MJP Journal of Education and Teaching Learning
Vol.4, No.1 (2026): 1720 – 1732
https://jurnalilmiah.co.id/index.php/MJPJETL

Development of Swansoft-Based CNC Milling Simulation Module for Vocational Students

[1)] Saifuddin Karim

[1)] Department of Mechanical and Industrial Engineering, Universitas Negeri Malang

***Corresponding Author:** saifuddin.karim.ft@um.ac.id

Article Info

Keywords:

CNC milling;
Learning module;
R&D;
Swansoft.

ABSTRACT

The limited availability of actual CNC machines and high safety risks pose major obstacles to CNC programming education in vocational high schools. This study developed a Swansoft-based CNC Milling Simulation Learning Module that meets three operational criteria: (1) valid, defined as achieving ≥80% agreement from media, language, and content experts on a 1-4 Likert scale; (2) practical, defined as achieving ≥80% positive student responses on comprehension questionnaires and ≥80% implementation observation scores; and (3) effective, defined as achieving a significant increase in learning outcomes measured by pre-test and post-test scores with N-Gain ≥0.3 (moderate to high category). The study employed Research and Development (R&D) using the 4D framework (Define, Design, Develop, Disseminate). Test subjects were 33 students from class XI TP-3 SMK Negeri 1 Tuban. Instruments included validation sheets, comprehension test questionnaires, implementation observation sheets, and pre-test and post-test questions. Validation results showed 89.71% from media experts, 87.50% from language experts, and 86.46% from content experts, all "Very Good." Student comprehension achieved 87.47% "Very Good", and observation indicated 94% of students could follow all steps. Effectiveness test showed significant average score increase from 68.2 to 90.8, with N-Gain of 0.71 "High" category. The module was declared valid, practical, and effective for self-directed learning for vocational high school students.

Informasi Artikel

Kata Kunci:

CNC milling;
Modul pembelajaran;
R&D;
Swansoft.

ABSTRAK

Keterbatasan jumlah mesin CNC riil dan risiko keselamatan yang tinggi menjadi kendala utama dalam pembelajaran pemrograman CNC di SMK. Penelitian ini mengembangkan Modul Pembelajaran Simulasi CNC Milling Berbasis Swansoft yang memenuhi tiga kriteria operasional: (1) valid, didefinisikan sebagai pencapaian ≥80% kesepakatan dari ahli media, bahasa, dan materi pada skala Likert 1-4; (2) praktis, didefinisikan sebagai pencapaian ≥80% respons positif siswa pada angket keterpahaman dan ≥80% skor observasi keterlaksanaan; dan (3) efektif, didefinisikan sebagai peningkatan hasil belajar yang signifikan yang diukur melalui nilai pre-test dan post-test dengan N-Gain ≥0,3 (kategori sedang hingga tinggi). Penelitian menggunakan model Research and Development (R&D) dengan pendekatan 4D (Define, Design, Develop, Disseminate). Subjek uji coba adalah 33 siswa kelas XI TP-3 SMK Negeri 1 Tuban. Instrumen meliputi lembar validasi, angket uji keterpahaman, lembar observasi keterlaksanaan, serta soal pre-test dan post-test. Hasil validasi menunjukkan persentase 89,71% dari ahli media, 87,50% dari ahli bahasa, dan 86,46% dari ahli materi dengan kategori "Sangat Baik". Uji keterpahaman siswa mencapai 87,47% kategori "Sangat Baik", dan observasi keterlaksanaan menunjukkan 94% siswa mampu mengikuti seluruh langkah praktik. Hasil uji efektivitas menunjukkan peningkatan nilai rata-rata dari 68,2 menjadi 90,8 dengan N-Gain 0,71 kategori "Tinggi". Modul dinyatakan valid, praktis, dan efektif digunakan sebagai media pembelajaran mandiri siswa SMK.

Article History

Received : 10/04/2026
Revised : 15/07/2026
Accepted : 21/07/2026

✉ ***Corresponding Author:*** (1) Saifuddin Karim, (2) Department of Mechanical and Industrial Engineering, (3) Universitas Negeri Malang, (4) Jl. Semarang No. 5, Malang, 65145, Indonesia, (5) Email: saifuddin.karim.ft@um.ac.id

Nomenclature and Abbreviations

Nomenclature

S	Spindle speed (unit: RPM)
X	Coordinate axis X (unit: mm)
Y	Coordinate axis Y (unit: mm)
Z	Coordinate axis Z (unit: mm)
P	Percentage of evaluation results (unit: %)
IP	Implementation Percentage (unit: %)
Σx	Total score obtained from trial subject responses
Σxi	Total maximum ideal score
g	N-Gain value

Abbreviations

CNC	Computer Numerical Control
SMK	Sekolah Menengah Kejuruan (Vocational High School)
R&D	Research and Development
4D	Define, Design, Develop, Disseminate
GSK	Guangzhou CNC Equipment Co., Ltd.
FANUC	Fuji Automatic Numerical Control
TPM	Teknik Pemesinan (Machining Engineering)
RPM	Revolutions Per Minute
PUEBI	Pedoman Umum Ejaan Bahasa Indonesia (General Duidelines for Indonesian Spelling)
STEM	Science, Technology, Engineering, and Mathematics

1. Introduction

The Industrial Revolution 4.0 has brought fundamental changes to the global manufacturing sector. Automation and digitalization of production processes have become imperative, and at the heart of this transformation lies Computer Numerical Control (CNC) technology. CNC machines enable the production of components with high precision, maintained geometric consistency, and the ability to create complex shapes that cannot be achieved with conventional machine tools [1], [2]. Consequently, mastery of CNC programming and machine operation skills has become a crucial competency for graduates of vocational high schools (SMK), particularly in the Machining Engineering program. This competency requirement aligns with the objective of vocational education, which is to prepare graduates who are work-ready and capable of adapting to industrial technological developments.

The SMK curriculum is designed to balance theoretical understanding and practical application. However, field realities often reveal a significant gap between the competencies expected by industry and the actual capabilities of SMK graduates. One of the primary causes is the limited student access to representative practical facilities and equipment, including CNC machines. Based on preliminary observations and interviews with the Machining Engineering subject teachers at SMK Negeri 1 Tuban, several critical problems were identified: (1) the availability of actual CNC machines is very limited, with an non-ideal student-to-machine ratio; (2) the operational costs of CNC machines are very high, including expenses for raw materials, machine maintenance, and replacement of damaged cutting tools; (3) direct learning on actual machines carries high safety risks and the potential for equipment damage, especially when students are still in the exploration and trial phase; and (4) there is no structured, systematic, and easily understandable simulation module or practical guide available for students with varying levels of ability.

Similar problems were also found in previous studies where CNC learning at the Bangka Belitung State Manufacturing Polytechnic was constrained by the limited number of machines and high operational costs [3]. The solution widely offered by researchers and vocational education practitioners is the utilization of simulation software as a safe, cost-effective, and flexible virtual learning environment [4], [5]. One of the most widely used CNC simulation software programs in both educational and industrial settings is Swansoft CNC Simulator. This software provides a realistic virtual environment, complete with control panels, coordinate systems, and cutting process visualization. Swansoft is capable of simulating various types of CNC machine controls including GSK980MDi and FANUC OiM, as well as various machine types such as Doosan Mynx750 [6]. The advantage of Swansoft is its ability to detect program errors and display them visually, enabling students to learn from mistakes without detrimental consequences.

However, the effectiveness of Swansoft usage is highly dependent on the availability of adequate guides or learning modules. The module serves as a roadmap that guides students step by step, from interface introduction, coordinate system understanding, G&M code writing, to the complete simulation process. A good module must meet the criteria of validity, accuracy of content and conformity with industry standards, ease of independent use, and effectiveness in improving student understanding. Based on the needs analysis conducted through interviews with teachers and students of class XI TPM-3 at SMK Negeri 1 Tuban, the following facts were discovered: (1) 87% of students stated difficulty in understanding CNC simulation due to the absence of written guides; (2) 94% of students wanted a module equipped with screenshot images for each step; and (3) 100% of teachers stated the need for learning resources that could facilitate student independent learning outside of school hours.

Although there have been several research studies on the development of simulation-based CNC learning media, the majority of these studies still have several limitations: (1) the developed modules generally only cover one type of control panel, making them less adaptive to the variety of machines available in industry; (2) practical instructions remain textual with minimal step visualization, making it difficult for students with visual learning styles; and (3) occupational safety aspects and anticipation of common student errors have not received adequate attention. Based on these research gaps, this study developed a CNC Milling simulation learning module with the following novelties: (1) the module covers two types of machine controls simultaneously, namely GSK980MDi and FANUC OiM in a single book, making it more comprehensive; (2) each simulation step is equipped with screenshots featuring clear arrows and numbering; (3) there is an explanation of the workflow from Mastercam to Swansoft; (4) it is equipped with preventive tables; and (5) it employs dialogic and simple analogical language to facilitate understanding of abstract concepts.

The design features of this module are grounded in established instructional design theories. First, Cognitive Load Theory [7] provides the rationale for using step-by-step screenshots with arrows and numbering, which serve as worked examples that reduce extraneous cognitive load by eliminating the need for students to mentally visualize interface navigation [8]. Second, Mayer's [9] Multimedia Learning Principles inform the integration of visual and textual information, particularly the spatial contiguity principle placing text near corresponding images and the signaling principle using cues to highlight key information. Third, the inclusion of two control panel types (GSK and FANUC) applies the principle of variability in practice, which Bruner [10] argued facilitates transfer of learning to new contexts. Fourth, the dialogic language style aligns with Vygotsky's [11] concept of the Zone of Proximal Development, where the module acts as a scaffold that enables students to perform tasks independently that would otherwise require teacher assistance. These theoretical foundations explain why the module's specific features—dual-control coverage, visual step-by-step guides, preventive tables, and dialogic language—are hypothesized to be effective for vocational students learning CNC simulation.

This development research aims to produce a Swansoft-based CNC Milling simulation learning module product for SMK students that meets three operational criteria: valid, practical, and effective. The module is declared valid if it achieves an average percentage of ≥80% from assessments by content, media, and language experts on a 1-4 Likert scale covering content feasibility, presentation feasibility, and linguistic aspects. The module is declared practical if it achieves ≥80% from the student comprehension test questionnaire covering language, material presentation, concept understanding, step implementation, and module benefits, and ≥80% from the implementation observation sheet measuring students' ability to follow each simulation step independently. The module is declared effective if there is a significant improvement in learning outcomes indicated by an N-Gain value of ≥0.3 from pre-test and post-test results consisting of 20 multiple-choice questions measuring CNC Milling concept understanding. Additionally, this research aims to describe the level of module validity based on expert assessments, to describe the level of module practicality based on student responses and implementation observations, and to analyze the level of module effectiveness in improving student understanding through pre-test and post-test score analysis.

Theoretically, this research is expected to enrich the body of knowledge regarding the development of simulation-based teaching materials in the field of vocational education. Practically, the findings of this research can serve as a reference for SMK teachers, lecturers, and CNC training instructors in organizing safe, efficient, and student-centered learning. Furthermore, the resulting module can be used as an independent learning resource for students who wish to prepare themselves before practicing on actual CNC machines, thereby minimizing damage risks and improving machine usage efficiency.

2. Research Method

2.1. Development Model

The development of the Swansoft-Based CNC Milling Simulation Learning Module constitutes Research and Development (R&D) [12]. The development model employed in this research is the 4D model proposed by Thiagarajan, Semmel, and Semmel [13]. The 4D model was selected because it provides a systematic, straightforward procedure that is easily adaptable for developing printed teaching materials such as learning modules. Additionally, the 4D model has been widely used in vocational education development research and has been proven to produce valid, practical, and effective products [5], [14], [15].

The 4D development model consists of four main stages, namely Define, Design, Develop, and Disseminate. These four stages were adapted and tailored to the needs of the research on developing the Swansoft-Based CNC Milling Simulation Learning Module for SMK students.

This study employs a one-group pretest-posttest design, which is appropriate for formative evaluation in the Development stage of the 4D model [16]. In this design, the same group of students (n=33) was assessed before and after using the module. The purpose is to evaluate whether the module shows potential for improving learning outcomes, not to establish causal efficacy. This design is consistent with typical R&D product testing in educational technology, where the focus is on product feasibility rather than comparative experimental research [17]. The researchers acknowledge the internal validity limitations of this design, including history effects other learning experiences during the study period, maturation effects natural skill development over time, testing effects improvement from taking the pre-test, and the absence of a comparison group. Therefore, all claims of effectiveness in this study should be interpreted as preliminary evidence of the module's potential, not as definitive proof of causation.

2.2. Development and Research Procedure

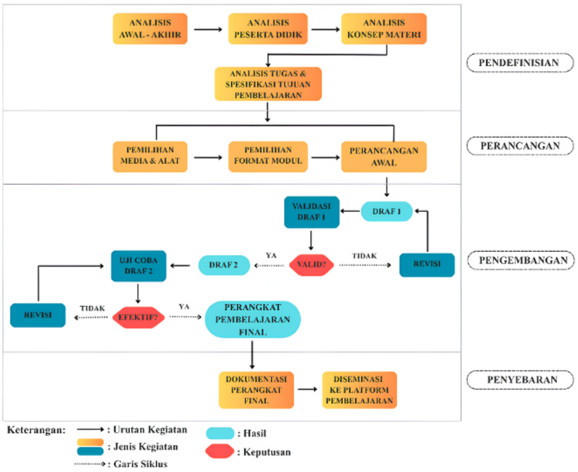

Figure 1. Modified Module Development Model

The module development procedure followed the four stages of the 4D model: (1) Define, at this stage an initial analysis was conducted to identify CNC learning problems at SMK Negeri 1 Tuban, including student needs analysis, material concept analysis, and analysis of the learning objective specifications to be achieved; (2) Design, this stage included the preparation of the module content map, selection of presentation format, and module structure design; (3) Develop, the designed module was then validated by three experts: media expert, language expert, and content expert. The validation instrument used a 1-4 Likert scale. After validation and revision, the module was tested on a limited basis with 33 students from class XI TP-3 at SMK Negeri 1 Tuban. Practicality data were collected through a 5-scale comprehension test questionnaire and an implementation observation sheet for simulation steps. Effectiveness data were collected through pre-test and post-test instruments consisting of 20 multiple-choice questions.

The module was implemented over four 2-hour sessions (total 8 hours) facilitated by the researcher, a trained CNC instructor with more than three years of experience teaching CNC programming, with the classroom teacher present as an observer. Each session followed this structure: Session 1: pre-test (30 minutes) followed by module introduction and basic theory (90 minutes); Session 2: coordinate systems and G/M codes (120 minutes); Session 3: simulation practice on Swansoft (120 minutes); Session 4: independent practice using the module guide (90 minutes) followed by post-test (30 minutes). Implementation fidelity was monitored through three mechanisms: (1) an observation checklist completed by the classroom teacher documenting completion of each module step for every student, (2) attendance tracking (100% attendance was achieved across all sessions), and (3) review of student simulation logs to verify that all simulation steps were completed. All 33 students completed all simulation steps independently using the module guide without significant protocol deviations. Improved understanding was calculated using the N-Gain formula [18]; and (4) Disseminate, the final module was documented and prepared for dissemination through journals and learning platforms.

2.3. Trial Subjects

The trial subjects in this research consisted of three categories. First, expert validators comprising one media expert, one language expert, and one content expert. Second, small group trial subjects consisting of 12 proportionally selected students from class XI TP-3 at SMK Negeri 1 Tuban. Third, large group trial subjects consisting of 33 students from class XI TP-3 at SMK Negeri 1 Tuban.

This study was conducted as part of regular educational program evaluation at SMK Negeri 1 Tuban and involved standard instructional activities. Written informed consent was obtained from all student participants and their parents/guardians. Student data were anonymized and reported only as aggregate statistics. The research protocol was reviewed and approved by the Faculty of Engineering Research Ethics Committee, Universitas Negeri Malang.

2.4. Types of Data

The data collected consisted of both qualitative and quantitative data. Qualitative data included suggestions, comments, and critiques from validators and students. Quantitative data included validation questionnaire scores, comprehension test questionnaire scores, implementation observation sheets, and pre-test and post-test scores.

2.5. Data Collection Instrument

Data collection in this research used questionnaire instruments that were submitted to material expert validators, media expert validators, language expert validators, and the class XI TP-3 SMK Negeri 1 Tuban student trial subjects. The assessment criteria used in the questionnaire instruments followed Sugiyono's assessment criteria which have four assessment scales: (a) score 4, meaning strongly agree/very good, (b) score 3, meaning agree/good, (c) score 2, meaning moderately agree/moderately good, and (d) score 1, meaning disagree/poor.

Several assessment instruments used included observation, documentation, and interview instruments. Observation was conducted to obtain data in the form of responses from trial subjects regarding questions not covered in the questionnaire. Documentary data collection techniques were used to complement the questionnaire data, interview processes, and ongoing research activities. Interviews were conducted to obtain various types of information required for the research process. The information needed included the CNC Milling learning system applied and the learning media used in the learning process at SMK Negeri 1 Tuban. The instrument grid is presented in Tables 1, 2, 3, 4, and 5. To ensure the measurability of these three criteria (valid, practical, effective), this study established operational indicators as presented in Table 6.

Table 1. Grid of Material Expert Validation Instrumen

Assessment Aspect	Indicators
Material Accuracy and Correctness (Content Feasibilty)	Conformity of material with basic competencies
	Material accuracy (CNC concepts, G/M codes, coordinate systems)
	Material learning support (images, tables, examples)
	Material currency (in accordance with CNC technology developments)
Learning Support Material (Presentation Feasibility)	Presentation technique (in accordance with scientific and technological developments)
	Presentation support (currency of features, examples, and references)
	Learning presentation (interconnection between concepts)
	Presentation completeness (includes jobsheets and exercises)
Language Assessment	Straightforward (easily understood by SMK students)
	Communicative (effective language use)
	Dialogic and interactive (contains trigger questions
	Conformity with student developmental level
	Coherence and integration of thought flow
	Use of terms, symbols, or icons

Table 2. Grid of Media Expert Validation Instrument

Assessment Indicators	Components
Module Size	Physical module dimensions (proportional)
Module Cover Design	Module cover layou
	Attractive and easy-to-use fonts
	Module cover illustrations
Module Content Design	Layout consistency
	Harmonious layout elements
	Complete layout elements
	Layout accelerates understanding
	Simple content typography
	Easy-to-read typography
	Content typography facilitates understanding
	Content illustrations (screenshots, diagrams, images)

Table 3. Grid of Language Expert Validation Instrument

Aspect	Indicators
Clarity and Effectiveness of Sentences	Correctness of sentence structure (clear subject and predicate)
	Sentence effectiveness (not convoluted)
	Ease of understanding the overall meaning of sentences
Standardization and Accuracy of Terms	Standardization of technical terms (using standard terms)
	Accuracy in using foreign terms (G/M codes, feed rate)
Punctuation and Spelling	Accuracy in punctuation usage (periods, commas, etc.)
	Conformity with the General Guidelines for Indonesian Spelling (PUEBI)
Communicativeness and Interactivity	Language ability to encourage student reading interest
	Dialogic/interactive language use
	Language ability to facilitate understanding of technical concepts
Conformity with Learners	Conformity of language with SMK students' thinking development level
	Language free from ambiguity

Table 4. Grid of Student Comprehension Test Instrument

Aspect	Indicators
Language	Simple and easily understandable language
	Sentences do not create ambiguity
	Technical terms (G00, G01, Zero Return) are clearly explained
Material Presentation	Explanations are presented systematically and coherently
	Font size and type are comfortable to read
	Images help understand Swansoft display and buttons
	Illustrations (right-hand rule) help remember coordinate axis directions
	Screenshots for each step facilitate direct practice on the computer
	G and M code tables are informative and easy to understand
	Arrow indicators and numbering on

	images facilitate following step sequence
Concept Understanding	Understanding the difference between conventional and CNC machines
	Understanding the functions of main CNC system components (control, panel, motor)
	Understanding the difference between Machine Zero and Workpiece Zero
	Understanding the difference between G90 (Absolute) and G91 (Incremental)
	Understanding the relationship between spindle speed (S), feed rate (F), and depth of cut
Step Implementation	Step-by-step instructions from machine startup to complete simulation are very clear
	Able to perform Zero Return by only reading the module
	Able to set workpiece zero point without teacher assistance
	Able to add and replace tools (cutting tools) in the simulator according to the guide
	Experience no significant difficulties when calling G-Code from Mastercam to Swansoft
Module Benefits	Guide for two machine types (GSK and FANUC) is very helpful and not confusing
	Module increases confidence to try CNC simulation
	Helps because learning can be done independently
	Module increases interest and motivation to learn CNC
	Feel more prepared to practice on actual machines

Table 5. Grid of Pre-Test and Post-Test Question Instruments

Basic Competency	Question indicators
Definition and Basic Concepts of CNC	Explaining the definition of CNC technology based on three main pillars (automation, stored program, program storage)
Coordinate System	Determining coordinate axis directions (X, Y, Z) using the right-hand rule
G-Codes	Identifying the appropriate G-code for rapid traverse without cutting (G00); Interpreting the program command G01 X50 Y25 F150
M-Codes	Explaining the function of M03 code in CNC milling programming
Reference Points	Distinguishing Machine Zero and Workpiece Zero
Programming Systems	Explaining that G90 (Absolute) mode measures all coordinates from the workpiece zero point
Machine Comparison	Explaining the fundamental difference between conventional machines and CNC machines
Tool Types	Selecting the appropriate tool type for making holes (U Drill / Twist Drill)
Cutting Parameters	Explaining the meaning of parameter S1500 (spindle speed in RPM)
Simulation Purpose	Identifying the purpose of using CNC simulation software (except replacing the function of actual machines in mass production)
Incremental System (G91)	Explaining that in G91 mode, the command G01 X10 Y5 moves relative to the current tool position
Workpiece Coordinates	Determining the coordinates of the first hole on a 50x50 workpiece with zero point at the upper left corner
Feed Rate (F)	Explaining the meaning of Feed Rate (tool movement speed when cutting the workpiece)
Simulation Procedure	Determining the first step after starting the machine and releasing the emergency stop (zero return)
Work Offset Setting (GSK)	Explaining the workpiece zero point setting step on GSK980MDi after the tool is positioned at the corner
End Mill Function	Identifying operations that do NOT use End Mill tools (drilling/making holes)
Write Protect	Explaining the correct action when the "Write Protect" message appears on the control screen M30 Code Explaining the function of M30 code (ending the program and returning the indicator to the program start)
M30 Code	Explaining the function of M30 code (ending the program and returning the indicator to the program start)

MJP Journal of Education and Teaching Learning
Vol.4, No.1 July (2026): 1720-1732

Table 6. Operational Criteria for Validity, Practicality, and Effectiveness

Criteria	Instrument	Indicator	Threshold	Data Source
Validity	Content expert validation sheet	Content feasibility, presentation, language	≥80% (Very Good)	Content expert (1 person)
	Media expert validation sheet	Size, cover design, content design	≥80% (Very Good)	Media expert (1 person)
	Language expert validation sheet	Clarity, standardization, communicativeness	≥80% (Very Good)	Language expert (1 person)
Parcticality	Student comprehension test questionnaire	Language, presentation, concepts, steps, benefits	≥80% (Very Good)	33 students of class XI TP-3
	Implementation observation sheet	Ability to follow simulation steps	≥80% of steps observed	Observer (subject teacher)
Effectiveness	Pre-test (20 multiple choice questions)	Initial understanding of CNC Milling concepts	N-Gain ≥0.3	33 students of class XI TP-3
	Post-test (20 multiple choice questions)	Final understanding of CNC Milling concepts	N-Gain ≥0.3	33 students of class XI TP-3

The pre-test and post-test instrument, consisting of 20 multiple-choice questions, was developed based on the blueprint presented in Table 5. The instrument underwent content validation by two CNC subject matter experts who assessed item relevance and content coverage. The Content Validity Index (CVI) was 0.89, indicating acceptable content validity. A pilot test was conducted with 15 students from class XI TP-2 (not part of the main study) to examine psychometric properties. The KR-20 reliability coefficient was 0.82, indicating good internal consistency. Item analysis revealed an average difficulty index (p) of 0.62 (range: 0.35-0.85) and an average discrimination index (D) of 0.38 (range: 0.22-0.55), indicating acceptable item quality (Ebel & Frisbie, 1991). These psychometric properties support the use of the instrument for measuring student understanding in this study.

2.6. Data Analysis Techniques

The data analysis method employed in this research utilized two types of analysis, namely descriptive qualitative and quantitative analysis. Qualitative data obtained from interviews, suggestions, and comments from validators and students were analyzed using descriptive narrative as complementary data. Quantitative data from validation questionnaires and comprehension tests were analyzed using the percentage formula according to Sugiyono [19]: 81.25%-100% (Very Good), 62.50%-81.25% (Good), 43.75%-62.50% (Moderately Good), and 25%-43.75% (Poor). Validity data were analyzed using the percentage formula by Sugiyono as shown in Eq. (1):

$$P = \frac{\sum x}{\sum xi} \times 100\% \quad (1)$$

Description:
P = Percentage of evaluation results
$\sum x$ = Total score obtained from validators
$\sum xi$ = Total maximum ideal score

The module feasibility criteria based on percentage: 81.25% - 100%: Very Good (valid), 62.50% - 81.25%: Good (sufficiently valid), 43.75% - 62.50%: Moderately Good (less valid), 25% - 43.75%: Poor (invalid). The module is declared valid if all assessment aspects from the three validators achieve a minimum of 80%.

Practicality was measured using two instruments: (1) Student comprehension test questionnaire: analyzed using the same percentage formula as shown in Eq. (1); (2) Implementation observation sheet: calculated using Eq. (2). The module is declared practical if both instruments achieve a minimum of 80%.

$$IP = \frac{Number\ of\ steps\ observed}{Total\ number\ of\ steps} (2)$$

Description:
IP = Implementation Percentage (%)
Number of steps observed = Total steps successfully performed by students
Total number of steps = Total steps in the simulation guide

Effectiveness was measured using N-Gain analysis [11] to determine the improvement in student understanding between pre-test and post-test as shown in Eq. (3):

MJP Journal of Education and Teaching Learning
Vol.4, No.1 July (2026): 1720-1732

$$N\text{-}Gain = \frac{Posttest\ Score - Pretest\ Score}{Maksimal\ Score - Pretest\ Score} \quad (3)$$

Description:
Posttest Score = Score obtained after using the module
Pretest Score = Score obtained before using the module
Maximum Score = Maximum possible score (100)

N-Gain interpretation criteria: $g > 0.7$: High (effective), $0.3 \leq g \leq 0.7$: Moderate (sufficiently effective), $g < 0.3$: Low (less effective). The module is declared effective if the N-Gain value is ≥ 0.3 (moderate or high category).

3. Result and Discussion

3.1. Module Validation Result

The developed module was then submitted to three validators: a content expert validator, a media expert validator, and a language expert validator for assessment. The recapitulation of validation results is presented in Table 7.

Table 7. Module Validation Results

No	Assessment Aspect	Σx	Σxt	P (%)	Criteria
1	Material Accuracy and Correctness	28	32	87.50	Very Good
2	Presentation Feasibility	31	36	86.11	Very Good
3	Language	24	28	85.71	Very Good
Total		83	96	86.46	Very Good

Based on Table 7, the material validation results conducted by the content expert on the Swansoft-Based CNC Milling Simulation Learning Module obtained a score of 86.46%. The breakdown for each aspect is: material accuracy and correctness aspect reached 87.50%; presentation feasibility aspect reached 86.11%; and language aspect reached 85.71%. Based on improvement suggestions, the content expert recommended adding module usage instructions at the beginning and correcting typos in the module writing. Overall, the Swansoft-Based CNC Milling Simulation Learning Module was declared feasible to proceed to the trial stage.

Table 8. Recapitulation of Media Expert Validation Result

No	Assessment Aspect	Σx	Σxt	P (%)	Criteria
1	Module Size	3	4	75.00	Good
2	Cover Design	15	16	93.75	Very Good
3	Content Design	43	48	89.58	Very Good
Total		61	68	89.71	Very Good

The validation results showed that the module size aspect obtained a percentage of 75.00%, the cover design aspect obtained 93.75%, and the content design aspect obtained 89.58%. The overall media expert validation percentage reached 89.71% with a Very Good category. Suggestions for improvement from the media expert included increasing the resolution of unclear screenshot images and ensuring consistent font usage throughout all pages. Revisions were made according to these suggestions, making the module feasible for trial.

Table 9. Recapitulation of Language Expert Validation Result

No	Assessment Aspect	Σx	Σxt	P (%)	Criteria
1	Straightforward	11	12	91.67	Very Good
2	Communicative	15	16	93.75	Very Good
3	Dialogic and Interactive	12	16	75.00	Good
4	Conformity with Student Development	11	12	91.67	Very Good
5	Coherence and Integration of Thought Flow	7	8	87.50	Very Good
Total		56	64	87.50	Very Good

The validation results showed that the straightforward aspect obtained a percentage of 91.67%, the communicative aspect 93.75%, the dialogic and interactive aspect 75%, the conformity with student development aspect 91.67%, and the coherence of thought flow aspect 87.50%. Overall, the language expert validation obtained a percentage of 87.50% with a Very Good category. The language expert recommended simplifying overly long sentences, breaking long paragraphs into several shorter paragraphs, and adding trigger questions at the beginning of each sub-chapter to enhance module interactivity. These recommendations were implemented in the final module revision, making the module feasible for trial.

3.2. Practicality Test Result

The module practicality trial was conducted through two stages: a small group trial involving 12 students and a large group trial involving 33 students from class XI TP-3 at SMK Negeri 1 Tuban. At this stage, students were asked to complete a comprehension test questionnaire covering three aspects: display, material presentation, and benefits. Additionally, implementation observations were conducted to observe students' ability to follow each simulation step based on the module guide. The practicality trial results are presented in Tables 10 and 11.

Table 10. Small Group Trial Result

No	Display (20)	Material Presentation (20)	Benefits (20)	Σn (60)	P (%)	Criteria
1	18	17	16	51	85.00	Very Good
2	19	18	17	54	90.00	Very Good
3	16	*15*	14	45	75.00	Good
4	20	19	18	57	95.00	Very Good
5	19	18	18	55	91.67	Very Good
6	18	17	16	51	85.00	Very Good
7	17	16	15	48	80.00	Good
8	19	18	17	54	90.00	Very Good
9	18	17	16	51	85.00	Very Good
10	17	16	15	48	80.00	Good
11	18	17	16	51	85.00	Very Good
12	19	18	18	55	91.67	Very Good
Average per Aspect	18.2	17.2	16.3			
Percentage per Aspect	90.83%	85.83%	81.67%			
Total	86.11%			620		

The results obtained from the small group trial of the Swansoft-Based CNC Milling Simulation Learning Module achieved a score of 620 out of a maximum total score of 720, with a percentage of 86.11% which falls into the Very Good criteria.

Table 11. Recapitulation of Large Group Trial Results

No	Aspect	Σn	ΣN	P (%)	Criteria
1	Display	610	660	92.42	Very Good
2	Material Presentation	577	660	87.42	Very Good
3	Benefits	545	660	82.58	Good
	Total	1732	1980	87.47	Very Good

The results obtained from the large group trial of the Swansoft-Based CNC Milling Simulation Learning Module achieved a score of 1732 out of a maximum total score of 1980, with a percentage of 87.47% which falls into the Very Good criteria. Based on the large group trial results, no significant suggestions or feedback were found, thus the module was declared feasible for use in instruction.

3.3. Effectiveness Test Result

The module effectiveness test aimed to measure the improvement in students' understanding of CNC Milling material before and after using the learning module. Measurement was conducted using pre-test and post-test instruments consisting of 20 multiple-choice questions. The pre-test was administered in the first session before students received the module, while the post-test was administered in the final session after the entire simulation sequence was completed. The effectiveness trial subjects involved 33 students from class XI

TP-3 at SMK Negeri 1 Tuban. The pre-test and post-test results and the N-Gain calculation to measure the module's effectiveness level are presented in Table 12.

Table 12. Effectiveness Test Results (N-Gain)

Description	Pre-test	Post-test	N-Gain	Category
Average Score	68.2	90.8	0.71	High
Highest Score	95	100	-	-
Lowest Score	30	60	-	-

To examine differential effects of the module, students were divided into three prior knowledge groups based on pre-test scores: Low (score < 50, n=6), Medium (50-75, n=18), and High (>75, n=9). The mean N-Gain scores for each group were 0.82 (Low), 0.69 (Medium), and 0.65 (High), suggesting that the module may be particularly beneficial for students with lower prior knowledge. However, these subgroup differences were not statistically tested due to the small sample size. The Pearson correlation between pre-test score and N-Gain was $r = -0.48$ ($p < 0.01$), indicating that students with lower initial understanding tended to gain more from the module. This pattern is consistent with the module's aim to serve as a scaffolding tool for students at various ability levels, as theorized by Vygotsky's (1978) Zone of Proximal Development

Based on Table 12, there was a significant average score increase of 22.6 points. The N-Gain calculation result of 0.71 falls into the High category ($g > 0.7$). This indicates that the use of the Swansoft simulation module is effective in improving students' understanding of CNC Milling material, particularly in the aspects of basic programming, coordinate systems, and simulation safety procedures.

3.4. Discussion

The validation results of the Swansoft-Based CNC Milling Simulation Learning Module developed in this research obtained an average percentage of 87.89%. This validation level is comparable to the findings of other CNC module development research. Kurniawan et al. in the development of a STEM-based learning module on CNC Milling Simulator material reported that the content expert validation results were in the Very Valid category and the media expert validation also obtained the Very Valid category [20]. Similarly, the research on developing a CNC Semi PU GSK 928 TC module for SMK showed validation results from language experts, design experts, and content experts with an average score of 84.43%, which falls into the Very Feasible criteria [21]. The validation achievement in this research, which reached 87.89%, is relatively higher than the 84.43% average, indicating that the developed module has an excellent level of feasibility.

The high validation percentage obtained, particularly in the material accuracy aspect of 86.46%, indicates that the CNC concepts presented conform to industry standards and correct CNC machine operational procedures. This aligns with Arsyad's assertion that learning media with attractive visual design can enhance student motivation and attention [22]. The advantage in the module content design aspect, indicating that layout, typography, and illustrations support readability, serves as a reinforcing factor for the high validation percentage achieved.

It is important to interpret the effectiveness findings with appropriate caution. The one-group pretest-posttest design employed in this study cannot definitively attribute the observed learning gains solely to the module, as other factors—including regular classroom instruction, practice effects from the pre-test, and natural maturation—may have contributed to the improvement. Nevertheless, the magnitude of improvement (N-Gain 0.71) is consistent with findings from similar simulation-based learning studies, suggesting that the module likely played a meaningful role in supporting student learning. The module should be viewed as a promising instructional tool that requires further validation through more rigorous experimental designs.

The module practicality test in this research showed consistent results, with the small group trial obtaining a percentage of 86.11% and the large group trial obtaining 87.47%. The implementation observation results showed an average percentage of 90.97%, indicating that the module is very practical to implement in learning. This finding is supported by the results of previous studies showing that 77.8% of students approved the use of video media and CNC milling lite simulators in CNC learning [23]. The high practicality percentage in this research reflects the positive acceptance of students toward the simulation-based learning module.

The module effectiveness test was measured through pre-test and post-test given to 33 students. The average pre-test score was 68.2, which increased to 90.8 in the post-test, with an improvement of 22.6 points. The average N-Gain calculation result was 0.71, which falls into the High category. This nearly identical improvement figure indicates that the Swansoft-based module in this research has comparable effectiveness to other CNC learning media. Another study conducted at SMK YPM 1 Taman Sidoarjo also showed significant improvement in learning outcomes, where the student mastery percentage from pre-test to post-test increased from 50% to 91.67% [21].

The comparison results with several previous studies indicate that the Swansoft-Based CNC Milling Simulation Learning Module developed has validity, practicality, and effectiveness levels that are comparable to or even better than similar research. The learning outcome improvement of 22.6 points, which is consistent with previous findings, indicates that the simulation approach is proven effective as a bridge between theory and practice in SMK [23].

Based on the research results, the developed module has met all three operational criteria established in the research objectives.

Table 13. Validity Criteria (≥80%)

Validity Aspect	Result	Threshold	Status
Content Expert	86.46%	≥80%	Achieved
Highest Score	89.71%	≥80%	Achieved
Lowest Score	87.50%	≥80%	Achieved

All three validation aspects achieved percentages above 80%, thus the module is declared valid. This indicates that the module has met the feasibility standards in terms of content, media, and language. The content expert's validation of 86.46% confirms that the CNC concepts presented conform to industry standards and correct CNC machine operational procedures. This aligns with Arsyad's assertion that learning media with attractive visual design can enhance student motivation and attention.

Table 14. Practicality Criteria (≥80%)

Validity Aspect	Result	Threshold	Status
Students Comprehension Questionnaire	87.47%	≥80%	Achieved
Implementation Observation	94%	≥80%	Achieved

Both practicality aspects achieved percentages above 80%, thus the module is declared practical. The implementation observation result of 94% indicates that almost all students were able to follow the simulation steps independently using the module. This finding is supported by the results of previous studies showing that 77.8% of students approved the use of video media and CNC milling lite simulators in CNC learning [22]. The high practicality percentage in this research reflects the positive acceptance of students toward the simulation-based learning module.

Table 15. Effectiveness Criteria (N-Gain ≥0.3)

Effectiveness Criteria (N-Gain ≥0.3)	Result	Threshold	Status
Pre-test (Average)	68.2	-	-
Post-test (Average)	90.8	-	-
N-Gain	0.71	≥0.3	Achieved

The N-Gain value of 0.71 falls into the High category (>0.7), thus the module is declared effective in improving student understanding. The average score increase of 22.6 points (from 68.2 to 90.8) indicates that the module is able to bridge theoretical understanding and CNC simulation practice significantly. The improvement of 22.6 points is very relevant when compared with previous research findings. Previous research reported that the use of video media and CNC milling lite simulators could improve student learning outcomes by 18.08 points or 30% from the previous score [23]. This nearly identical improvement figure indicates that the Swansoft-based module in this research has comparable effectiveness to other CNC learning media. Another study conducted at SMK YPM 1 Taman Sidoarjo also showed significant improvement in learning outcomes, where the student mastery percentage from pre-test to post-test increased from 50% to 91.67% [21].

The comparison results with several previous studies indicate that the Swansoft-Based CNC Milling Simulation Learning Module developed has validity, practicality, and effectiveness levels that are comparable to or even better than similar research. The learning outcome improvement of 22.6 points, which is consistent with previous findings, indicates that the simulation approach is proven effective as a bridge between theory and practice in SMK [23].

Thus, the module is declared valid, practical, and effective in improving student understanding, and is ready for use as an independent learning resource for CNC Milling simulation. These findings provide an empirical contribution to the development of CNC teaching materials in SMK and can serve as a reference for future researchers in developing simulation-based learning modules for other technical subjects.

4. Conclusion

This research and development has produced a product in the form of a Swansoft-Based CNC Milling Simulation Learning Module for class XI students at SMK Negeri 1 Tuban. The module was developed using the 4D development model which includes the Define, Design, Develop, and Disseminate stages. The module is organized into seven chapters covering CNC basic theory, coordinate systems, G and M codes, tools and cutting parameters, milling program creation, and simulation guides on Swansoft for GSK980MDi and FANUC OiM types.

The developed learning module has met the assessment criteria with a feasibility level categorized as Very Good. The content validation conducted by the content expert obtained a score of 86.46%. The media validation conducted by the media expert obtained a percentage result of 89.71%. The language validation conducted by the language expert obtained a percentage result of 87.50%.

The small group trial conducted with 12 students obtained a percentage result of 86.11%. The large group trial conducted with 33 students obtained a percentage of 87.47%. The implementation observation results showed an average percentage of 90.97%. The effectiveness test showed an average score improvement from 68.2 to 90.8 with an N-Gain of 0.71. Based on the operational criteria established in this research, the module meets the validity criterion with all three expert validations achieving ≥80% (content: 86.46%, media: 89.71%, language: 87.50%); the module meets the practicality criterion with student comprehension achieving 87.47% and implementation observation achieving 94% (both ≥80%); and the module meets the effectiveness criterion with an N-Gain of 0.71 (≥0.3, high category). Based on all these results, the Swansoft-Based CNC Milling Simulation Learning Module falls into the Very Good criteria and is feasible for use in learning activities in the Machining Engineering subject at SMK Negeri 1 Tuban.

Several limitations of this study should be acknowledged. First, the limited sample—one class at a single SMK with specific characteristics (urban location, moderate facility availability, one CNC machine)—means the findings may not transfer directly to other contexts. Second, the one-group pretest-posttest design without a control group limits causal inferences about the module's effectiveness. Third, the study did not examine long-term retention of learning or transfer of skills to actual CNC machines. Future research should replicate this study with: (a) larger and more diverse samples across multiple SMKs, (b) different regions with varying facility conditions, (c) different vocational programs, (d) randomized controlled trials to establish causal efficacy, and (e) longitudinal designs to assess skill retention. Despite these limitations, the design principles employed—step-by-step visualization, worked examples, dual-control coverage, and dialogic language—are likely transferable as instructional design heuristics for simulation-based learning in vocational contexts.

Acknowledgment

Authors would like to express their gratitude to the teachers and students of SMK Negeri 1 Tuban for their participation and cooperation in this research. Appreciation is also extended to the Faculty of Engineering, Universitas Negeri Malang, for providing the facilities and support necessary for the completion of this study.

References

[1] R. Eko, "OPTIMASI PARAMETER PEMROGRAMAN CNC MILLING TERHADAP PROSES KERJA YANG EFESIEN DENGAN SIMULASI SWANSOFT CNC MILLING," PhD Thesis, Universitas Muhammadiyah Ponorogo, 2023. Diakses: 30 April 2026. [Daring]. Tersedia pada: https://eprints.umpo.ac.id/11817/

[2] K. Kumar, C. Ranjan, dan J. P. Davim, *CNC Programming for Machining*. dalam Materials Forming, Machining and Tribology. Cham: Springer International Publishing, 2020. doi: 10.1007/978-3-030-41279-1.

[3] "Lap Ii Pemrograman Cnc Milling Dengan Software Swansoft Cnc Simulation Sistem Operasi Fanuc Oi M Nc [34wmk857jml7]." Diakses: 30 April 2026. [Daring]. Tersedia pada: https://idoc.pub/documents/lap-ii-pemrograman-cnc-milling-dengan-software-swansoft-cnc-simulation-sistem-operasi-fanuc-oi-m-nc-34wmk857jml7

[4] Asmungi, "Menyiasati Fasilitas Laboratorium CNC bagi SMK yang Berkekurangan Finansial," *J. Tek. Ind. HEURISTIC*, vol. 12, no. 1, hlm. 53–59, Apr 2015.

[5] K. A. Pangestu, "Pengembangan media pembelajaran interaktif nc/cnc menggunakan software swansoft cnc simulator pada kompetensi keahlian bidang Teknik Mesin / Kukuh Andreng Pangestu," diploma, Universitas Negeri Malang, 2022. Diakses: 30 April 2026. [Daring]. Tersedia pada: https://repository.um.ac.id/269018/

[6] W. M. Kusuma, S. Setuju, dan D. Ratnawati, "Development of learning media lathe machining based on animation video," *J. Taman Vokasi*, vol. 7, no. 1, hlm. 54–61, Jul 2019, doi: 10.30738/jtv.v7i1.4779.

[7] J. Sweller, "Cognitive load during problem solving: Effects on learning," *Cogn. Sci.*, vol. 12, no. 2, hlm. 257–285, 1988.

[8] A. Renkl, "Toward an Instructionally Oriented Theory of Example-Based Learning," *Cogn. Sci.*, vol. 38, no. 1, hlm. 1–37, Jan 2014, doi: 10.1111/cogs.12086.

[9] R. E. Mayer, *Multimedia Learning*. Cambridge University Press, 2009.

[10] J. Bruner, *Toward a theory of instruction*. Harvard university press, 1974. Diakses: 15 Agustus 2026. [Daring]. Tersedia pada: https://www.google.com/books?hl=id&lr=&id=28bmEAAAQBAJ&oi=fnd&pg=PA1&dq=Toward+a+Theory+of+Instruction&ots=0qMk8W_nBC&sig=1It8Bw85E9oVrjafDInLSlcWg-A

[11] L. S. Vygotsky dan M. Cole, *Mind in Society: Development of Higher Psychological Processes*. Harvard University Press, 1978.

[12] P. P. Kuantitatif, "Metode penelitian kunatitatif kualitatif dan R&D," *Alf. Bdg.*, 2016, Diakses: 30 April 2026. [Daring]. Tersedia pada: https://www.researchgate.net/profile/Hery-Purnomo/publication/377469385_METODE_PENELITIAN_KUANTITATIF_KUALITATIF_DAN_RD/links/65a89006bf5b00662e196dde/METODE-PENELITIAN-KUANTITATIF-KUALITATIF-DAN-R-D.pdf?__cf_chl_tk=nCoUyuEGaYY_sI703pQR98sN2_hY3g4HU1pMZwpG_us-1739947478-1.0.1.1-LdQU9dWiAysvCtpvd4Uu6KNXvu7bCNUUxgfLLZulaEo

[13] S. Thiagarajan, "Instructional development for training teachers of exceptional children: A sourcebook.," 1974, Diakses: 30 April 2026. [Daring]. Tersedia pada: https://eric.ed.gov/?id=ED090725

[14] M. F. R. Pratama, "Pengembangan media pembelajaran berbasis video youtube dengan software swansoft cnc pada mata kuliah cnc dasar di Universitas Negeri Malang / M. Farih Rizki Pratama</p>," diploma, Universitas Negeri Malang, 2023. Diakses: 30 April 2026. [Daring]. Tersedia pada: https://repository.um.ac.id/313924/

[15] A. P. Afandi dan N. A. Susanti, "PENGEMBANGAN MODUL PEMBELAJARAN CNC MILLING MENGGUNAKAN SOFTWARE MASTERCAM X9

PADA MATA PELAJARAN CNC DI JURUSAN TEKNIK PEMESINAN SMKN 1 BLITAR," 2022, Diakses: 30 April 2026. [Daring]. Tersedia pada: https://ejournal.unesa.ac.id/index.php/jurnal-pendidikan-teknik-mesin/article/view/45072

[16] S. Thiagarajan dan A. Others, "Instructional Development for Training Teachers of Exceptional Children: A Sourcebook," Council for Exceptional Children, 1920 Association Drive, Reston, Virginia 22091 (Single Copy, $5, 1974. Diakses: 30 April 2026. [Daring]. Tersedia pada: https://eric.ed.gov/?id=ED090725

[17] K. Juuti dan J. Lavonen, "Design of a Primary School Physics Web-based Learning Environment: The Teacher's Role in the Educational Design Research Project," dalam *Educational design research*, T. Plomp dan N. Nieveen, Ed., Enschede,the Netherlands: SLO, 2013, hlm. 49–69.

[18] R. R. Hake, "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. Phys.*, vol. 66, no. 1, hlm. 64–74, 1998.

[19] D. Sugiyono, "Metode penelitian pendidikan pendekatan kuantitatif, kualitatif dan R&D," 2013, Diakses: 30 April 2026. [Daring]. Tersedia pada: https://digilib.unigres.ac.id/index.php?p=show_detail&id=43

[20] E. D. Kurniawan, N. Nopriyanti, R. Hermawan, dan P. I. Yanti, "Pengembangan modul pembelajaran berbasis stem pada materi cnc milling simulator," *J. Pendidik. Tek. Mesin*, vol. 10, no. 2, hlm. 204–216, 2023.

[21] M. B. ULUM, "Pengembangan Modul Cnc Semi Pu Gsk 928 Tc Untuk Meningkatkan Aktivitas Dan Hasil Belajar Siswa Kelas XII Smk Ypm 1 Taman Sidoarjo," PhD Thesis, State University of Surabaya. Diakses: 30 April 2026. [Daring]. Tersedia pada: https://www.neliti.com/publications/249936/pengembangan-modul-cnc-semi-pu-gsk-928-tc-untuk-meningkatkan-aktivitas-dan-hasil

[22] A. Arsyad, "Media pembelajaran." Jakarta: PT Raja grafindo persada, 2011. Diakses: 30 April 2026. [Daring]. Tersedia pada: https://www.academia.edu/download/30484693/jiptiain--umarhadini-8584-5-baii.pdf

[23] "The Influence of Video-Based Media and Simulator CNC Milling Lite Applicati." Diakses: 30 April 2026. [Daring]. Tersedia pada: https://journals.indexcopernicus.com/search/article?articleId=4396032