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Case method textbook innovation for Autodesk inventor- assisted CAM learning

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ABSTRACT

Manufaktur menghadapi kesenjangan antara perkembangan teknologi dengan program pelatihan rekayasa, termasuk pendidikan vokasi yang berperan dalam menyiapkan tenaga terampil. Kendala utama adalah tingginya biaya operasional dan fasilitas pembelajaran terutama pada pembelajaran CAD/CAM terkait CNC, di mana mahasiswa mengalami kesulitan dalam membuat program CNC dikarenakan ketidakmampuan dalam memvisualisasikan gerakan pahat dan minimnya akses fisik terhadap mesin CNC. Penelitian ini mengembangkan buku ajar berbasis Autodesk Inventor (CAM) terintegrasi dengan Case Method untuk memudahkan perancangan gambar dan simulasi program CNC yang valid dan praktis. Jenis penelitian yang digunakan adalah Research and Development (R&D) dengan model pengembangan ADDIE. Hasil penelitian menunjukkan bahwa bahan ajar yang telah dikembangkan valid. Hal ini ditunjukkan dengan penilaian ahli materi dan ahli media yang berada pada kategori sangat baik. Kepraktisan buku ajar dalam proses pembelajaran berjalan dengan baik, hal ini ditunjukkan pada uji coba one-to-one, small-group, dan field test yang berada pada kategori sangat baik. Buku teks yang dirancang secara sistematis sesuai dengan karakteristik dan strategi belajar siswa dan integrasi bahan ajar Autodesk Inventor dan Case Method ini diharapkan dapat menjembatani kesenjangan teori-praktik dan meningkatkan literasi teknologi siswa secara kritis dan kreatif.

ABSTRACT

Manufacturing faces a gap between technological developments and engineering training programs, including vocational education, that play a role in preparing skilled workers. The main obstacle is the high operational costs and learning facilities, especially in CAD/CAM learning related to CNC, where students experience difficulties in creating CNC programs due to the inability to visualize tool movements and limited physical access to CNC machines. This study developed a textbook based on Autodesk Inventor (CAM) integrated with the Case Method to facilitate the design of drawings and simulations of valid and practical CNC programs. The type of research used is Research and Development (R&D) with the ADDIE development model. The results of the study indicate that the developed teaching materials are valid. This is proven by the material and media experts' assessment results in the "very good" category. The practicality of the textbook in the learning process runs well, as shown in one-to-one, small-group, and field tests that are in the "very good" category. This textbook, which was systematically designed according to the students' characteristics and learning strategies and integrates Autodesk Inventor and Case Method teaching materials, is expected to bridge the theory-practice gap and improve students' technological literacy critically and creatively.

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INTRODUCTION

Manufacturing is one of the main pillars of the community's economy (Chryssolouris, 2006). The rapid development of new technologies in the manufacturing sector is not accompanied by engineering training programs (Chelini & Richert, 2023). The university environment is no exception (Sola-Guirado et al., 2022). Through the use of technology, a good educational approach and communication between academics and industry, it is hoped that the gap can be overcome (Stavropoulos et al., 2018). Recent studies have emphasized the importance of integrating real-world industry projects into the engineering curriculum to improve student readiness for modern manufacturing environments. According to López-Torres et al. (2025), incorporating industry-driven mentorship and project-based learning significantly enhances both technical and soft skills of engineering students. Furthermore, the adoption of Industry 5.0-based pedagogy, which leverages emerging technologies such as AI, IoT, and cyber-physical systems in classrooms, provides students with a more immersive and relevant educational experience (Wang et al., 2025). Collaborative models such as Lean R&D and structured internships have also shown effectiveness in bridging academic theory with industrial practice, especially when institutions actively partner with companies on applied research and innovation (Mehta & Ahuja, 2024). These initiatives demonstrate that strategic alignment between education and industry is critical in preparing graduates who can thrive in rapidly evolving manufacturing systems.

Education plays a role in developing human resources in the industry to make high-value-added products (Oshima & Morishita, 2011). Vocational education has a fundamental value as a competitive workforce producer (Kurniawan, 2015); graduates who are ready to enter the world of work (Fajar & Hartanto, 2019) have specific job skills (Sudira, 2016) and can work (Wardina et al., 2019) and are related to the acquisition of knowledge, skills, attitudes, and expertise needed in the world of work (Haricahyo et al., 2020; Kuswana, 2013). The main problem in vocational education is the high cost of operations and learning facilities. Learning facilities aim to support the learning process (Setiono, 2018) and affect students' learning outcomes (Mahmud et al., 2019) (Aini & Sudira, 2015; Putri et al., 2016). Unavailability of facilities results in unoptimal learning outcomes and students' learning interests (Prianto & Pramono, 2017).

CAD/CAM (*Computer Aided Design/Computer Aided Manufacturing) Courses* related to CNC aim to provide knowledge and skills in designing drawings using CAD and simulating CNC programs without the need to write *G-code* manually, but rather, by using a CAM facility to automatically generate it based on the CAD design (Taufik et al., 2012). This course is vital because it is relevant to the manufacturing field that adjusts to RI 4.0 (Estriyanto et al., 2021). Industries are heavily using CAM machines to achieve higher productivity (Nugroho & Sukardi, 2019). CAM refers to a computer that converts engineering designs to the final product (Ningsih, 2005). CAD/CAM learning strategies in the form of product design, then optimised by the CAM system to be used as a numerical code that controls the CNC center (Plaza & Zebala, 2019) to simulate tool movements, estimate time, predict product shape deviations (Dittrich et al., 2019), and maximise efficiency and minimise errors (Schmid & Pichler, 2020). Reform of CAD/CAM teaching through activities starting from design to product manufacturing is the focus of learning (Yixian et al., 2014) and the need to upgrade the skills of educators (Zhu et al., 2018).

The problem is that students have difficulty making CNC programs because it is difficult to imagine the movement of the tool and the unavailability of CNC machines. With the help of the application Autodesk Inventor, which has a CAM feature, it will make it easier for students to create CNC programs. Therefore, the original need for simulation software to learn CNC programming is highly expected (Nair et al., 2018). Recent research highlights the importance of integrating simulation-based learning in CNC education. According to Hoang et al. (2024), the use of SSCNC simulators significantly reduced students' cognitive load and increased programming accuracy in CNC coursework. In another study, Prasetya et al. (2023) developed a virtual CNC laboratory using immersive 3D environments, which enhanced students' ability to understand complex toolpaths even without physical machine access. Moreover, Suyetno and Yoto (2021) found that a CNC simulator-based platform achieved an 84% effectiveness in maintaining CNC training outcomes during remote learning periods. These findings affirm that digital tools like Autodesk Inventor CAM, when combined with virtual simulation, not only bridge the gap in physical resources but also improve students' spatial reasoning and programming confidence.

Previous research has developed a Mastercam application, CNC learning video (Kurniawan, et al., 2023), CNC teaching materials (Kurniawan et al., 2024; Kurniawan et al., 2018), CNC jobsheet (Putra, 2021; Prasetya et al., 2020), CAM teaching materials (Burhanudin et al., 2023), *and prototype* virtual CNC interactive media (Purwoko, 2009). The latest of this research is the object of CAM material using the *Autodesk Inventory* and integrated into the *Case method,* which can improve knowledge and skills (Bayona & Durán, 2024) and connect theory and practice (McLean, 2016). *Case method* student-centered (Shohani et al., 2023) encourages independent students in learning and increasing interaction (Xu et al., 2024), and can see the application of learning relevance to the real world (Yadav et al., 2010). *The case method* is more effective than lectures in improving understanding (Rosier, 2022).

Learning Methods of *the Case method* is a teaching approach that can improve the cognitive learning process, often applied in face-to-face learning situations in the classroom (Chen et al., 2006) and is considered effective in developing students' skills (Rosidah & Pramulia, 2021). *The case method* is through the following steps: individual case studies before the class session, small-group discussions before or during the class session, and large-group discussions in the class with all participants. It emphasises that students analyse cases to identify problems and conduct additional research. Preparation is carried out independently and in study groups, which form the basis for a thorough discussion of key issues relevant to the case under discussion (Telaumbanua et al., 2022). T*he Case method allows* students to answer questions not only about how but also why, while engaging in a learning process that builds trust and permits them to see from multiple perspectives. *The case method* also encourages students to find solutions to problems with creativity, enrich the value of knowledge literacy, and develop a critical perspective on various problems (Jamaludin & Alanur, 2021).

Based on the above problems, the research intends to develop teaching materials for CAM learning *Autodesk Inventory,* which functions for creating drawing designs and simulating them in a CNC program. Teaching materials determine the quality of learning (Cahyadi, 2019), compiled entirely and systematically (Magdalena et al., 2020), which consists of the content of the material, teaching methods, parameters explained, and evaluation techniques designed in a structured and attractive manner, with the main goal of achieving competencies and subcompetencies comprehensively (Lestari, 2013). Teaching materials are made according to the set learning objectives, individual characteristics of students, and appropriate learning strategies to achieve each learning goal (Seels & Richey, 1994). Teaching materials contain information, both printed and electronic, used by students to achieve learning objectives (Cahyadi, 2019). This research is essential to help students design drawings and simulate CNC programs. These teaching materials are expected to guide students in making CNC designs and programs. The purpose of the research is to develop valid and practical teaching materials.

METHOD

This research belongs to Research and Development (R&D). The development employed the ADDIE model (*Analyse*, *Design, Develop*, *Implement,* and *Evaluate)* (Lee S Owens, 2004). ADDIE is a product development concept. The ADDIE concept is applied to build performance-based learning. In the development stage, the researchers designed a research instrument consisting of a clear grid to ensure it covers all relevant aspects of the case method-based textbook. The instrument grid includes several components: 1) formulating the objectives to be achieved through the use of the textbook; 2) determining the topics to discuss in the textbook; 3) explaining the case method approach used in each topic; and 4) developing an evaluation tool to measure students' understanding after using the textbook. Then, the validity and reliability of the research instrument were ensured through the following steps.

1. Validity

The instrument was tested by material and media experts for an objective assessment. Content validity was carried out using validation techniques by experts experienced in CAM and education fields. The assessment results showed that the instrument developed was in the "very good" category, with an average score above 85%.

2. Reliability

The instrument trial was conducted through initial testing involving a group of students. The results of this trial were analysed using the Cronbach's Alpha method, which showed a reliability value above 0.8, indicating that the instrument had a high level of consistency.

In the conclusion drawing, the researchers used descriptive analysis to evaluate the data obtained from expert assessments and trial results. The data collected were analysed quantitatively and qualitatively to provide a comprehensive picture of the effectiveness of the textbook. Conclusions were drawn based on previously established validity and practicality criteria, as well as feedback from trial participants who provided insight into their experiences of using the textbook. The teaching materials based on *the case method* in the CAD/CAM for Basic CAM material course were only up to the development stage. The material expert test is two, the media expert test is two, the *one-to-one trial involved* three students, the limited trial involved nine students, and the field trial involved 20 students. The data collection technique was distributing a questionnaire to research subjects from August to October 2024.

The instrument sheet was analysed using the data tendency category. The scores from the assessment were then converted into values using the tendency table as shown in the Table 1 (Sukardjo, 2008).

Table 1. Data tendency categories

No	Interval	Category
1	$(\bar{X}_i + 1.80\ \text{SBI}) < X$	Excellent
2	$(\bar{X}_i + 0.60\ \text{Sbi}) < X \leq (\bar{X}_i + 1.80\ \text{Sbi})$	Good
3	$(\bar{X}_i - 0.60\ \text{Sbi}) < X \leq (\bar{X}_i + 0.60\ \text{Sbi})$	Enough
4	$(\bar{X}_i - 1.80\ \text{Sbi}) < X \leq (\bar{X}_i - 0.60\ \text{Sbi})$	Less
5	$X \leq (\bar{X}_i - 1.80\ \text{SBI})$	Very Less

Information:
$\bar{X}$i (Average Ideal Score)= 1/2 (maximum score + minimum score) SBi (ideal standard intersection)=1/6 (maximum score – minimum score)
X= Actual score

RESULT

This research aims to produce valid and practical CAD/CAM teaching materials for Basic CAM Materials Assisted by Autodesk Inventory Application based on *the Case method* in the Mechanical Engineering Education Study Program of FKIP Unsri. The concept of teaching materials developed is a combination of learning media with learning methods, expected to enable students to manage their learning independently by providing real-world case questions. Development of CAD/CAM teaching materials for Basic CAM Materials Assisted by Autodesk Inventory Application based *on the Case method* using the ADDIE (*Analysis, Design, Development, Implementation, Evaluation)* development model. The stages are adapted to the research and are shown in Figure 1.

Analysis stage

Curriculum analysis

The analysis of the curriculum based on the FKIP Unsri 2021 Mechanical Engineering Education Curriculum shows that the Basic CAD/CAM Teaching Materials, assisted by the Autodesk Inventor application based on *the Case method,* are related to CNC courses. Students are directed to draw objects on CAD translated by CAM into CNC programs, with learning including manual program creation and validation through CAM. The material to discuss in the CNC Simulator for Android Guidebook includes: (1) Introduction, (2) Computer Aided Manufacturing (CAM), (3) Autodesk Inventor, (4) Inventor CAM Ultimate, (5) Operation of Inventor CAM Ultimate, and (6) Practice Questions.

Learning process analysis

The observations and interviews with the lecturers show that lecture methods and manual exercises dominated the basic CAD/CAM courses. Therefore, the students often had difficulty associating theory with practical applications. In addition, the time allocated for practicing using the Autodesk Inventor application was limited, so they were less trained in applying CAM concepts effectively.

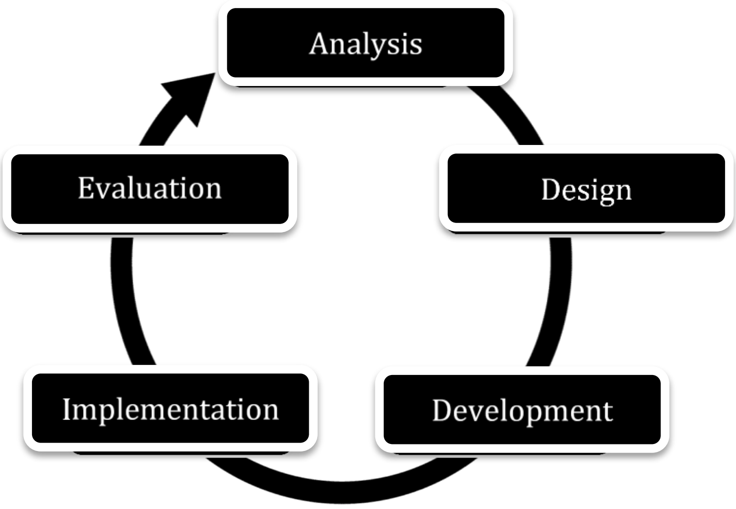

Figure 1. The ADDIE research method adopted in this study

Analysis of student characteristics

FKIP Unsri Mechanical Engineering Education students have diverse educational backgrounds, including high school, vocational, and MA graduates, which causes differences in the understanding level of materials, especially engineering drawing. Students from high school and MA had generally never studied engineering drawings, so it required more effort than those from vocational schools. The results of a survey of 75 students showed that 89.4% of new students used Autodesk Inventor for the first time, and 98.66% needed additional guidance to understand and apply CAM materials. In addition, students showed high interest in project-based learning or real cases that are applicable and relevant to the industrial world.

Learning resource analysis

The results of observations on the CNC Practice learning process show that students do not have standard learning resources, so learning is focused on the educator's explanation in one direction. Educators provide explanations and examples that are then followed by students, so they have not encouraged the critical thinking process. Therefore, the development of Basic CAD/CAM Teaching Materials CAM Materials assisted by the Autodesk Inventor application is expected to provide opportunities for students to develop knowledge and understanding independently. This approach allows students to learn through direct exploration, so that their understanding of technology is more in-depth than just receiving explanations from educators.

Analysis of learning facilities and technology

The analysis of the laboratory facilities showed that the computer had sufficient specifications to run Autodesk Inventor, but was constrained by differences in hardware capabilities and licensing limitations, so not all students could access the software simultaneously. Suboptimal internet network stability is also a hindrance, especially for complex simulations and downloading materials. Students without personal devices can only use laboratory facilities during lecture hours, while access to online tutorials and other resources through the institution's portal is still limited and does not support the *case method* approach that meets the curriculum.

Design stage

Developers determine the specific competencies achieved by students, methods, teaching materials, learning strategies, and learning media. Overall, the Basic CAD/CAM Teaching Materials Assisted by CAM Materials Autodesk Inventory Application consists of sections arranged in a good book order. The preparation of the textbook includes (a) Cover, (b) Preface, (c) Table of Contents, (d) Table List, and (e) List of Pictures. The core section consists of 5 chapters, namely (1) Introduction, (2) Computer Aided Manufacturing (CAM), (3) Autodesk Inventor, (4) Inventor CAM Ultimate, (5) Operation of Inventor CAM Ultimate, and (6) Practice Questions. Then, at the end are a Bibliography, Glossary, Index List, and About the Author.

Develop stage

At this stage of development, a prototype of a textbook based on *the Case method* was made, which included the development of cover design, preparation of manuscripts and materials, media editing, and assembly of elements such as text, images, and illustrations. The completed prototypes were checked before being validated and tested on students. The validation process involved judgment from material and media experts, who provided assessments through questionnaires and suggestions for improvement, both verbally and in writing, until the product was declared suitable for testing.

Material validity

This stage begins with evaluating the Case-Based Textbook *method* using material assessment instruments to examine the correctness and feasibility aspects of the material, which aims to assess the quality of the product developed and provide input for initial improvement or revision. The results of validation by material experts are shown in Table 2.

Table 2. Material expert validation results

No	Aspects	Validator		Average	Category
		1	2		
1	Learning	63	64	4.24	Excellent
2	Contents/materials	56	54	4.23	Excellent
3	*Assessment of case method* teaching materials	47	42	4.45	Excellent
	Sum	167	162	4.22	Excellent

Based on the accumulated total score obtained by adding the number of validator scores, the total number for the validation of material experts is 329. The calculation of the data tendency resulted in the pad range of 327.6 < X, which means that, according to material experts, the validity level of the Textbook based on *the Case method* is very good.

Media validity

This stage begins with evaluating the Case-based Textbook *method* by media experts using media assessment instruments. Media experts tested the product with assistance from developers and provided comments and suggestions recorded on the evaluation sheet to be used as revision guidelines. The results of validation by the two media validators as a whole are presented in Table 3.

Table 3. Media expert validation results

No	Aspects	Validators		Average	Category
		1	2		
1	Cover Design	22	21	4.30	Excellent
2	Textbook Design Content	30	31	4.35	Excellent
3	Font Quality	23	24	3.91	Good
4	Image Quality	35	33	4.25	Excellent
	Sum	110	109	4.21	Excellent

Based on the accumulated total score obtained by adding the number of validator scores, the total number for media expert validation is 219. Based on the calculation of the data tendency, it is in the range of 218.4 < X, which means that, according to media experts, the validity level of the Textbook based on *the Case method* is very good.

Implementation stage

The development of case method-based textbooks employed the ADDIE *(*Analysis, Design, Development, Implementation, and Evaluation) *learning system design model*. The subjects of the research are FKIP Unsri Mechanical Engineering Education students who have taken Basic CAD/CAM courses. This research experienced three trials consisting of problem analysis, design planning, textbook making, design validation, design improvement, and trial stages. The first test was carried out at *the one-to-one stage,* involving nine students. The second stage was *a small-group* trial, covering nine students, and *a field test* consisting of 20 students.

At each stage, students were grouped based on a predetermined number. Students could only be in one type of trial stage. In its application, students were briefed, and materials related to the textbooks were developed. In the learning, students were directed to carry out case method-based learning. The steps of *the Case method* are described in the sub-chapters of each main chapter: (1) Preparation of Relevant Cases, (2) Orientation and Introduction of Cases to Students, (3) Group Formation and Case Division, (4) Information Collection and Case Analysis, (5) Group Discussion and Collaboration, (6) Presentation and Class Discussion, (7) Case Reflection and Evaluation, (8) Application and Generalisation, and (9) Final Assessment.

Evaluation One-to-One

This one-to-one *trial* was carried out to 3 students. The Table 4 presents the result of the trial.

Table 4. Results of *one-to-one trial*

No	Aspects	Respondents			Sum
		1	**2**	***3***	
1	Display aspects	42	43	44	129
2	Learning aspects	43	44	43	130
3	Content/material aspects	53	56	55	164
	Sum	138	143	142	423

Small-group *trials*

The respondents to this *small-group* trial amounted to 9 students. The results are shown in the Table 5.

Table 5. Small group trial assessment results

No	Aspects	Sum	Average	Category
1	Assessment Aspects	381	4.23	Excellent
2	Learning Aspects	383	4.26	Excellent
3	Content/Material Aspects	484	4.17	Excellent
	Sum	1252	4.21	Excellent

Field test

The *field test* was carried out with 20 students of the Mechanical Engineering Education Study Program of FKIP UNSRI who had taken the Basic CAD/CAM Course. The result is shown in the Table 6.

Table 6. Assessment results of *field test trials*

No	Aspects	Sum	Average	Category
1	Assessment Aspects	840	4.20	Excellent
2	Learning Aspects	847	4.24	Excellent
3	Content/Material Aspects	1095	4.21	Excellent
	Sum	2782	4.21	Excellent

Product revision

Products that have been validated by material and media experts as well as one-to-one, *small-group*, and *field test* trials were then revised according to the suggestions given. The revisions carried out include the following aspects as shown in the Table 7.

Table 7. Product revision suggestions

No	Assessment aspects	Suggestions for improvement
	Material	In the preface, this MK is Advanced CAD/CAM or Basic CAD/CAM as in the research title. In the Introduction, adjust the title of the book to what has been designed. In the instructions for students, the resulting G-Code is not implemented in the CNC Turning Simulator but the CNC Lathe Simulator. Create material of "Implementation of CAM in the world of Education". Add material on the Minimum Specification for installing the Autodesk Inventory application. In the scope of Autodesk Inventory in Chapter III, the title of the Simulation subchapter should be "Presentation"
	Picture	Consistent image size, less clear/bright images corrected
	Writing	There are several writing errors, capital letters, italics. Don't 1 paragraph of sentences. If an abbreviation has been explained at the beginning, then there is no need to explain it again later
	Cover	Book titles make readers more interested, don't be too rigid

DISCUSSION

Learning in the Mechanical Engineering Education Study Program of FKIP UNSRI includes theory and practice to prepare students' skills. Practical learning, which aims to improve students' skills, uses appropriate methods and equipment. Case-method-based textbooks have the potential to support practicum learning, especially in Basic CAD/CAM courses, by providing independent and systematic learning opportunities. The development of this textbook begins with an analysis of the curriculum, learning process, characteristics of students, and existing resources. The textbook covers four main interrelated topics to support student learning.

After the textbook was developed, the validity and practicality test of the textbook was carried out. A teaching material that is developed, which can only be used in practical learning, must first pass the validity and practicality test (Richey et al., 2004).

The development of a case method-based textbook for Basic CAD/CAM directly addresses the challenge of integrating theoretical knowledge with practical skills acquisition in engineering education, which is increasingly complex in the digital era (Ahmed, 2021; Chen et al., 2023). Case-Based Learning (CBL) in the contemporary context is not only rooted in constructivist theory but has also evolved to accommodate the needs of digital simulation-based learning and problem-driven design (Müller et al., 2023). The finding that the case method aspect of the textbook scored "VERY GOOD" (mean 4.45) is in line with recent research that proves the effectiveness of CBL in Enhancing the transfer of abstract concepts to technical solutions: Zhang & Lee's (2024) study showed a 40% increase in students' ability to transform CNC programming principles into toolpath designs through an industrial case approach.

Strengthening simulation-based conceptual understanding: Integration of real-world cases with Autodesk Inventor CAM simulations has been shown to reduce the cognitive gap between theory and practice through incremental scaffolding (Kumar & Singh, 2023).

Material validity

Valid means that it has provided accurate information about the teaching materials developed

(Trianto, 2010). Validation of textbooks based on *the Case method* in the CAD/CAM course was conducted by two validators who are experts in their respective fields of study, so the results are accountable. Textbook-based *Case method,* which has been developed, has met the learning aspect with an average score of 4.237, or in the very good category. Content/material aspect had an average score of 4.2, or in the very good category. Assessment aspects of the *Case method* teaching materials had an average score of 4.45, or in the very good category.

The total accumulated score by adding the number of validator scores 1 and 2 is to obtain the total number for the validation of material experts amounting to 329. Based on the calculation of the data tendency for the validation of material experts, it is in the very good category, which is in the range of 327.6 < X. The value obtained is 292, meaning that, according to the material experts, the validity level *of the Textbook based on the Case method* is very good. Recent studies have shown that such designs increase skill transfer in digital manufacturing by 25-40% by embedding cases (Lee & Zhang, 2023) and incorporating emerging CAM strategies such as adaptive tool paths (Fernández et al., 2023).

Media validation

The assessment employed a questionnaire instrument prepared by the developer. In addition, assessments in comments and suggestions for improvement were also submitted orally or written on the provided sheet. This stage begins by submitting the developed product of the Case method-based textbook to be evaluated with media assessment instruments. Accompanied by a product developer, the media experts tried the produced Case method-based textbook.

Data obtained from the assessment of 2 media experts from several aspects of cover design showed that in the cover design aspect, a score of "very good" was obtained with an average of "4.3". The design aspect of the content of the textbook obtained a score of "very good" with an average of "4.35". The quality aspect of letters was obtained with a score of "good" with an average of "3.91", and the image quality aspect obtained a score of "very good" with an average of "4.21". Based on the calculation of the accumulated total value obtained by adding the number of validator scores 1 and 2, the total number for validation of media experts is 219. Based on the calculation of the tendency of the data for the validation of material experts, it is in the very good category, which is in the range of 218.4 < X. The value obtained is 219, meaning that, according to media experts, the validity level of the Textbook based on the Case method is very good. The textbook's excellent media validity (score of 219) demonstrates the application of advanced neurocognitive design principles to complex spatial domains such as CAD/CAM. Dynamic Visualisation System: The high image quality score (4.21) is consistent with research showing that 3D interactive diagrams improve spatial reasoning by up to 40% in CAM toolpath visualisation (Kim et al., 2023; Rayhan, & Kurniawan, 2024).

Practicality of textbooks by students

The textbook practicality test by students is carried out through a student response questionnaire. The questionnaire was given to students to see the response of students after participating in one learning activity using a learning textbook based on a scientific approach. This stage consists of the following three stages.

One to one

Based on the accumulated total score of the *one-to-one* trial involving three students, a total of 423 was obtained. Based on the calculations, the data tendency for the practicality of *the one-to-one* stage is in the very good category, which is in the range of 415.8 < X. The score obtained is 423, meaning that, according to the assessment of students in the *one-to-one stage* for the level of practicality, the Case method-based textbook is very good.

Small group

Data obtained from the assessment of 9 students in the learning aspect showed that: (a) in the assessment aspect, a score of "very good" was obtained with an average of "4.23"; (b) in the learning aspect, a score of "very good" was obtained with an average score of "4.25"; and (c) in the learning aspect, a score of "very good" was obtained with an average score of "4.17". Based on the accumulated total score of *the small-group* trial, involving 9 students, a total of 1252 was obtained. Based on the calculation of the data tendency for the practicality of *the small-group* stage, it is in the very good category, which is in the range of 1247.4 < X. The value obtained is 1252, meaning that, according to the assessment of students in the *small-group* stage, the level of practicality of the *Case-method* textbook is very good.

Field test

The field trial is the predominant test to measure the practicality of the textbook, which aims to revise the final stage so that a feasible and practical textbook is obtained. The field trial was carried out on 20 students. Data obtained from the assessment of 20 students in the learning aspect showed that: (a) in the assessment aspect, a score of "very good" was obtained with an average of "4.2"; (b) in the learning aspect, a score of "very good" was obtained with an average score of "4.23"; and (c) in the learning aspect, a score of "very good" was obtained with an average score of "4.21".

Based on the accumulated total score of the *field test* trial amounting to 20 students, a total of 2782 was obtained. Based on the calculation of the data tendency for the practicality of the *field test stage,* it is in the very good category, which is in the range of 2772 < X. The score obtained is 2782, meaning that, according to the assessment of students in the *field test* stage, the practicality level of *the Case-method* textbook is very good. Practical textbooks mean making it easier for students to understand the basic CAD/CAM learning of CAM materials. The good or bad of a learning is supported by the users of learning media (Susilana S Riyana, 2007). Teaching materials Textbooks are able to make the learning atmosphere fun, because students are more motivated to complete practicum to see what tools/products they can later produce.

Trial results

Based on this, the following are the results of the trial to assess the achievement of learning objectives through the use of Case Method-based textbooks. To ensure that the learning objectives in the development of Case Method-based teaching materials are truly achieved, three stages of trials were carried out, namely one-to-one, small-group, and field tests.

The results of this third stage show that students understand the basic concepts of CAM and are able to operate Autodesk Inventor CAM independently. They also able to analyse real problems through a case approach and develop solutions based on CNC programming. Then, show increased motivation and active participation in the learning process. The average practicality score in the third stage of the trial was in the "Very Good" category, namely (1) One-on-one: 423 points from 3 respondents (very good category), (2) Small-group: 1252 points from 9 respondents (very good category), and (3) Field test: 2782 points from 20 respondents (very good category).

The results show that the textbook is not only valid in terms of content and media but also proven effective in helping students achieve learning competencies, especially in mastering CAM based on the Autodesk Inventor application. This strengthens the validity of the findings that the developed textbook is suitable for technology-based vocational learning processes. The results of the practicality test of the module teaching materials by students showed that the level of practicality fell into the practical category, where the Reproducibility Coefficient or Kr was 0.915, while the Scalability Coefficient or Ks was 0.835. This shows that the learning module can improve students' abilities (Kurniawan, E.D. et al., 2023).

CONCLUSION

The results of the research and discussion concluded that the validation of material experts and textbook media based on *the Case method* is in the very valid category. the results of the textbook practicality test in the one-*to-one, small-group,* and *field test* stages are in the very practical category. This shows that the case method-based textbook can improve students' ability in learning basic CAD/CAM materials. The results of this study strengthen the position of case-based learning (CBL) as an effective pedagogical approach in integrating conceptual knowledge with practical skills, especially in technology-based CAD/CAM learning. The development of Case Method-based teaching materials integrated with the Autodesk Inventor CAM application is not only proven to be valid and practical, but also shows strong potential in improving analytical thinking competencies, problem solving, and learning independence of engineering education students. Theoretically, this confirms that case-based learning combined with digital simulation can strengthen the transfer of knowledge (CAM theory and G-code) to simulation. The limitations of this study are that the subjects are limited to one study program, the use of the Autodesk Inventor application is limited by license limitations, and not all students have full access to the software. Recommendations for further research are Population and Scope Expansion, and some long-term studies to measure the effect of teaching materials on knowledge retention, work readiness, and problem-solving skills after graduation.

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Author contributions

The authors contributed to the study's conception, design, data analysis, interpretation, and discussion of results. They reviewed and approved the final manuscript.

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Conflict of interest

No potential conflict of interest.

Data availability statement

All data are available from the authors.

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