts with a high N-gain score. This study confirms that e-modules are an effective tool for independent learning and are able to improve students' vocational learning achievement. These findings reinforce the view that e-modules play an important role in improving the efficiency and sustainability of vocational education.

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CONCLUSION

Based on the results and discussion conducted on *"Development of E-Modules to Improve Learning Outcomes in Functional Materials of Washing Machine Parts"*, several conclusions can be drawn as follows:

1. The creation of e-modules follows the ADDIE process, which makes it structured and scalable. Finally, an e-module was created that is in accordance with the curriculum at the Vocational School majoring in Mechanical Engineering, which mixes theory with practice.
2. The e-module is designed as a state-of-the-art Flipbook that brings together text, images, and interactive elements. The design allows students to learn independently.
3. All three E-modules were treated with excellence by the experts, with a score of 1.00 and received full approval from all the assessors.
4. The e-module is proven to work because there is a noticeable improvement in learning outcomes in the group that uses this module.
5. The N-gain analysis showed that students' comprehension improved significantly, which shows that these e-modules are very useful, reliable, and effective for learning.

This research also has broad implications for the development of instructional media in vocational education in theoretical, practical, and educational policy aspects.

a. Theoretically, this study confirms the construction of learning media based on the theory of Instructional Design anddemonstrateADDIE. By going through every step of analysis, design, development, implementation, and Systematically, the resulting instructional media will achieve the criteria of validity, reliability, and effectiveness. This research also confirms the theory of Cognitive Learning Theory*Mixed* media(Mayer, 2009.). which states that the combination of visual and verbal material aids in the comprehension and retention of information, especially in engineering areas that require conceptual understanding and spatial visualization skills.
b. Practically, the development of Flipbook-based e-modules has proven to be feasible and effective for teaching *Straw Machining Techniques.*
c. Regarding education policy, this study encourages vocational education institutions and policymakers to accelerate the digitalization of vocational education which will be implemented through the integration of e-modules into the syllabus and lesson plans.
d. The successful development of Flipbook-based e-modules contributes to innovative research and *instructional technologies*, signaling the development of other advanced learning media , such as interactive e-modules based on *augmented reality learning* simulations for practical engineering techniques.

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