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DEVELOPMENT OF STEM-ORIENTED WORKSHEET USING PROJECT-BASED LEARNING IN 2D ARCHITECTURAL DRAWING FOR GRADE XI VOCATIONAL HIGH SCHOOL STUDENTS

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Abstract

There has to be a steady supply of skilled workers, particularly in the field of vocational education, if science and technology are to keep up with the current rate of advancement. Limited learning facilities and an inadequate teaching staff are only two of the many problems that vocational education in Indonesia continues to confront. The purpose of this research is to use the Project-Based Learning (PjBL) approach to create STEM-focused Student Worksheets for the Building Information and Modeling Design (DPIB) course at technical institutions, with a focus on two-dimensional (2D) architectural drawing. Analysis, design, development, implementation, and evaluation are the steps that make up the ADDIE development model, which was used as the research technique in this study. Thirty students from the eleventh grade at SMK Negeri 11 Malang participated in the study. Questionnaires on students' learning requirements, validation sheets from experts, and readability exams administered to students were all used to gather data. Descriptive quantitative methods were used for data analysis. With an average expert validation score of 90.20% and a student readability score of 88.34%, the created worksheets were deemed extremely valid and intelligible, according to the findings. These results show that the worksheets improve students' knowledge and abilities in architectural drawing as measured by industry standards. Thus, STEM-focused PjBL-based worksheets constitute a viable and efficient medium for vocational education instruction.
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Keywords: Worksheets, STEM, Project-Based Learning, Architectural Drawing

Introduction

The rapid development of science and technology (IPTEK) in the era of globalization demands the availability of quality human resources (HR), especially in the field of vocational education. Vocational High Schools (SMP) as vocational secondary education institutions aim to produce competent graduates who are ready to work in their respective fields of expertise (Maghfiroh et al., 2019; Setiaji et al., 2020). Vocational schools prepare their students to become competent and productive individuals so that after graduation, they are expected to be able to compete in the world of work in accordance with their competencies (Fathoni et al., 2019; Sudarsono, 2020). These demands refer to the needs of the 21st-century workplace, which emphasizes innovation skills, access to information, media, technology, as well as life and career skills for anyone who wants to survive in the workplace (Tafakur & Suyanto, 2015). Therefore, critical thinking, problem solving, collaboration, leadership, agility, adaptability, oral and written communication, curiosity, and information access skills are essential in today's workplace. Therefore, critical thinking, problem solving, collaboration, leadership, agility, adaptability, oral and written communication, curiosity, and information access skills are essential in preparing students for the workplace(Arthur et al., 2019; Maharani et al., 2024). In line with this, vocational education must prioritize the development of work skills and character required by the industry, in addition to information mastery (Mardhiyah et al., 2021; Widiastuti et al., 2024).

However, there are still many obstacles that must be overcome in Indonesia's vocational education system. The fact that high school/vocational school graduates still have the highest open unemployment rate compared to graduates of other education levels is one such difficulty, as shown by data from the Central Statistics Agency (BPS) in 2024 (Badan Pusat Statistik, 2025). This indicates a gap between the skills possessed by graduates and those sought by employers (McGrath et al., 2020; Sugiartiningsih et al., 2019). Limited learning facilities, a lack of innovative media, and uneven teacher skills further exacerbate the challenges in achieving vocational education goals (Ernawati, 2021).

One of the programs that requires high technical mastery is Building Modeling and Information Design (DPIB), where technical drawing skills are a basic competency that students must master before entering the workforce (Hanifah & Adistana, 2023; Oktariansyah et al., 2019). These competencies include the ability to produce two-dimensional (2D) and three-dimensional (3D) technical drawings, both manually and through computer-aided design software such as AutoCAD (Atmajayani, 2018). However, based on initial observations, the technical drawing skills of students in the DPIB program are still relatively low. Most students have not been able to achieve the expected skill standards because the learning process is still dominated by lecture methods, lacks variety, and minimizes the use of interesting learning media (Titania, 2016).

Previous studies by Yani et al (2020) have emphasized the importance of integrating appropriate learning approaches and technology in improving students' technical drawing competencies. Demonstrated that technical drawing instruction combining manual drawing skills with computer-aided design software, such as AutoCAD, is more effective in enhancing students' understanding and visualisation skills compared to conventional methods. These findings indicate that mastery of 2D and 3D drawing competencies is not solely determined by students' individual abilities, but is also strongly influenced by the learning approach and the extent to which technology is integrated into the instructional process. Nevertheless, this study did not specifically examine how the effectiveness of such learning approaches is supported by the availability and adequacy of educational facilities in vocational schools (Yani et al., 2020).

In contrast, Murtinugraha, Ramadhan, and Andarista (2021) reported that the suitability of facilities and infrastructure standards in the DPIB competency at vocational high schools remains relatively low, particularly in terms of practice rooms and supporting learning equipment. This condition potentially limits the optimal implementation of technical drawing instruction, especially software-based learning, even though graduates are expected to master both manual and digital drawing skills to meet industry demands (Murtinugraha et al., 2021).

By synthesising these findings, it can be inferred that improving the technical drawing competencies of DPIB students cannot be separated from the integration of learning approaches, the use of technology, and the availability of adequate facilities and infrastructure. Therefore, this study offers novelty by examining the relationship between students' technical drawing skills and the actual learning conditions, encompassing both pedagogical aspects and supporting facilities. This comprehensive perspective is expected to provide a stronger empirical basis for improving technical drawing instruction in DPIB vocational high schools.

Students enrolled in the DPIB program at a public high school/vocational school in Malang City are required to demonstrate architectural drawing skills as a basic skill. Although some students have shown improvement, preliminary statistics and classroom observations indicate that students' technical drawing skills are still below average. Among the many causes of this problem is a lack of interesting and appropriate educational materials. To date, most classroom teaching has taken the form of boring lectures, which fail to inspire students (Widiastuti et al., 2024). To overcome this problem, vocational school students' competencies need to be formulated and adapted to the current needs of the industry through competency-based learning that is integrated with work patterns, rules, and industry standards (Azizah et al., 2019; Ernawati, 2021). Vocational education requires minimum competency standards that students must master, with success measured according to industry criteria (McGrath et al., 2020; Sugiartiningsih et al., 2019). Thus, vocational school students must be equipped with attitudes, knowledge, and learning skills relevant to the needs of the world of work (Lawitta et al., 2017).

The Project-Based Learning (PjBL) model is one of the most appropriate alternatives to be applied in vocational education (Kusumaningrum, S., & Djukri, 2016; Mulyadi, 2016). The PjBL model places students as active participants in the learning process through real and contextual projects (Azizah et al., 2019; Sudira, 2019). Vocational high school students can benefit from increased work readiness through the development of creative thinking, independence, and problem-solving skills through PjBL (Problem-Based Learning) (Rumondang et al., 2019). Selain itu, pendekatan STEM (Sains, Teknologi, Teknik, dan Matematika) harus dimasukkan ke dalam pembelajaran untuk mengatasi kesulitan di era globalisasi. In addition, the STEM (Science, Technology, Engineering, and Mathematics) approach must be incorporated into learning to overcome difficulties in the era of globalization. According to Ceylan and Ozdilek (2015), students' problem-solving skills are greatly enhanced by STEM components. Among the many ways the STEM approach improves vocational education is by stimulating students' interest and talent in STEM subjects (Brand, 2020). The research by Amri et al. (2020) shows that the application of the Project-Based Learning (PjBL) model combined with the STEM approach has the potential to improve the technical skills and work character of vocational school students. However, this research is still conceptual in nature and has not specifically examined its application in technical drawing, particularly two-dimensional (2D) architectural drawing in the Building Modeling and Information Design (DPIB) competency. Furthermore, the study has not developed concrete learning tools that can be used directly in the classroom, such as structured worksheets oriented towards industry standards. Therefore, further research is needed to design and test the feasibility of PjBL-STEM-based worksheets to support contextual and applied 2D architectural drawing learning in vocational schools (Amri et al., 2020).

The objectives of this study are to develop an industry-standard, STEM-oriented worksheet based on the Project-Based Learning (PjBL) model for 2D architectural drawing in the Building Modeling and Information Design (DPIB) program; to evaluate the feasibility and validity of the developed worksheet through expert judgment and user responses; and to analyze students' learning difficulties in 2D architectural drawing to identify potential improvements in vocational education practices. The findings of this study are expected to provide practical contributions to the enhancement of vocational education, particularly in the DPIB field in Indonesia.

Research Methods

This study adopted a research and development (R&D) approach aimed at developing and evaluating the feasibility of a worksheet as a learning product, particularly in terms of its validity and practicality (Hidayat et al., 2024; Sari N & Vebrianto, 2017) . The development model used is ADDIE, which consists of five stages, namely analysis, design, development, implementation, and evaluation (Anafi et al., 2021). This model allows for assessment by experts to provide input and improvements before field testing (Cahyadi, 2019). This model was selected due to its systematic and structured framework, which enables expert assessment and revision prior to field implementation (Wulandhary & Tambunan, 2025).

During the analysis stage, a needs analysis was conducted using questionnaires administered to Grade XI students of the Building Modeling and Information Design (DPIB) program who were undertaking 2D architectural drawing instruction. The questionnaire explored students' prior learning experiences, learning needs, and challenges encountered throughout the learning process. Subsequently, the design stage focused on formulating the worksheet framework based on the results of the needs analysis, including the specification of learning objectives, worksheet structure, instructional materials, and targeted competencies.

The development stage involved expert validation to assess the feasibility of the developed worksheet. A total of three validators participated in this process, consisting of two material experts, a lecturer from the Department of Civil Engineering and Planning, Universitas Negeri Malang, and a DPIB subject teacher from SMK Negeri 11 Malang, and one media expert from the Faculty of Education, Universitas Negeri Malang. The validators were selected based on their academic qualifications and professional expertise relevant to the instructional content and media design. Feedback, critiques, and recommendations provided by the experts were used as the basis for revising and refining the worksheet.

The implementation stage was conducted through a limited field trial involving one DPIB subject teacher and 30 Grade XI DPIB students at SMK Negeri 11 Malang. The student participants were selected using a random sampling technique, whereby samples were drawn randomly without considering strata or specific abilities (Sugiyono, 2017). Data were collected using readability and practicality questionnaires administered on a Likert scale.

Evaluation is the final step in this research process; evaluation aims to determine how well the product achieves its objectives. Formative and summative assessments are used in education. By measuring the quality of the product through formative assessment, it is possible to make adjustments or improvements to the final product. Students' abilities in the specified skills were assessed through summative assessment, which was supplemented with pre- and post-tests (Ramadhani & Pratiwi, 2025). Because this study was primarily concerned with determining whether the media created was appropriate or not, rather than whether the learning media created was successful or not, only formative evaluation was conducted at this stage (Ulfah et al., 2025).

This research was conducted during the second semester of the 2024–2025 academic year at SMK Negeri 11 Malang. The research location was deliberately selected because, among the two public vocational high schools in Malang City offering the DPIB program—namely SMK Negeri 6 Malang and SMK Negeri 11 Malang—SMK Negeri 11 Malang places a stronger emphasis on building construction competencies, which are directly aligned with 2D architectural drawing instruction. In contrast, the DPIB program at SMK Negeri 6 Malang primarily focuses on road and bridge construction. Therefore, SMK Negeri 11 Malang was considered the most appropriate setting for implementing and evaluating the developed worksheet. Student reading tests, subject matter expert validation sheets, media expert validation sheets, and learning needs questionnaires were the research tools used. Learning needs were identified using a needs questionnaire. The alignment of the content with the curriculum and the clarity of the language were examined using subject matter expert validation sheets. The suitability of the design, visuals, and appearance were evaluated using the media expert validation sheet. The purpose of conducting the readability test was to ascertain the extent to which the worksheets created were understood by students. Students filled out the questionnaire, while validators filled out the evaluation sheet to collect data. Tables 1 and 2 detail the characteristics and metrics for each tool.

Table 1. Validity Indicators

Aspects	Indicators
Content Suitability	- Aligns with curriculum and Learning Outcomes - Contains STEM - Supports technical (AutoCAD) and theoretical (drawing floor plans) skills - Contextual and relevant to real life - Encourages student engagement - Can be used by all students - Consistent with values, morality, and social values - Trains communication of opinions and work results - Increases students' knowledge - Guides students in developing concepts
Language	- Clear and easy-to-read language - Grammar and spelling comply with rules - Language motivates independent and collaborative learning - Information is presented clearly - Language is appropriate to students' ability levels
Presentation	- Systematic according to PjBL syntax - Clear learning activity objectives - Complete structure (title, instructions, outcomes, information, tasks, work steps, and assessment) - STEM integration - Provides space for critical thinking and project completion
Media	- Easy to use - Clear instructions - Font size, font, and layout support readability - Not too Many fonts - Attractive design and non-distracting colors - Consistent layout - Clear and proportional heading levels - Component displays work together - Illustrations, tables, and images support understanding

Table 1. Student Readability Indicators

Aspects	Indicators
Appearance	- Neat, attractive, and easy-to-understand layout and design - Illustrations facilitate comprehension - Colors and visuals support focus - Clear and legible fonts
Interest	- Interesting material to learn - Learning is not boring - Motivates students
Aspects	**Indicators**
Content suitability	- STEM material is relevant to everyday life - Material is easy to understand

Aspects	Indicators
	- Relevant illustrations and examples - Adapted to students' learning pace
Language	- Clear sentences and paragraphs - Simple language and appropriate to students' level of understanding

Using quantitative and qualitative descriptive methods, the collected data was examined. Questionnaires were sent to students, subject instructors, media specialists, and subject matter experts to collect quantitative data. Comments and recommendations from validators and subject instructors, along with student input, were sources of qualitative data. Curriculum data analysis, student profiles, initial skills, and prerequisites were some of the descriptive approaches used in the first stage of data analysis. This stage also included analysis of questionnaires on student needs and data from interviews and observations with subject instructors. Second, two specialists participated in the validation data analysis: one from the Department of Civil Engineering and Planning at Malang State University and another from the Faculty of Education at Malang State University and a DPIB subject teacher at SMK Negeri 11 Malang. A number of actions were taken in response to the findings of the validation sheet. For starters, you can see the test results in Table 3.

Table 3. Worksheet Content Validation Scores

Score	Criteria
5	Very Good/Very Appropriate/Very Valid
4	Good/Appropriate/Valid
3	Fair/Fairly Appropriate/Fairly Valid
2	Poor/Poor Valid
1	Very Poor

The second step is to calculate the validity level as follows:

$$Validation\ value = \frac{\sum expert's\ answer\ score}{\sum total\ score} \times 100\%$$

Percentage figures are used to assess the validity of the research product, as shown in Table 4.

Table 4. Worksheet Validity Criteria

Score	Criteria
100% - 81%	Very Suitable
80% - 61%	Suitable
60% - 41%	Fairly Suitable
40% - 21%	Less Suitable
20% – 0%	Not Suitable

(Riduwan & Buditjahjanto, 2015)

Next, an analysis of the readability data obtained from students through questionnaires and feedback was conducted (Suwandi, 2021). This small group testing stage involved 30 students. The steps taken to obtain the worksheet readability results were to give assessment scores according to Table 5.

Table 5. Worksheet Readability Scores

Simbol	Description	Skor
SB	Very good	5
B	Good	4
C	Fair	3
K	Poor	2
SK	Very poor	1

The data obtained from the readability test was then analyzed using the following percentage formula:

$$P = \frac{\sum number\ of\ scores\ given}{\sum total\ score} \times 100\%$$

The readability percentage results were interpreted based on the readability criteria shown in Table 6.

Table 6. Worksheet Readability Criteria

Criteria	Score (%)
Easy to understand	$60 < P$
Poorly understood	$40 < P \leq 60$
Difficult to understand	$P < 40$

(Riduwan & Buditjahjanto, 2015)

Research Results and Discussion

Grade XI DPIB students at SMK Negeri 11 Malang will use the PjBL approach to create STEM-oriented worksheets that describe the layout of a 2D multi-storey house. Analysis, design, development, implementation, and evaluation are the five stages that form the ADDIE model, which is used to describe the development process. Both the worksheet development process and product feasibility are discussed in the findings of this study.

The analysis stage constitutes the initial phase of the ADDIE model and aims to identify learning needs prior to product development. This stage examined curriculum demands, student characteristics, initial abilities, and learning needs of Grade XI DPIB students. Based on the Merdeka Curriculum Phase F, students are required to master 2D architectural drawing competencies, particularly in producing multi-storey house floor plans. To clarify the findings of the needs analysis, the results of observations and questionnaires are summarized in Table 7.

Table 7. Summary of Needs Analysis Results

Analysis Aspect	Findings
Curriculum Demands	Students are expected to produce 2D architectural drawings of multi-storey houses, with an emphasis on accurate floor plan design aligned with industry standards.
Learning Preferences	Students show higher interest in applied and practice-based learning rather than purely theoretical instruction.
Initial Abilities	Some students are familiar with AutoCAD; however, most still experience difficulties in applying technical drawing principles and integrating STEM concepts into complete designs.
Learning Difficulties	Difficulties in understanding complex design concepts, limited mastery of AutoCAD tools, and challenges in visualizing multi-storey building layouts.

Analysis Aspect	Findings
Learning Needs	Need for structured learning guidance through worksheets, increased opportunities for hands-on practice, and step-by-step support in software usage.
Learning Constraints	Limited understanding of STEM theory, insufficient utilization of learning facilities, and uneven levels of students' technical skills.

As shown in Table 7, observation results indicate that students tend to respond more positively to applied learning activities, although there are noticeable variations in their abilities, particularly in understanding complex architectural design concepts. These findings are consistent with previous studies emphasizing the importance of contextual and practice-oriented learning in vocational education (Jazuli et al., 2023; Kustandi et al., 2021; Susilo & Suwahyo, 2019). Furthermore, the analysis of students' initial abilities reveals that familiarity with AutoCAD does not necessarily translate into mastery of technical drawing skills. Many students still struggle to apply STEM concepts and produce accurate multi-storey house plans, which supports earlier findings by N et al. (2013) (N et al., 2013). The needs assessment survey further confirms that most students require more structured instructional support, particularly in the form of worksheets, additional practice activities, and guided use of design software (Saprita et al., 2025). Overall, the analysis stage demonstrates that learning challenges are influenced not only by students' individual abilities but also by the availability of appropriate learning media and instructional strategies. Therefore, the development of STEM-oriented worksheets based on the Project-Based Learning (PjBL) model is considered a relevant and necessary solution to address these needs and to enhance both conceptual understanding and practical skills, as also suggested by Yulinda et al. (2024) (Yulinda et al., 2024).

The design stage was carried out through the creation of prototypes and the compilation of worksheet content based on STEM-oriented Project-Based Learning (PjBL). The worksheet prototype was designed to provide an initial overview of the product, including learning objectives, work steps, instructions for using the software (AutoCAD), and the assessment system. The content was compiled systematically based on an analysis of learning needs, the curriculum, and the characteristics of the students. The material focuses on the skills of drawing two-dimensional floor plans using AutoCAD in accordance with building drawing standards. The worksheet structure includes usage instructions, learning objectives, brief material, project-based tasks, work steps, fill-in sheets, evaluation, and reflection (Putri et al., 2025). The integration of STEM aspects is applied through the use of software technology, the application of building structure design techniques, and calculations of scale, proportion, and dimensions.

During development, the first worksheet product was compiled using the information and prototypes that had been developed. This product has six main sections that form the worksheet, as listed by Prastowo (2014): title, instructions, key competencies/main content, additional information, tasks/work stages, and evaluation (Prastowo, 2014). The worksheet developed is based on Project-Based Learning (PjBL) oriented towards STEM on the subject of drawing multi-storey house plans (2D) with a total of 37 pages. The compilation of the WORKSHEET follows the PjBL syntax and contains supporting elements such as a cover, project concept map, project description, information on the STEM approach, material summary, and project work instructions. An example of the initial product development is shown in Figure 7, which contains images of the worksheet.

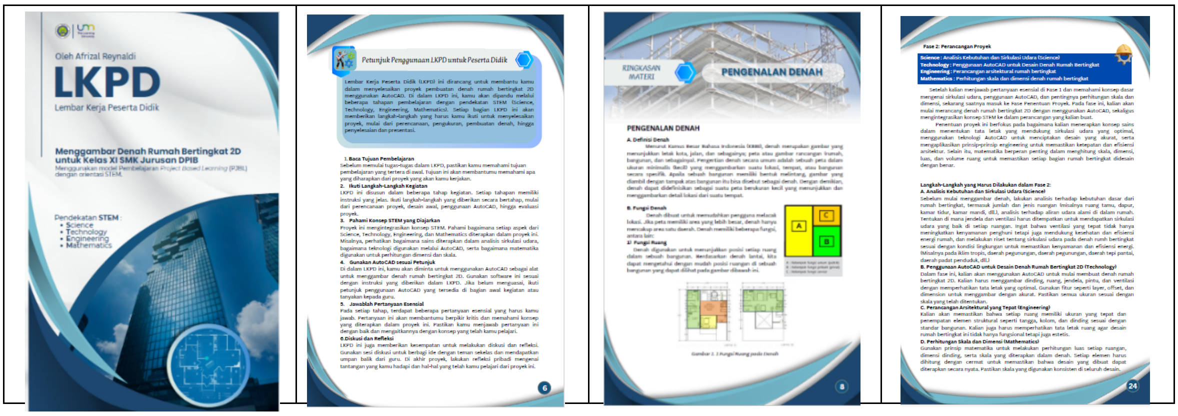


Figure 1. Initial Product Development of worksheet

Next, product validation was carried out to assess the feasibility of the worksheet and obtain input from experts to improve quality before the trial stage with students. The aspects validated included content feasibility, language, presentation, and media. Data was obtained through validation sheets containing written assessments and suggestions from validators, which were then analyzed and used as a basis for revision. The percentage of validation results from experts is presented in Table 8.

Table 8. Worksheet Validation Results

Assessment Aspects	Percentage Score (%)	Criteria
Content Suitability	87	Very Suitable
Language	90	Very Suitable
Presentation	86	Very Suitable
Media	97,78	Very Suitable
Average Score	**90,20**	**Very Suitable**

Based on Table 8, the overall expert validation score for the worksheet validation aspects was 90.20%. This indicates that the STEM-oriented worksheet with the PjBL model on the subject of drawing multi-storey house plans (2D) is highly suitable for use in learning. Product revisions were made based on the suggestions and comments from the experts. The suggestions and comments from the validators are as follows:

Before After

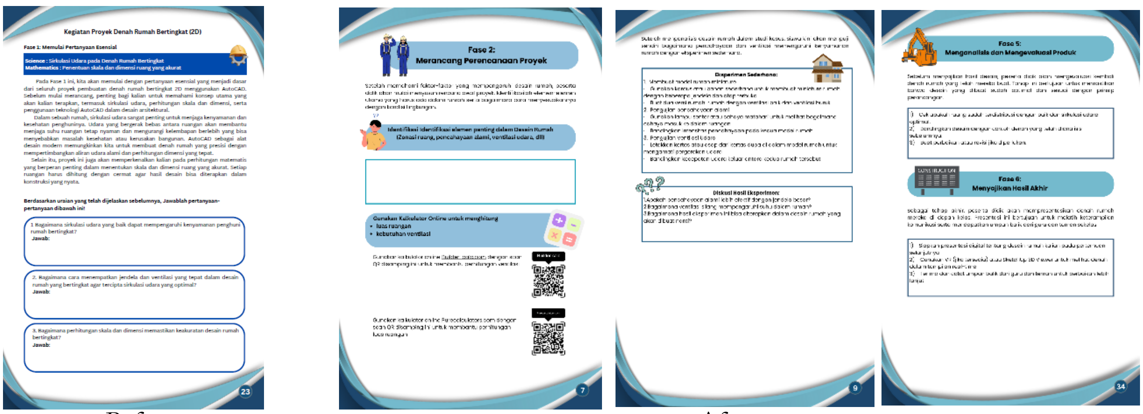
Figure 2. Before and After View of Revision Worksheet Divided into Several Modules

Based on Figure 2, improvements were made according to the validator's suggestion that the WORKSHEET be divided into several smaller modules to make it easier for students to understand. The revised module was divided into four modules, namely introduction to basic concepts of house design and STEM principles in PjbL, use of AutoCAD, design of multi-storey house plans, and project presentation and evaluation.

Before After

Figure 3. Before and After View of Revisions Adding Interactive Activities to worksheet

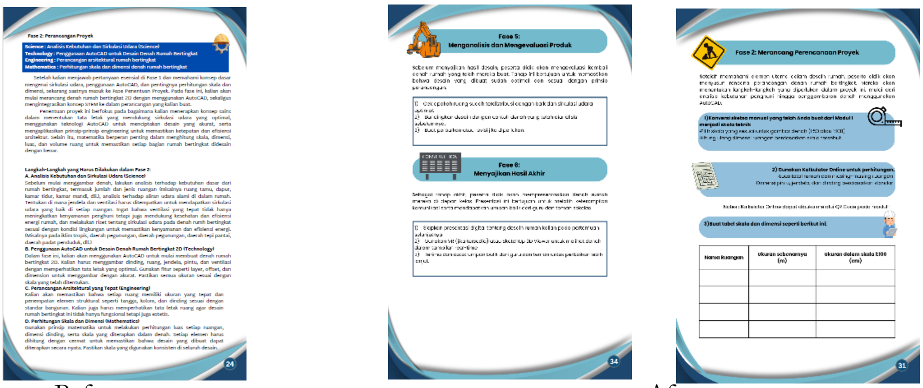
Based on Figure 3, the worksheet in the initial development did not include interactive activities. The validator suggested adding interactive activities such as brainstorming, simulations, and case studies. The revised version shows that the worksheet now includes interactive activities such as brainstorming, where students are divided into small groups to discuss several questions to identify elements in house design, and case studies, which ask students to observe several examples of houses in the surrounding environment. then asked to examine the advantages and disadvantages of each house design, as well as simulation activities where students use AutoCAD with 3D or virtual reality (if available) to see the design results in a more realistic view.



Before After

Figure 4. Before and After Revision View Showing STEM Integration with Technology Based

Figure 4 shows that the worksheet before revision still displays theoretical STEM integration and does not provide practical technology-based experiences. Based on input from validators, strengthening STEM integration is necessary. Therefore, after revision, the WORKSHEET is equipped with STEM-based activities, such as simple experiments in the form of making miniature houses using simple materials to test scientific concepts related to lighting and ventilation for room comfort. In addition, an online calculator is included to help students calculate room area and ventilation, which can be accessed via a QR code so that it can be used anytime as needed, as well as Virtual Reality, a technology that allows students to view designs in 3D from the SketchUp application for a more immersive experienc



Before After

Figure 5. Before and After View of Revisions Adding Process Skills

Figure 5 shows the results of the worksheet improvements after revision. Before revision, the worksheet was still focused on understanding drawing theory and techniques. After revision, the worksheet was enriched with components that emphasized process skills, particularly problem solving, collaboration, creativity, and communication. Problem-solving skills were demonstrated in module 1, where students were given a case study of a house design to analyze its strengths and weaknesses, while in module 3 they were asked to evaluate designs based on the principles of lighting, ventilation, and space circulation. Collaboration skills are integrated into each module, such as brainstorming and case study analysis in module 1, determining scale and project planning in module 2, and developing floor plan designs with AutoCAD and providing mutual feedback in module 3. Creativity is developed through the freedom given to students to design innovative house floor plans, while communication skills are trained through design presentations to teachers and peers to obtain feedback. In addition, the worksheet is equipped with field observation activities, where students observe house designs in their surroundings as a form of strengthening the connection between learning and the real world.

The revised initial product then entered the implementation stage. For the implementation stage, the revised product was applied to students to assess their level of understanding and the practicality of the worksheet that had been developed. The small group trial involved 30 students majoring in DPIB in grade 11. Students were given a questionnaire to assess the readability of the worksheet. Students were directed to study and use the worksheet that had been compiled, then provide feedback through a readability questionnaire that had been provided using a Likert scale. Table 9 shows a summary of the readability test results by students.

Table 9. Results of Student Readability Test

Assesment Aspect	**Percentage (%)**	**Criteria**
Worksheet layout and design	92	Easy to understand
Illustrations facilitate understanding	86,67	Easy to understand
Color and visual elements support focus	86,67	Easy to understand
Font clarity	86	Easy to understand
Multi-story house plan material is attractive	87	Easy to understand
Learning is not boring	86,67	Easy to understand
Increases enthusiasm for learning	90	Easy to understand

STEM material is relevant to everyday life	88,67	Easy to understand
Material is easy to understand	91,33	Easy to understand
Illustrations and examples are relevant and support the learning process	85,33	Easy to understand
Assesment Aspect	**Percentage (%)**	**Criteria**
Suitable for student learning pace	88	Easy to understand
Sentences and paragraphs are clear	90	Easy to understand
Language is simple and appropriate for student	88	Easy to understand
Average	**88,34**	**Easy to understand**

Based on Table 9, the readability test results show that the average readability score of the worksheet is 88.34%. This indicates that students can easily understand and follow the content of the developed worksheet. Thus, this implementation stage can

provide an initial picture of the effectiveness of the worksheet in a real classroom context, even though it does not directly measure its effect on learning outcomes. However, the high readability results provide a strong basis that this learning media can be used to support an active, structured, and contextual learning process in vocational schools.

The final stage of the development process is evaluation. The evaluation in this research was conducted formatively, which aimed to evaluate the feasibility of the worksheet product before it was used more widely in learning. This evaluation does not include summative evaluation, because the focus of this research is on the development and feasibility of learning media, not on measuring the effectiveness or impact on student learning outcomes. The evaluation was carried out in accordance with the revisions obtained previously, including revisions from experts to improve the media to make it better and more feasible to use.

The findings of this study indicate that the STEM-oriented worksheet developed using the Project-Based Learning (PjBL) model demonstrates good overall quality, particularly in terms of content relevance, instructional structure, and media design. The alignment of the worksheet material with curriculum requirements and learning outcomes supports previous studies emphasizing that curriculum-aligned instructional materials contribute to clearer learning direction and improved student engagement in vocational education (Armeth Daud Al Kahar & Anjani Putri, 2023). Although the material content is relatively dense, students were still able to comprehend it effectively due to the systematic organization and guided learning steps, which is consistent with findings by Saprita et al. (2025) regarding the role of structured worksheets in facilitating independent learning (Saprita et al., 2025).

However, expert feedback highlighted the need to simplify technical concepts, particularly in the use of AutoCAD, to accommodate students with limited prior experience. This finding aligns with N et al. (2013), who reported that beginner vocational students often face difficulties when complex software operations are introduced without gradual scaffolding. Simplification and step-by-step guidance are therefore essential to reduce cognitive load and support meaningful learning.

From a media perspective, the visual design of the worksheet—including layout consistency, clarity of illustrations, and appropriate color selection—was found to effectively support the learning process. This result is in line with multimedia learning principles, which suggest that well-designed visual elements can enhance comprehension and focus (Susilo & Suwahyo, 2019). Nevertheless, the need for further analysis regarding the distinction between worksheets, e-books, modules, and textbooks reflects concerns raised by Prastowo (2014), who emphasized that each learning material format serves different pedagogical functions and should be selected based on specific instructional goals (Prastowo, 2014).

The readability test results further indicate that worksheets provide systematic guidance that helps students focus on learning steps when drawing multi-storey house plans. Similar findings were reported by Jazuli et al. (2023), who found that project-based worksheets encourage active participation and sustained attention during practical learning activities. Students' requests for additional practical exercises also reinforce the importance of repeated hands-on practice in developing technical drawing skills, as highlighted in vocational learning studies by Yulinda et al. (2024) (Jazuli et al., 2023; Yulinda et al., 2024).

Moreover, the application of the PjBL model in this worksheet encouraged students to engage actively in real-world projects, thereby improving not only their AutoCAD skills but also higher-order thinking skills such as problem solving, collaboration, and creativity. This supports previous research demonstrating that STEM-oriented PjBL environments are effective in fostering critical thinking and collaborative skills through authentic learning experiences (Jazuli et al., 2023). The inclusion of applied elements such as simple experiments, online calculators, and technology-based simulations further addresses challenges in connecting STEM theory with practice, which has been identified as a persistent issue in vocational education (Susilo & Suwahyo, 2019).

Despite these positive outcomes, the implementation of the worksheet faces several challenges, including limited school facilities, restricted software licenses, and variations in students' technical proficiency. Similar constraints have been reported in vocational education contexts, where infrastructure limitations often affect the effectiveness of technology-integrated learning (Murtinugraha et al., 2021). In addition, the PjBL approach requires extended instructional time and active teacher facilitation, which underscores the importance of teacher training and differentiated instructional strategies to accommodate diverse student abilities.

Overall, the synthesis of these findings suggests that STEM-oriented PjBL worksheets have strong potential to enhance students' conceptual understanding, practical skills, and learning motivation in vocational education. However, sustainable implementation requires institutional support, adequate facilities, and continuous teacher assistance. Future research should expand the implementation of this learning media across different vocational schools, explore the development of interactive digital worksheet formats, and examine the long-term impact of PjBL–STEM integration on students' learning independence, job readiness, and soft skills

Conclusion

This study concludes that the development of a STEM-oriented worksheet based on the Project-Based Learning (PjBL) model constitutes an appropriate instructional solution for supporting 2D architectural drawing learning in the DPIB vocational program. The findings indicate that the integration of PjBL and STEM principles provides structured learning guidance that bridges theoretical understanding and practical application, which is essential in vocational education contexts.

The feasibility and practicality evidence obtained through expert validation and student readability analysis demonstrate that the developed worksheet meets the essential requirements of learning media for vocational schools. More importantly, the synthesis of these findings suggests that the worksheet is capable of facilitating active, contextual, and skill-oriented learning processes, rather than merely functioning as supplementary teaching material. Through project-based activities and technology integration, students are encouraged to engage in problem solving, collaboration, and creative design practices that are relevant to industry-oriented competencies.

Nevertheless, the effectiveness of the worksheet implementation is influenced by external factors, particularly the availability of facilities, access to software, and differences in students' technical proficiency. These conditions imply that instructional innovation through PjBL–STEM worksheets must be accompanied by institutional support, teacher facilitation, and differentiated learning strategies to achieve optimal outcomes.

Based on these conclusions, future research is recommended to employ experimental or quasi-experimental designs to examine the impact of the developed worksheet on learning outcomes more comprehensively. Further development of digital and interactive worksheet formats is also suggested to enhance adaptability to technological advancements and to support broader implementation in vocational education settings.

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