

DEVELOPMENT OF MANUFACTURING ENGINEERING DRAWING LEARNING E-MODULES TO IMPROVE STUDENTS' BASIC UNDERSTANDING OF 3D DRAWING MATERIALS MACHINING ENGINEERING EXPERTISE PROGRAM

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ARTICLE HISTORY

Received : 06-08-2026
Revised : 21-08-2026
Accepted : 10-09-2026

KEYWORDS

3D Drawing, Autodesk
Inventor, Drawing
Manufacturing
Engineering, E-
Module,

ABSTRACT

The rapid development of digital technology requires vocational education to provide innovative learning media that can improve students' understanding of manufacturing engineering drawing concepts, particularly 3D drawing. This research and development study aimed to determine the effectiveness and practicality of an Autodesk Inventor-based e-module for Manufacturing Engineering Drawing learning. The study employed the ADDIE development model and a two-group pretest–posttest design involving Grade XI students of the Machining Engineering Program at SMK IPT Karangpanas. Data were collected through learning achievement tests and practicality questionnaires. The findings indicate that the developed e-module is both effective and practical. Students in the experimental group achieved higher learning outcomes than those in the control group, with mean posttest scores of 86.83 and 73.21, respectively. The experimental group also demonstrated a higher learning improvement, as indicated by a high N-Gain score (0.7603), compared with the control group, which achieved a moderate N-Gain score (0.5564). In addition, the practicality assessment showed that the e-module obtained a score of 81%, indicating that it is highly practical for classroom implementation. These findings demonstrate that the Autodesk Inventor-based e-module effectively enhances students' learning outcomes and provides an engaging digital learning resource for Manufacturing Engineering Drawing, particularly in learning 3D drawing.

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INTRODUCTION

Manufacturing engineering drawing is a fundamental subject in the Machining Engineering Expertise Program because it provides the essential knowledge and skills required for planning, production, and evaluation processes in the manufacturing industry (Jiménez López et al., 2025). Students are expected to master engineering drawing standards, including projection methods, symbols, tolerances, and ISO standards, as these competencies are indispensable for machining

practice and future industrial work. However, many vocational high school students still experience difficulties in understanding these concepts, resulting in low learning achievement and limited readiness for practical activities (Aryanto, 2021; Fajri et al., 2022; Sujarwo et al., 2025).

The integration of computer-aided engineering drawing software into Grade XI learning presents additional challenges for students who have not yet developed a strong foundation in conventional engineering drawing (Regassa Hunde & Debebe Woldeyohannes, 2022). Although schools generally provide computer laboratory facilities, their utilization is often constrained by limited access, shared computer use, and ineffective learning behavior, reducing opportunities for students to practice independently. Consequently, learning remains teacher-centered, students tend to be passive, and the achievement of learning outcomes is still below expectations (Azzahra et al., 2023; Darmono et al., 2024; Vikiyanto et al., 2023).

To address these challenges, digital learning media have become increasingly important in vocational education. E-modules provide interactive learning experiences by integrating text, images, videos, animations, and self-assessment exercises into a flexible digital platform. Such learning media enable students to study independently according to their own learning pace while supporting teachers in implementing student-centered learning, as required by the Independent Curriculum. Previous studies have demonstrated that e-modules can improve students' motivation, engagement, and learning outcomes in engineering and vocational education (Afriyadi & Hayati, 2023; Fatriyanto et al., 2024; Septantiningtyas, 2025). Furthermore, teachers continue to play an essential role in motivating students and maximizing the effectiveness of digital learning media during classroom instruction (Jainiyah et al., 2023).

Several studies have developed e-modules for Manufacturing Engineering Drawing using Autodesk Inventor and reported positive impacts on students' learning outcomes (Ammar et al., 2025; Edwin & Kurniawan, 2023; Hasanuddin et al., 2023; Hendrawan, 2025; Salim & Arsana, 2023). However, most previous studies focused primarily on developing learning media or evaluating its feasibility and practicality. Limited studies have comprehensively examined the effectiveness of Autodesk Inventor-based e-modules specifically for 3D drawing materials using an experimental design that compares learning outcomes between experimental and control groups. This limitation indicates the need for further research to provide stronger empirical evidence regarding the effectiveness of digital learning media in vocational education.

Based on these considerations, this study aims to develop an Autodesk Inventor-based e-module for Manufacturing Engineering Drawing on 3D drawing materials and to evaluate its validity, practicality, and effectiveness in improving the learning outcomes of Grade XI students in the Machining Engineering Expertise Program. The findings of this study are expected to contribute to the development of innovative digital learning media that support student-centered learning and enhance vocational education, particularly in Manufacturing Engineering Drawing.

METHOD

The study employed a Research and Development (R&D) approach using the ADDIE model, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because it provides a systematic framework for developing educational products while allowing continuous evaluation and revision throughout the development process. The effectiveness of the developed e-module was subsequently evaluated using a quasi-experimental Two-Group Pretest–Posttest Design, which enabled comparisons of learning outcomes between students who learned using the developed e-module and those who received conventional instruction.

The research was conducted during the even semester of the 2025/2026 academic year at SMK IPT Karangpanas, involving Grade XI students of the Machining Engineering Expertise Program. The research subjects consisted of two intact classes selected through purposive sampling because the classes had similar learning characteristics, curriculum, and academic backgrounds. One class served as the experimental group, which learned using the Autodesk Inventor-based Manufacturing Engineering Drawing e-module, while the other served as the control group, which received conventional learning. The experimental class consisted of 18 students, whereas the control class consisted of 19 students.

The development process followed the five ADDIE stages. During the Analysis stage, curriculum requirements, student characteristics, learning problems, and instructional needs related to 3D manufacturing engineering drawing were identified through classroom observations and interviews with teachers. In the Design stage, learning objectives, instructional

materials, learning activities, assessments, and the e-module interface were designed according to the Independent Curriculum. During the Development stage, the Autodesk Inventor-based e-module was produced and subsequently evaluated through expert validation before revision. The Implementation stage involved classroom trials using the developed e-module in the experimental class, while the control class learned through conventional instruction. Finally, the Evaluation stage assessed the validity, practicality, and effectiveness of the developed e-module based on expert judgments, students' responses, and learning outcome data.

Before classroom implementation, the e-module was validated by three media experts and three subject-matter experts, all of whom possessed academic expertise and teaching experience in engineering education and manufacturing engineering drawing. In addition, the learning achievement test was evaluated by eight expert validators to determine the quality of the test items. Research instruments included (1) media validation sheets, (2) material validation sheets, (3) pretest and posttest instruments, and (4) student practicality questionnaires using a five-point Likert scale.

The experimental procedure began with administering a pretest to both groups to determine students' initial knowledge. The experimental group then learned using the Autodesk Inventor-based e-module, whereas the control group received conventional teacher-centered instruction using existing learning materials. After the instructional sessions were completed, both groups were given the same posttest to measure learning achievement. Students in the experimental group also completed the practicality questionnaire to evaluate the usability of the developed e-module.

The validity of the media and material validation instruments was analyzed using the Content Validity Ratio (CVR) because it is appropriate for determining the relevance of assessment indicators based on expert judgment. Instrument reliability was evaluated using Percentage Agreement (PA) to determine the consistency among validators. The validity of the learning achievement test was analyzed using Aiken's V, while its reliability was determined using the Intraclass Correlation Coefficient (ICC) because the test items were assessed by multiple experts. Learning outcome data were analyzed descriptively to summarize students' performance. Prior to hypothesis testing, the Shapiro–Wilk test was conducted to examine data normality, whereas Levene's homogeneity test was performed to determine the equality of variances between groups. Since both assumptions were satisfied, an independent-samples t-test was employed to identify significant differences in posttest scores between the experimental and control groups. Furthermore, N-Gain analysis was used to determine the magnitude of students' learning improvement after the implementation of the developed e-module. The practicality questionnaire data were converted into percentages and interpreted according to practicality criteria ranging from impractical to very practical.

RESULT AND DISCUSSION

Result

Validity and Reliability

Prior to use in the study, the research instruments underwent expert validation. This validation applied to the assessment tools for educational materials (media resources and content) as well as the assessment tools for the quality of examination tasks.

CVR Validity and Reliability

Table 1. Media Validity Results

Indicator	CVR	Categories
1	1	Valid
2	1	Valid
3	1	Valid
4	1	Valid
5	1	Valid
6	1	Valid
7	1	Valid
8	1	Valid

Indicator	CVR	Categories
9	1	Valid
10	1	Valid

Source: IBM SPSS Statistical Applications (2026)

The validity of the media assessment instrument was analyzed using the Content Validity Ratio (CVR), and reliability was assessed using the Percentage of Agreement (PA) indicator. As shown in Table 1, all indicators confirmed its validity: CVR values ranged from 0.75 to 1.00. Furthermore, the PA reliability test demonstrated 100% agreement among experts ($R = 1.00$) with a mean score of 1. These results indicate a very high level of agreement among the experts; thus, it can be concluded that the instrument is highly reliable and suitable for data collection in this study.

Table 2. Material Validation Results

Indicator	CVR	Categories
1	1	Valid
2	1	Valid
3	1	Valid
4	1	Valid
5	1	Valid
6	1	Valid
7	1	Valid
8	1	Valid
9	1	Valid
10	1	Valid

Source: IBM SPSS Statistical Applications (2026)

Based on the data in Table 2, the analysis results indicate that all material evaluation indicators meet the established criteria, with CVR values ranging from 0.75 to 1.00. Reliability checks show 100% agreement among the assessments, indicating a very high level of consensus among the validators.

Aiken Validity and ICC Reliability

Table 3. Question Validity Results

Indicator	Aiken V Index	Categories
1	0,833	Valid
2	0,667	Valid
3	0,917	Valid
4	0,875	Valid
5	1	Valid
6	0,667	Valid

Source: Microsoft Exel (2026)

Based on the data presented in Table 3, the validity assessment using Aiken's V coefficient yielded values ranging from 0.667 to 1.0, with a mean of 0.826. When combined with the reliability assessment results obtained using the intraclass correlation coefficient (ICC), these data confirm the validity of all indicators within the item quality assessment tool.

Table 4. Reliability Test Results Questions

Type Icc	Value	Categories
Single Measures	0,449	Moderate

Average Measures	0,867	Good
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Source: Microsoft Exel (2026)

The reliability assessment of this instrument is based on an ICC Average Measures value of 0.867 (categorized as "good"), given that the study utilized the average scores from eight raters. Although the ICC Single Measures value was 0.449 (categorized as "moderate"), as shown in Table 4, this quality assessment instrument was found to be reliable and suitable for research data collection.

Descriptive Analysis

Table 5. Control Class

	N	Minimum	Maximum	Red	Std. Deviation
Pre-test	19	20	67	40,74	13,324
Post-test	19	60	90	73,21	9,543

Source: IBM SPSS Statistical Applications (2026)

Based on Table 5 above, it can be seen that the pre-test scores show a minimum of 20, a maximum of 67, a mean of 40.74, and a standard deviation of 13.324. Meanwhile, the post-test scores are as follows: a minimum of 60, a maximum of 90, a mean of 73.21, and a standard deviation of 9.543.

Table 6. Experimental Classes

	N	Minimum	Maximum	Red	Std. Deviation
Pre-test	18	20	77	50,17	16,797
Post-test	18	70	100	86,83	10,739

Source: IBM SPSS Statistical Applications (2026)

Based on Table 6 above, it can be seen that the minimum score for the pre-test was 20, the maximum was 77, the mean was 50.17, and the standard deviation was 16.797. Meanwhile, the post-test scores showed a minimum of 70, a maximum of 100, a mean of 86.83, and a standard deviation of 10.739.

Normality Test

Table 7. Normality Test Results

Classes	Statistics	df	Sig.
Pre-test control class	0.942	19	0.283
Control class post-test	0.928	19	0.162
Pre-test of the experimental class	0.916	18	0.112
Post-test experimental class	0.906	18	0.072

Source: IBM SPSS Statistical Applications (2026)

Based on the data in Table 7, it is evident that all significance indicators for pre-testing and post-testing in both groups exceed 0.050. Thus, it can be concluded that all data obtained by the researcher are normally distributed.

Homogeneity Test

Table 8. Homogeneity Test Results

		Living Statistic	df1	df2	Sig.
Pre-test Class	Based on Mean	0,751	1	38	0,392
Post-test Classes	Based on Mean	0,654	1	35	0,424

Source: IBM SPSS Statistical Applications (2026)

Based on the data in Table 8, it can be seen that the significance level for the preliminary test results is 0.392 (> 0.050); therefore, it can be concluded that all data belong to the same population or are characterized by homogeneity of variance.

Independent T-test

Table 9. Independent T test results

		Levene's Test for Equality of Variances		T-test for Equality of		Means
		F	Sig.	t	df	Sig. (2-tailed)
Results	Equal variances assumed	0,654	0,424	-4.084	35	.000
	Equal variances not assumed			-4.071	33.986	.000

Source: IBM SPSS Statistical Applications (2026)

The obtained significance value is 0.424, which is greater than 0.05. Furthermore, the t-test results show a significance value (two-tailed) of 0.000 (less than 0.05). Thus, from a statistical perspective, the null hypothesis (H0) is rejected, and the alternative hypothesis (Ha) is accepted.

Analysis of N gain

Table 10. N Gain Yield

Classes	N Gain	N Gain%
Control Class	0,5564	55,64%
Experimental Classes	0,7603	76,03%

Source: IBM SPSS Statistical Applications (2026)

The data in Table 10 show a difference in effectiveness between the groups. In the control group, the normalized gain (N-Gain) was 0.5564 (55.64%), an average figure indicating limited effectiveness in improving student achievement. Conversely, in the experimental group, the N-Gain reached 0.7603 (76.03%), which is considered high. Thus, the teaching methods and tools employed proved effective in enhancing student achievement.

Practicality

Table 11. Percentage of Practicality

Total Score	Maximum Score	%
2244	2775	81%

Source: Microsoft Exel (2026)

Based on usability test results, the Autodesk Inventor-based electronic module for production drawing development achieved a usability rating of 81%. According to the interpretation criteria applied, this result is categorized as "very easy to use".

Discussion

Media Feasibility Based on Expert Validation

Expert evaluations confirm that the Autodesk Inventor-based e-learning module for Mechanical Engineering Drafting is suitable for use in the educational process. These findings not only confirm that the developed educational material aligns with established standards but also demonstrate a successful combination of relevant content, sound methodological development, and effective digital learning tools. According to e-learning resource theory, high-quality learning tools should facilitate productive student interaction with the material and assist them in achieving their educational goals. Thus, the

positive evaluation results support the conclusion that this module is pedagogically appropriate for teaching mechanical engineering drafting.

These positive expert reviews align with previous research indicating that well-designed digital educational resources enhance the quality of professional learning by providing systematic materials and enabling interactive engagement (Hendrawan, 2025; Salim & Arsana, 2023). Consequently, the developed electronic module provides a reliable foundation for deepening students' understanding of the subject matter, even prior to evaluating its effectiveness in a real-world learning environment.

Validity and reliability analyses revealed that the assessment instruments used provided sufficient accuracy and consistency in measuring students' knowledge and skills. The use of valid and reliable instruments is crucial, as it ensures that observed improvements in academic performance reflect actual learning progress rather than measurement error. This allows for greater confidence when interpreting differences between the experimental and control groups.

Reliable assessment instruments play a key role in pedagogical research, enhancing the validity of the results. Expert involvement in the instrument validation process ensured that each task aligned with the competencies required to master the Mechanical Engineering Drafting course. Thus, the effectiveness of the Autodesk Inventor-based electronic module was assessed using tools that accurately determine students' levels of conceptual understanding and practical knowledge.

The Effectiveness of E-Module

The research results indicate that students learning via Autodesk Inventor-based online modules achieved higher learning outcomes compared to those taught using traditional methods. This advantage stems from Autodesk Inventor's features, which provide interactive 3D visualization, helping students better grasp abstract technical drawing concepts. Unlike traditional approaches that rely primarily on verbal explanations and demonstrations, Autodesk Inventor enables students to manipulate objects, view engineering components from various perspectives, and directly link theoretical concepts to practical applications (Trajkovski et al., 2025).

These findings support constructivist learning theory, which posits that students acquire knowledge more effectively when they actively construct it through meaningful learning activities (Prasetya et al., 2024). The interactive learning environment created by the online modules encourages students to independently explore concepts, repeatedly practice drafting skills, and master the material at their own pace. This active learning approach fosters a deeper understanding of concepts and enhances problem-solving skills in mechanical engineering drafting.

These results align with previous studies by (Ammar et al., 2025) and (Darmono et al., 2024), which found a positive impact of Autodesk Inventor-based learning materials on student performance. However, unlike earlier studies that focused primarily on product development or feasibility testing, this research provides more compelling empirical evidence by evaluating learning effectiveness through a quasi-experimental design comparing experimental and control groups. Thus, this study adds to the existing body of evidence regarding the high effectiveness of Autodesk Inventor-based learning modules in vocational education.

Learning Improvement Based on N-Gain Analysis

Analysis of the N-Gain metric (relative knowledge gain) indicates that students learning via Autodesk Inventor-based e-learning modules demonstrated significantly greater learning gains compared to those receiving traditional instruction. This substantial increase in knowledge reflects not only higher final exam scores but also indicates that the e-learning modules fostered deep conceptual understanding throughout the course. The data show that students were able to consistently build new knowledge by linking theoretical concepts with practical tasks involving mechanical engineering drawings.

The effectiveness of the e-learning modules stems from their methodological features. The combination of 3D visualization, step-by-step instructions, and structured learning tasks enabled students to more easily grasp complex technical drawing concepts. Furthermore, students could repeatedly access course materials and practice independently at their own pace. This flexibility is crucial in vocational education, where students are required to master both theoretical knowledge and practical skills. These findings support constructivist learning theory, which posits that deep understanding is achieved when students actively construct knowledge through meaningful learning activities. The Autodesk Inventor-based learning modules encouraged students to independently explore drafting procedures, visualize engineering objects, and directly apply learned

concepts in practice. Consequently, students developed deeper conceptual understanding and problem-solving skills, attributes that distinguish this approach from traditional, teacher-centered instruction.

These findings align with previous research (Ammar et al., 2025; Darmono et al., 2024; Hendrawan, 2025), which found that Autodesk Inventor-based learning materials enhance student understanding and academic performance. However, this study complements earlier work by providing empirical evidence that the use of Autodesk Inventor-based electronic modules not only improves learning outcomes but also accelerates the rate of material mastery, as evidenced by the higher knowledge gains recorded in the experimental group.

Practicality of the E-Module

The high level of ease of use associated with the Autodesk Inventor-based e-learning module indicates that students hold a positive perception of this learning tool and are able to utilize it effectively during class. Ease of use is a crucial aspect of digital learning materials, as educational technology contributes to improved learning outcomes only when students can access and use it without significant difficulty. Thus, the ease-of-use assessment results confirm that this e-learning module successfully combines usability with effective learning content.

Several characteristics contribute to the ease of use of the developed e-learning module. The systematic organization of learning materials, intuitive navigation, visual illustrations, and clear instructions for completing practical tasks in Autodesk Inventor enable students to complete learning assignments independently with minimal instructor assistance. These features also reduce student reliance on in-class demonstrations and provide opportunities to review learning materials as needed. This flexibility fosters the development of independent learning skills, a key objective of vocational education within the Independent Curriculum program.

These results align with previous research demonstrating that interactive electronic modules enhance student motivation, engagement, and independent learning capabilities by providing flexible access to digital educational resources (Afriyadi & Hayati, 2023; Fatriyanto et al., 2024). Consequently, the Autodesk Inventor-based electronic module serves not only as an effective teaching tool but also as a practical digital resource that supports both classroom instruction and independent study.

Overall, the combination of high practicality and positive learning outcomes suggests significant potential for the wider implementation of this electronic module in vocational education institutions. Integrating Autodesk Inventor into digital learning materials provides students with hands-on experiences that closely mirror real-world manufacturing conditions, thereby strengthening their technical competencies and preparing them for future employment (Xie et al., 2022).

CONCLUSION

This study demonstrates that an Autodesk Inventor-based e-learning module for Mechanical Engineering Drafting, developed using the ADDIE model, meets criteria for validity, usability, and effectiveness in teaching 3D modeling and drafting concepts within professional mechanical engineering training programs. The developed module significantly improved learning outcomes: the experimental group achieved higher post-test scores and greater knowledge gains compared to the control group. Furthermore, high usability ratings indicate that the module is user-friendly and facilitates independent student work during class.

Beyond confirming the effectiveness of the developed product, this study contributes to the advancement of professional education by providing empirical evidence that integrating Autodesk Inventor into digital educational resources enhances the understanding of mechanical engineering drafting fundamentals and supports a student-centered learning approach. The results also suggest that systematically developed digital educational resources can facilitate flexible curriculum implementation (such as Independent Study programs) and improve student readiness for practical work in high-tech industrial environments. Thus, this electronic module can serve as an alternative learning resource for vocational instructors and educational institutions seeking to improve the quality of mechanical engineering drafting instruction.

This study has several limitations. The pilot study was conducted at a single vocational institution with a limited number of students, and the evaluation focused primarily on cognitive learning outcomes and the module's practicality. Consequently, the generalizability of the findings is limited.

Future research should involve larger and more diverse groups of participants from various vocational institutions, examine the module's long-term impact on students' practical competencies and spatial reasoning skills, and incorporate additional Autodesk Inventor features or other modern digital technologies to further enhance vocational training.

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