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STEM-Based CNC Advanced Learning Material: Integration of CNC Milling and Plasma Cutting Using Mastercam for Vocational Education

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ABSTRACT

This research aims to develop valid and practical Advanced CNC teaching materials based on Mastercam-assisted STEM for the Advanced CNC course. Using the ADDIE development model Analyze, Design, Develop, Implement, and Evaluate these teaching materials are designed to integrate CNC Milling and Mastercam-assisted Plasma Cutting materials, while enhancing the 4C skills (communication, collaboration, critical thinking, and creativity). Validation by material and media experts yielded average scores of 4.00 and 3.89, respectively, categorized as excellent. A field trial involving 39 students yielded a practicality score of 3.63, indicating excellent/practical usability.For the 4C skills, the communication aspect achieved 82%, collaboration 87%, critical thinking 92%, and creativity 88%. These results confirm that the developed teaching materials meet the criteria for validity and practicality. With a high N-Gain improvement, the teaching materials are proven to be effective in supporting learning oriented towards industry needs and modern manufacturing technology.

Keywords: STEM-Based, CNC milling, plasma cutting, mastercam

INTRODUCTION

The rapid development of Industry 4.0 has accelerated the transformation of modern manufacturing systems through digitalization, automation, and cyber-physical integration. According to the World Economic Forum [1],[2], advanced manufacturing technologies have become a strategic priority in improving industrial competitiveness. CNC technology, particularly CNC milling and CNC plasma cutting, has become a central element in modern manufacturing systems within the Industry 4.0 framework [3], [4]. CNC machines utilize computerized control systems to ensure high precision, repeatability, and production efficiency [5], [6].

CNC milling systems are widely implemented in manufacturing education through digital simulation prior to real machining processes. The integration of CNC with CAD/CAM software enables the optimization of subtractive manufacturing processes. One of the most established CAD/CAM platforms is Mastercam, recognized as one of the oldest and most widely used CAD/CAM software applications globally [7]. Mastercam has been extensively implemented in vocational institutions for CNC programming instruction [8], and empirical findings indicate that its utilization significantly improves students' competencies in CNC milling programming [9].

In addition to milling technology, CNC plasma cutting represents an advanced thermal cutting process that employs highly ionized gas directed by numerical control to cut metallic materials such as steel and aluminum [10]. The plasma cutting process generates extremely high temperatures capable of melting materials efficiently, while gas flow removes molten residues to produce clean edges [11]. Furthermore, the implementation of plasma cutting technology in engineering education has been shown to enhance students' confidence and active participation during practical learning [12].

Despite these advancements, prior studies have generally developed instructional materials for CNC milling and CNC plasma cutting separately. Research has produced CNC milling learning modules using Mach3 software [13], Android-based digital CNC modules developed through the ADDIE model [14], jobsheet-based instructional materials [15], and plasma cutting learning media [16]. Moreover, STEM-based learning approaches have demonstrated significant influence on students' critical thinking skills [17] and learning outcomes in CNC milling instruction using Mastercam [18]. STEM learning integrates science, technology, engineering, and mathematics in problem-solving contexts and has strong potential to improve vocational learning quality [19], [20].

However, the comprehensive integration of CNC milling, CNC plasma cutting, STEM pedagogy, and Mastercam-based digital simulation into a single Advanced CNC instructional module remains limited. Existing instructional developments tend to focus on a single machining technology and have not combined milling and plasma cutting within an integrated STEM-based framework, particularly in vocational higher education.

Based on the state-of-the-art review, the scientific novelty of this study lies in the development of an integrated STEM-based Advanced CNC teaching module that combines CNC milling and CNC plasma cutting technologies supported by Mastercam in a unified learning system. This integration aligns digital design, simulation, and manufacturing processes within a contextual problem-solving framework relevant to current industrial digitalization [21].

The research problem addressed in this study is the absence of comprehensive and integrated teaching materials capable of facilitating Advanced CNC learning that combines milling and plasma cutting technologies within a STEM framework. Accordingly, the research hypothesis proposes that the development of a STEM-based Advanced CNC teaching module integrated with Mastercam will result in valid, practical, and effective instructional materials that enhance students' competencies in digital manufacturing learning.

Therefore, the objective of this study is to develop and evaluate the feasibility of a STEM-based Advanced CNC teaching module integrating CNC milling and CNC plasma cutting supported by Mastercam in vocational mechanical engineering education

RESEARCH METHODS

This research method employed a Research and Development (R&D) approach. The researchers developed and validated learning materials for an Advanced CNC course that combines CNC Milling and Plasma Cutting technologies based on STEM using Mastercam software and tested their effectiveness. The CNC textbook development adheres to the ADDIE development model, which includes the stages of Analysis, Design, Development, Implementation, and Evaluation [22]. The development phase begins with a needs analysis, followed by the design of learning materials, then the development of learning materials, classroom implementation, and evaluation of the effectiveness of Advanced CNC learning. The product development, in the form of structured learning materials, was tested for validity through expert validation, its practicality through a questionnaire with students who had taken the Advanced CNC course, with categories as shown in the table.

Table 1. Data Tendency Categories [23]

Score Interval	Category
$M_i + 1{,}5\ Sd_i \leq X \leq M_i + 3\ Sd_i$	Very Good/Valid/Practical
$M_i \leq X < M_i + 1{,}5\ Sd_i$	Good/Valid/ Practical
$M_i - 1{,}5\ Sd_i \leq X < M_i$	Poor/Adequately Valid/ Practical
$M_i - 3\ Sd_i \leq X < M_i - 1{,}5\ Sd_i$	Very Poor/Less Valid/ Practical

Meanwhile, the effectiveness of the STEM-based CNC textbook in improving students' 4C skills was analyzed using the N-Gain formula [24] with a pretest-posttest control group design [25]. The research procedure is described in a research flow diagram that combines the ADDIE development concept with STEM steps as follows:

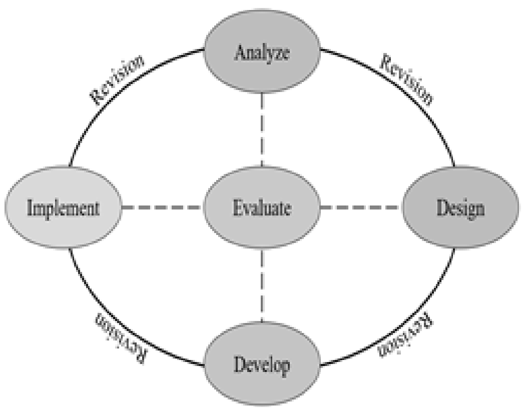

Figure 1. ADDIE Development Procedure

1. Product Trial Design

Trials are conducted by asking expert evaluators to evaluate the product under development. Trial respondents are usually selected to represent the target group. Product validation subjects consist of two experts: a materials expert and a media expert.

The sampling technique used is purposive sampling [26]. The sample is selected based on specific considerations or criteria deemed relevant by the researcher. The trial subjects for the Advanced CAM

Teaching Material: Integration of CNC Milling and STEM-Based Plasma Cutting Assisted by Mastercam were 39 students. The following aspects were assessed to test its validity. Media aspect: Design, Language, Illustrations, Typography, Layout. Material Aspects: Learning, Content/Material.

2. **Data Analysis Techniques**

The instrument sheet was analyzed using data tendency categories. The resulting assessment scores were then converted into values by using a tendency category table, Interval categories for mean scores, On a scale of 1–4: M_i=2.5, SD_i=0.5

Table 2. Data Tendency Categories

Score Interval	Category
3,25 ≤ X ≤ 4,00	Very Good/Valid/Practical
2,50 ≤ X < 3,25	Good/Valid/ Practical
1,75 ≤ X < 2,50	Poor/Adequately Valid/ Practical
1,00 ≤ X < 1,75	Very Poor/Less Valid/ Practical

RESULT AND DISCUSSION

Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model development [22]

1. **Define Stage**

Based on observations of several students who have completed the advanced CNC course over 16 sessions, the observations focused on learning activities, learning tools, media used, and teaching materials. Learning takes place using a lecture, demonstration, and then practice format. However, the practical portion relies more heavily on the use of the VMV CNC Simulator Milling for Android application than Mastercam, and it has not yet been integrated with the Plasma Cutting machine. The learning tool uses the VMC application, Mastercam software for creating milling programs (Facing, Countor, Pocket), while CNC Plasma Cutting is still limited to pattern or design creation. Learning media are still separate for VMC Milling, Mastercam, and Plasma Cutting, and there is no integrated module. Learning materials lack integration of STEM (Science, Technology, Engineering, and Mathematics) concepts, resulting in students having difficulty setting toolpath parameters in Mastercam, and there are no projects combining milling and plasma cutting in a single product. A similar finding was noted in a vocational education study, which demonstrated the need for modules that combine simulation, practice, and parameter analysis to improve learning outcomes. [27].

The needs analysis shows the need for integrated teaching materials based on STEM, Science (Spindle Speed Concept, Feed Rate Concept, Cutting Speed Concept, Cut Parameter), Technology (Mastercam Software, VMC Simulator, Plasma Cutting), Engineering (Basic determination of Tool/Nozzle Movement, Direction of Movement/Program Code), Mathematics (Spindle Speed, Feed Rate, Cutting Speed, Cut Parameter). Practical and portfolio assessment rubrics. This integration is in line with research recommendations on strengthening digital manufacturing skills and standardized learning modules that can be replicated in other institutions [28]. This finding is consistent with the literature showing the effectiveness of practical modules and PjBL in CNC learning [29]. 74% stated they needed more practical Mastercam teaching materials that integrated CNC Milling and Plasma Cutting. 82% needed project examples that integrated both machines. 69% felt the need for STEM-based learning that helps them understand the technical rationale behind each machining decision. 61% had difficulty reading toolpath simulation results. Project-Based Learning (PjBL) can enhance creativity and academic achievement. Therefore, developing teaching materials that are not only informative but also include integrated milling-plasma cutting projects will be more suited to student needs and closer to actual manufacturing practices [30]. Practical learning provides hands-on, focused experience, and is supported by adequate tools/modules, which tends to improve student understanding [31] .

Interviews with lecturers teaching advanced CNC courses strongly support the development of integrated modules that emphasize student understanding. While teaching materials exist, they do not yet integrate plasma cutting, nor does a STEM module exist, leading lecturers to deliver science and engineering concepts verbally without structure. Lecturers emphasize that students often memorize Mastercam steps without understanding the technical logic. Lecturers hope for a comprehensive module that explains cutting principles, provides examples of integrated designs (milling + plasma) in the Mastercam application, and clearly lists machining parameters. Developing modules with a STEM approach is considered relevant to industry needs [31]. Support from previous research on practicum-based learning, module development, and PjBL reinforces that this integrated module development solution has a sufficient empirical basis [31].

2. **Design Stage**

Developing the initial design of STEM-based open materials and integration. The developer determines the specific competencies achieved by students, methods, open materials, learning strategies and learning media. Overall, Advanced CNC Teaching Materials for Integration of CNC Milling and Plasma Cutting Based on STEM Assisted by Mastercam consist of parts that are arranged to become a good book. The arrangement of teaching materials includes Cover section, Foreword, Table of contents, List of figures, List of tables. The core section consists of 5 chapters, namely Introduction, CNC Milling, Plasma Cutting, Mastercam Software, Integration of CNC Milling and Plasma Cutting with Mastercam. Then at the end there is a Bibliography, Glossary, Index List and About the author

Figure 2. *Teaching Material Prototype*

3. Development Stage

This development stage is carried out by developing the cover title of the learning material, script and material, editing media, and creating products and assembling media elements such as text, images and illustrations. The development of STEM-based learning materials on CNC Milling and Plasma Cutting materials is integrated into one unit in the Mastercam application following the steps described in the design stage. Therefore, at this development stage, a prototype of STEM-based learning materials on CNC Milling and Plasma Cutting materials using Mastercam has been created. The following Learning Activities with the STEM Approach consist of structured learning steps, including Ask questions, Research, Imagine (Brainstorming), Plan, Create (Build a prototype), Test and Improve. STEM Learning Plan: Understanding CNC Milling and Plasma Cutting with the help of Mastercam.

At this stage, the researcher submitted the instructional material prototype along with the research instruments to material and media expert validators. The experts assessed the quality of the instructional material and provided the necessary feedback for improving both the content and the visual presentation.

Material Expert Validation

Material Expert Validation In this development, the material expert validator was Romy Saputra, S.Pd., M.Pd.T. The learning and content/material components were developed into 46 indicators. Based on the validation process conducted by this expert, the assessment data were obtained as described below.

Table 3. Table of Material Expert Validation

Assessment Aspects	Validator
Learning	4.00
Content/Material	4.00
Average	4.00

The table above shows the results of the material expert validation, with an average aspect score of 4.00, falling into the valid category. Using intervals to convert these scores into specific categories using a trend table, 3.25 ≤ X ≤ 4 falls into the Very Good category. The material expert assessment, with an average score of 4.00, falls into the valid category. From the assessment results received, it can be concluded that trials and improvements can be implemented based on the results of the material expert validation assessment, in accordance with the recommendations. Students can experiment with the media.

Media Expert Validation

The media expert validation in this development is Efri Meldianto, S.Pd., M.Pd. The Media Expert Aspect consists of 5 aspects, namely Design (4 Indicators), Language (5 Indicators), Illustration (3 Indicators), Typography (4 Indicators) and Layout (3 Indicators), consisting of 38 statements.

Table 4. Table of Media Expert Validation

Assessment Aspects	Validator
Design	3.75
Language	3.88
Illustration	4.00
Typography	3.83
Layout	4.00
Average	3.89

The table above shows the results of media expert validation, with an average aspect assessment of 3.89, which is included in the valid category. If using intervals to convert these scores into specific categories using a trend table, 3.25 ≤ X ≤ 4 is in the Very Good category. From the assessment results received, it can be concluded that trials and improvements can be carried out based on the results of the material and media expert validation assessments in accordance with the recommendations. This is in line with the research findings [32], [33], who stated that learning tools categorized as feasible can be used in the learning process. research [34]showed that the results of the syllabus and lesson plans validation categorized as feasible can be used in learning. Therefore, it can be concluded that interactive science modules based on ethnoscience and critical thinking skills instruments can be implemented in science learning.

4. Implementation Stage

The teaching materials were finalized, validated, and pilot-tested for validity and practicality. They were then implemented with a wider group of students in a real-life learning environment to gauge the effectiveness of the STEM-based teaching materials. Next, pre-tests and post-tests were administered to measure students' STEM skill levels using the teaching materials.

The user testing phase was conducted to assess the effectiveness of the STEM model in improving STEM skills. STEM skills were measured in two stages: through an e-learning quiz and observation of the 4C skills (communication, collaboration, critical thinking, and creativity). The e-learning quizzes were administered as pre- and post-tests, and improvements were then assessed using N-gain and the average.

Based on the calculation results, the N-Gain was 0.72, thus concluding that the increase in learning outcomes was in the high category. The average pretest score was 58.67 and the posttest score was 90.15, indicating a significant increase in competency after the STEM-Based Advanced CNC learning process.

Measurement of the improvement in the 4C skills was conducted through observation. These skills included communication, collaboration, critical thinking, and creativity. The following are the results of the 4C skills measurements

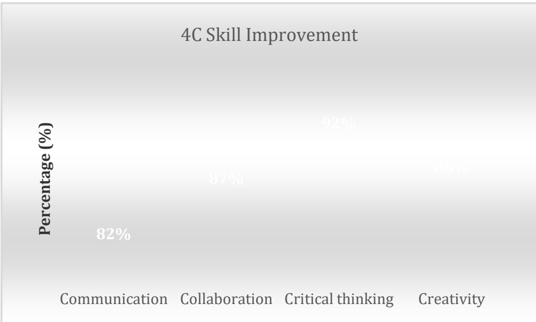

Figure 3. *4C Skills*

5. Evaluation Stage

Product evaluation stage: Analyzing data from experts and respondent questionnaires to determine the validity and practicality of STEM-based teaching materials. The evaluation stage is the final stage in the ADDIE development model, which aims to measure the achievement of learning objectives, the quality of the developed teaching materials, and the effectiveness of their implementation in improving students' STEM skills in the Advanced CNC course.

This development resulted in STEM-Based CNC Teaching Materials for Vocational Education that are feasible and practical. The development procedure used the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model [35], [36], [37]. The Analyze stage comprises learning activities, learning tools, media used, and teaching materials. The Design stage determines the specific competencies achieved by students, methods, teaching materials, learning strategies, and learning media. The Development Stage consists of Validation by a team of experts; First Revision; Individual Evaluation (one on one); Second Revision; Small Group; and Third Revision; Field Testing. Based on the results of the validity and practicality tests, it is hoped that the teaching material will be valid and practical for use in the teaching and learning process in the Mechanical Engineering Education study program. After trials and testing, the Advanced CNC teaching material was developed. The developed product is valid and practical in supporting the learning and teaching process of the Advanced CAD course. This can be seen from the validity results of the material and media experts who obtained an average score of 4.00 from the material experts and 3.89 from the media experts, which can be categorized as teaching materials that have been developed have been included in the valid category and are worthy of being tested with revisions according to the suggestions of material experts and media experts [38], [39]. This means that the teaching materials are valid and suitable for use. Parameters assessed by the teaching materials development experts include feasibility factors that require valid content, presentation, and language before being used in the next test. This shows that the validation test for creating good teaching materials is related to the theoretical foundation of development and to determine whether the teaching materials are used in the learning process. This aligns with research [40], which concluded that ethnoscience-based student worksheets are suitable for use and can improve skills. Research [41], [42] concluded that ethnoscience-based modules can improve students' critical thinking. Research [43] demonstrated that ethnoscience e-modules achieved suitable results for use in learning. Research [44] shows that the STEM-based PBL model has a moderate influence on creative thinking skills. The results of research [43], [45]can be concluded that through STEM learning, students' skills are improved. [46]concluded that ethnoscience can improve higher-order thinking skills, one of which is improving students' critical thinking skills. If the development product is richer than textbooks and easy to use by students or educators, it is considered practical. In a one-to-one trial, the teaching materials were tested with three students with different academic abilities by providing responses in the form of comments and completing an assessment questionnaire. The results showed that the practical guidebook was used in this trial, with a distribution ratio of 67% very practical and 33% practical. Small Group trials were conducted with 39 students of various academic ability levels who provided their responses in the form of comments and completing an assessment questionnaire. The results showed an average of 3.63 in the practical category with a score distribution ratio of 90.75%, indicating that the Practical learning materials were used in small-group trials. in line with research [47], practical interactive multimedia can be used easily by students in the learning process.

The practicality test focused on data on students' ability to confirm success in improving STEM skills. Therefore, the validity and practicality of the learning materials were declared appropriate and practical to support the learning process of the Advanced CNC course. The learning materials were finalized, validated, and tested for validity and practicality. They were implemented with a wider group of students in a real-life learning environment to measure the effectiveness of the STEM-based learning materials. The calculation results yielded an N-Gain of 0.72, concluding that STEM skills were in the high category, which concludes that STEM skills are in the high category, In line with the [35] N-Gain of 82, which indicates a high category.

The average pretest score was 58.67 and the posttest score was 90.15, indicating a significant increase in competency after the Advanced CNC Integration of CNC Milling and CNC Plasma Cutting Based on STEM with the assistance of Mastercam. This aligns with the research findings [48] on Project-Based STEAM Learning (PjBL-STEAM), which has been shown to be effective in developing students' creativity, collaboration, and problem-solving skills.

In addition, there was an increase in each of the 4C skills. Communication reached 82%, collaboration 87%, critical thinking 92%, and creativity 88%. STEM activities are designed to be carried out in groups, thus improving students' skills in collaboration, critical thinking, and creativity, while communication still needs to be improved. Relevant to research [32]. The results show that the developed module has valid, practical, and effective criteria for improving students' critical thinking skills.

CONCLUSION

Based on the results and discussion, it can be concluded that the Development of Advanced CNC Teaching Materials integrated with Mastercam CNC Milling and STEM-Based Plasma Cutting is proven to be valid, practical, and effective to use. The STEM model can improve STEM skills by integrating Mastercam-assisted CNC Milling and Plasma Cutting materials related to Trellis Fence Design. Improved STEM skills can be obtained through STEM-based learning models. For further research, broader integration can be carried out for several courses. So that students' mastery of the material is more comprehensive and relevant to the industrial world.

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REFERENCES

[1] World Economic Forum, *Future of Jobs Report 2023*. Geneva: WEF, 2023. doi: 10.1142/11458.

[2] X. Xu, “Machine Tool 4.0 for the new era of manufacturing,” 2017. doi: 10.1007/s00170-017-0300-7.

[3] A. Rojko, “Industry 4.0 concept: Background and overview,” *International Journal of Interactive Mobile Technologies*, vol. 11, no. 5, 2017, doi: 10.3991/ijim.v11i5.7072.

[4] C. Zoberis, “Calculating Cnc Automation Roi,” *Cutting Tool Engineering*, vol. 75, no. 8, 2023.

[5] T. von Hahn and C. K. Mechefske, “Machine Learning in CNC Machining: Best Practices,” *Machines*, vol. 10, no. 12, 2022, doi: 10.3390/machines10121233.

[6] Matercam Indonesia, “Mastercam – software program CNC Terbaik,” 2020.

[7] J. Bueno Gutiérrez, “Técnicas de torneado con Mastercam,” 2021.

[8] A. R. Adi, A. M. Irfan, A. P. Ashar, D. Djuanda, and M. Z. Muhsin, “Pelatihan Simulasi Untuk Program Nc dengan CAD/CAM Software Mastercam X5 Bagi Mahasiswa Jurusan Pendidikan Teknik Mesin Fakultas Teknik UNM,” *Vokatek : Jurnal Pengabdian Masyarakat*, vol. 1, no. 3, 2023, doi: 10.61255/vokatekjpm.v1i3.266.

[9] W. R. Cahyadi, A. S. Nugraha, Suprapto, and M. K. Nafis, “Pelatihan Program CNC dengan Media Mastercam X5 Diaplikasikan Pada Mesin CNC Milling GSK,” *IMPACT: Jurnal Pengabdian Kepada Masyarakat*, vol. 01, no. 01, pp. 8–14, 2025.

[10] D. Mourtzis, J. Angelopoulos, and N. Panopoulos, “A Literature Review of the Challenges and Opportunities of the Transition from Industry 4.0 to Society 5.0,” 2022. doi: 10.3390/en15176276.

[11] R. T. Lermen, R. M. Dos Passos, C. P. Lisboa, T. L. Pilotto, and R. D. A. Silva, “Development of a CNC plasma cutting machine: design and construction for didactic purposes,” *Revista de Arquitetura IMED*, vol. 12, no. 2, p. 100, 2023, doi: 10.18256/2318-1109.2023.v12i2.4957.

[12] D. Yatim, “Inovasi Penggunaan Plasma Cutting sebagai Media Pembelajaran Praktek di SMKN 2 Pinggir,” *Pendidikan Tambusai*, vol. 8, pp. 3261–3267, 2024.

[13] L. D. Widayanto and F. Y. Utama, “Pengembangan Modul Pembelajaran CNC Dengan Pengaturan Titik Awal Pada Posisi Center Menggunakan Software Mach3 SMK Negeri 5 Surabaya,” *JPTM*, vol. 7, no. 2, pp. 21–27, 2018.

[14] A. H. Abdillah, A. Atiqoh, and H. Karyono, “Pengembangan Media Pembelajaran Berbasis Aplikasi Android dalam Pembelajaran CNC di Kelas XII Teknik Pemesinan,” *EDUKASIA: Jurnal Pendidikan dan Pembelajaran*, vol. 4, no. 2, pp. 2209–2218, 2023, doi: 10.62775/edukasia.v4i2.569.

[15] S. Y. T. Putra and R. Hermawan, “Pengembangan Jobsheet Berbasis Project Based Learning pada Mata Kuliah Praktik Pemesinan di Program Studi Pendidikan Teknik Mesin Universitas Sriwijaya,” *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, vol. 8, no. 6, pp. 5893–5898, 2025, doi: 10.54371/jiip.v8i6.8284.

[16] A. Salam, B. Nasrullah, K. Elizhabet, A. Hakim, and M. Multazam, “Pengembangan Mesin CNC Plasma Cutting Sebagai Media Pembelajaran,” vol. 22, no. 1, pp. 136–145, 2024.

[17] V. Sumanti, A. Dwi, J. Suhandoko, and U. Terbuka, “Pengembangan Perangkat Pembelajaran Berbasis STEM - Project Based Learning Untuk Meningkatkan Keterampilan Berpikir Kritis Dan Keterampilan Kolaborasi Siswa SD Pengembangan Perangkat Pembelajaran Berbasis STEM-Project Based Learning Untuk,” vol. 6, no. 1, pp. 130–155, 2025.

[18] A. P. Afandi and N. A. Susanti, “Pengembangan Modul Cnc Milling Software Mastercam X9 Mata Pelajaran Cnc Jurusan Teknik Pemesinan Smkn 1 Blitar,” *Jptm*, vol. 11, no. 02, pp. 1–6, 2022.

[19] A. Muhaimin, S. Menengah, and K. Negeri, “Penerapan Project Based Learning dengan Pendekatan STEM dalam Upaya Meningkat Kemampuan Menyusun Program CNC Pada Kelas XI Teknik Pemesinan SMK Negeri 3 Mataram,” 2020.

[20] R. Farwati, K. Metafisika, I. Sari, D. S. Sitinjak, D. F. Solikha, and S. Solfarina, “STEM Education Implementation in Indonesia: A Scoping Review,” *International Journal of STEM Education for Sustainability*, vol. 1, no. 1, pp. 11–32, 2021, doi: 10.53889/ijses.v1i1.2.

[21] S. Gao and L. K. Bhagi, “Design and research on CADDCAM system of plane based on NC machining technology.,” *Comput. Aided. Des. Appl.*, vol. 19, no. S2, pp. 64–73, 2022, doi: 10.14733/cadaps.2022.S2.64-73.

[22] D. R. Martatiyana, H. Usman, and H. D. Lestari, “Application of the Addie Model in Designing Digital Teaching Materials,” *Jurnal Pendidikan dan Pengajaran Guru Sekolah Dasar (JPPGuseda)*, vol. 6, no. 1, pp. 105–109, 2023, doi: 10.55215/jppguseda.v6i1.7525.

[23] A. N. Putri and A. Widayati, “Relevansi Kurikulum SMK Dengan Permintaan Dunia Industri: Persepsi Guru Akuntansi SMK Di Kab. Sleman,” *Jurnal Pendidikan Akuntansi Indonesia*, vol. 18, no. 2, pp. 01–14, 2020.

[24] R. R. Hake, “Analyzing change/gain scores,” *Unpublished.[online] URL: http://www. physics. indiana. edu/\~ sdi/AnalyzingChange-Gain. pdf*, vol. 16, no. 7, 1999.

[25] Sugiyono, *Metode Penelitian Kuantitatif, Kualitatif, dan R&D. In Sugiyono, Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. 2023.

[26] Asrulla, Risnita, M. S. Jailani, and F. Jeka, “Populasi dan Sampling (Kuantitatif), Serta Pemilihan Informan Kunci (Kualitatif) dalam Pendekatan Praktis,” *Jurnal Pendidikan Tambusai*, vol. 7, no. 3, 2023.

[27] V. Teodor, F. Moros, and F. Susac, “Implementation of an Academic Learning Module for CNC Manufacturing Technology of the Part ” Double Fixing Fork ”,” pp. 1–18, 2025.

[28] Y. Rapitsenyane, R. Moalosi, O. J. Sealetsa, V. Ruele, T. Mosepedi, and B. Matake, “Integration of digital manufacturing skills in industrial design education and its impact on small and medium enterprises,” no. October, pp. 1–17, 2023, doi: 10.3389/fmech.2023.1254866.

[29] M. Kamaludin, D. Hafid, and H. Setiawan, “Model Project Based Learning Secara Daring Menggunakan Software CAM Mata Pelajaran Teknik,” vol. 3, no. September, pp. 325–333, 2022.

[30] H. D. Cahyo, “Increasing Creativity And Achievement Learning Science Through Project Based Learning In Class VIII Students,” *Jurnal Inovasi Pendidikan Dan Sains*, vol. 4, no. 1, 2023, doi: 10.51673/jips.v4i1.1487.

[31] I. R. Ritonga *et al.*, “Peningkatkan Pemahaman dan Nilai Mahasiswa Dengan Metode Praktikum,” *JURNAL INOVASI PENDIDIKAN DAN SAINS*, vol. 4, no. 2, 2023, doi: 10.51673/jips.v4i2.1519.

[32] M. S. Ihsan and M. Z. Pahmi, “Development Of Etnoscience Based Interactive Science Module To Improve Student’s Critical Thinking Ability,”

Jurnal Inovasi Pendidikan Dan Sains, vol. 3, no. 3, 2022, doi: 10.51673/jips.v3i3.1151.
[33] T. AAIA, A. W. Jufri, and A. Ramdani, “Pengembangan Model Praktikum Berbasis Software Most Probable Number (Mp-Bsmpn) Pada Mata Kuliah Mikrobiologi Air,” *Jurnal Pijar Mipa*, vol. 12, no. 2, 2017, doi: 10.29303/jpm.v12i2.340.
[34] R. Rahmasari, Gartika & Rsmiati, “e-Learning Pembelajaran Jarak Jauh Untuk SMA,” 2012.
[35] F. Rahmah, A. Susanto, A. Pohan, H. Hamjah, and M. Mahmud, “Development of Digital Comic Media to Prevent Bullying in Early Childhood,” *Jurnal Inovasi Pendidikan dan Sains*, vol. 7, no. 1, pp. 94–104, Feb. 2026, doi: 10.51673/jips.v7i1.2801.
[36] R.- Ramadhani and H. Rais, “Pengembangan Modul Matematika Berbasis Pendekatan Saintifik pada Materi Pola Bilangan,” *Jurnal Inovasi Pendidikan dan Sains*, vol. 6, no. 1, 2025, doi: 10.51673/jips.v6i1.2349.
[37] S. Syahwinsyah, I. Fitriati, A. Ahyar, A. R. Hakim, and A. Prayudi, “Pengembangan e-eval_uasi Quizalize Berbasis Gamifikasi untuk Meningkatkan Motivasi Belajar Siswa,” *Jurnal Inovasi Pendidikan dan Sains*, vol. 6, no. 1, 2025, doi: 10.51673/jips.v6i1.2467.
[38] A. Saputra, A. Sutono, and I. Dwijayanti, “Developing Edupreneurship-Oriented Natural and Social Sciences Teaching Materials Using the Project-Based Learning to Improve Students’ Creativity for Primary School,” *Jurnal Inovasi Pendidikan dan Sains*, vol. 6, no. 3, pp. 625–635, Nov. 2025, doi: 10.51673/jips.v6i3.2648.
[39] M. R. Hati and A. Sahrina, “Development of an Electronic Module Assisted by the Metaverse to Support Contextual Learning in the Geography Subject,” *Jurnal Inovasi Pendidikan dan Sains*, vol. 6, no. 3, pp. 711–719, Nov. 2025, doi: 10.51673/jips.v6i3.2653.
[40] L. Septiaahmad, I. Sakti, and I. Setiawan, “Pengembangan Lembar Kerja Peserta Didik (LKPD) Fisika Berbasis Etnosains Menggunakan Model Discovery Learning Untuk Meningkatkan Keterampilan Berpikir Kritis Siswa SMA,” *Jurnal Kumparan Fisika*, vol. 3, no. 2, 2020, doi: 10.33369/jkf.3.2.121-130.
[41] Trio Ageng Prayitno, Nuril Hidayati, and Noventianus Umbu Ranja Uma, “Pengembangan Buku Ajar Biologi Berbasis STEM education-PjBL pada Materi Plantae,” *Jurnal Biologi dan Pembelajarannya (JB&P)*, vol. 11, no. 1, 2024, doi: 10.29407/jbp.v11i1.23022.
[42] E. Yulianti, E. Hamimi, and R. Rahmagusviana, “Pengembangan Buku Ajar IPA Berpendekatan STEM untuk Mengembangkan Kreativitas Siswa pada Tema Tekanan,” *Phenomenon : Jurnal Pendidikan MIPA*, vol. 11, no. 2, 2021, doi: 10.21580/phen.2021.11.2.7775.
[43] E. Puspitasari, P. Dwi Aristya Putra, and R. D. Handayani, “Pengembangan Buku Ajar Fisika Berbasis Science, Technology, Engineering, and Mathematics (STEM) pada Pokok Bahasan Suhu dan Kalor di SMA,” *Jurnal Literasi Pendidikan Fisika (JLPF)*, vol. 2, no. 1, 2021, doi: 10.30872/jlpf.v2i1.465.
[44] N. Sara, P. Murni, and S. Syamsurizal, “The Effect of the Problem-Based Learning Model Based on the Science, Technology, Engineering, and Mathematics (STEM) Approach on Students’ Creative Thinking Ability,” *Jurnal Inovasi Pendidikan dan Sains*, vol. 6, no. 2, 2025, doi: 10.51673/jips.v6i2.2528.
[45] F. D. Wijayanti, S. Sarwanto, and D. Harjunowibowo, “A Bibliometric Study of Models Fostering Critical Thinking, Communication, Creativity, and Collaboration Skills,” *Jurnal Inovasi Pendidikan dan Sains*, vol. 6, no. 1, 2025, doi: 10.51673/jips.v6i1.2454.
[46] A. Widyawati, S. I. A. Dwiningrum, and R. Rukiyati, “Pembelajaran ethnosciences di era revolusi industri 4.0 sebagai pemacu Higher Order Thinking Skills (HOTS),” *Jurnal Pembangunan Pendidikan: Fondasi dan Aplikasi*, vol. 9, no. 1, 2021, doi: 10.21831/jppfa.v9i1.38049.
[47] G. Gunawan, A. Harjono, L. Herayanti, S. Husein, and F. Fathoroni, “Investigating Student’s Critical Thinking Disposition Based On Gender In Physics Teaching With Interactive Multimedia,” *JPPS (Jurnal Penelitian Pendidikan Sains)*, vol. 9, no. 1, 2020, doi: 10.26740/jpps.v9n1.p1766-1771.
[48] W. Wijayati, W. Widiyanti, and Y. Yoto, “Integration of STEAM Chemistry Learning Based on Local Wisdom to Strengthen Students’ Vocational Skills and Science Literacy: A Systematic Literature Review (2020–2025),” *Jurnal Inovasi Pendidikan dan Sains*, vol. 7, no. 1, pp. 1–9, Jan. 2026, doi: 10.51673/jips.v7i1.2724.