

IMPLEMENTATION OF AUTODESK INVENTOR-ASSISTED DRILL METHOD TO IMPROVE ENGINEERING DRAWING LEARNING OUTCOMES OF VOCATIONAL HIGH SCHOOL STUDENTS

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Abstract

This study aims to describe changes in the mastery of technical drawing learning outcomes on orthogonal projection material after the application of the drill method assisted by Autodesk Inventor. The study used classroom action research with two cycles, each of which included planning, action, observation, and reflection. The subjects of the study were 36 students of class X TKRO 2 at SMK Negeri 1 Kepanjen in the 2024/2025 academic year. Data were obtained through tests, observations, and documentation, then analyzed descriptively. In the pre-cycle, 21 students (58.3%) obtained scores above the Minimum Completion Criteria (KKM) of 75, while 15 students (41.7%) had not exceeded this limit. In the first cycle, the number of students who obtained scores above the Minimum Completion Criteria (KKM) increased from 24 students (66.7%) in the pre-test to 27 students (75.0%) in the post-test. In the second cycle, the number increased from 30 students (83.3%) in the pre-test to 35 students (97.2%) in the post-test. The pre-test and post-test each consisted of 20 questions. The results showed a pattern of descriptive improvement in mastery during the intervention and improved learning. Because individual scores and inferential tests were not available, the findings do not indicate statistical significance or an isolated causal effect.

Keywords: *Autodesk Inventor; Engineering Drawing; Learning Outcomes; Drill Method; Orthogonal Projection.*

A. INTRODUCTION

Technical drawing competency is a crucial component of vocational education in the engineering field because drawings are used to precisely communicate the shape, size, relationships between components, and design of objects. At the vocational high school (SMK) level, students need to understand more than just recognizing symbols or memorizing drawing rules; they need to understand how two-dimensional representations depict three-dimensional objects. Orthogonal projection requires students to connect front, top, and side views and to interpret spatial relationships between parts. Difficulty visualizing three-dimensional objects from two-dimensional drawings can hinder understanding and accuracy of the drawings.

The literature on engineering drawing education positions spatial visualization as a competency related to technical drawing learning and readiness for engineering, design, and digital manufacturing. A systematic review of engineering drawing and spatial visualization skills demonstrates a relationship between engineering drawing learning experiences and spatial skills, while also emphasizing that research at the secondary education level needs to be expanded (Ripoll Chacón, 2025). The review of spatial skills in engineering design also cautions that spatial abilities should not be treated as a substitute for drawing, sketching, and using computer-aided design tools (Gittinger & Wiesche, 2024). Therefore, instruction should provide students with opportunities to practice reading and constructing pictorial representations, rather than simply receiving verbal explanations.

Initial problems reported in class X TKRO 2 SMK Negeri 1 Kepanjen indicate that technical drawing learning tends to be teacher-centered, while the media used is limited to the blackboard and modules. In pre-cycle conditions, 15 of 36 students (41.7%, rounded up to 42%) have not obtained a score above the KKM 75. These data indicate a need to strengthen the practice process and visual support on orthogonal projection material. This figure is the initial condition reported in the research source, not the results of a test that identifies a single causal factor in isolation.

One approach to training procedural skills is the drill method, which involves providing structured and repeated practice accompanied by guidance, answer checking, and feedback. Repeated practice has the potential to help students reinforce basic skills, recognize errors, and improve fluency in completing tasks. A systematic review of retrieval practice shows that information retrieval activities through drills or tests can support learning across various school contexts, especially when well-designed (Agarwal et al., 2021). McDermott (2021) also outlined that retrieval practice can help maintain access to previously learned knowledge. While retrieval practice is not entirely the same as drawing drills, this literature provides a conceptual foundation for considering planned practice in learning.

In orthogonal projection material, exercises can be combined with visualization of three-dimensional objects. Autodesk Inventor was used in this study as a medium to display 3D objects and help students connect the shape of the object with a two-dimensional view. A literature review of computer-aided design (CAD)-based learning in vocational education highlighted the potential of 2D/3D visualization to support drawing accuracy and projection understanding, while emphasizing the need to consider device access, teacher competency, and instructional design (Telaumbanua & Zalukhu, 2026). A study of the development of an augmented reality-assisted engineering drawing module positioned visualization as a support for drawing interpretation at the vocational high school level (Mizian et al., 2025a), while a review of vocational mechanical engineering education identified opportunities and constraints for using AR for technical topics (Sabila et al., 2025). These AR media differ from Autodesk Inventor; their relevance is limited to the same 2D–3D learning issues.

Research on learning technical drawing and design software has developed a technical drawing module for vocational students (Arfianti, 2022), a basic AutoCAD 3D drawing module (Falah & Pramono, 2023), and a manufacturing drawing module for vocational students (Riyadi & Wibowo, 2023). A study at a vocational high school in Surabaya also examined the relationship between technical drawing learning outcomes and software applications and interior design (Lazuadi & Mulyono, 2022). A study on vocational high school students' technological literacy in CAD material placed technology use competency as part of the learning context (Saputra et al., 2025). Meanwhile, research on the drill method in technical drawing has been reported in other vocational high school contexts, including classroom action research focused on difficulties in reading and creating drawings (Sobah et al., 2017). These studies provide relevant context, but do not replace the need to report results in the classroom studied here.

This study employed classroom action research (CAR) with two cycles. In each cycle, planning, action, observation, and reflection were used to improve the learning process. This iterative approach allowed subsequent learning decisions to be based on observations and student achievement in the previous cycle. Guidelines for reporting classroom interventions emphasize the importance of transparently explaining the context, characteristics of the action, procedures, and outcomes to enable readers to assess the applicability of the findings (Hill et al., 2026).

The objectives of this study were (1) to describe the mastery of technical drawing learning outcomes before the application of the drill method; (2) to describe the mastery after cycle I; (3) to describe the mastery after cycle II; and (4) to describe changes in mastery from

pre-cycle to cycle II. The focus of the results was limited to cognitive achievement represented by the number and percentage of students who exceeded the KKM. This study did not test for mean differences, did not report effect sizes, and did not isolate the influence of the drill method from all other factors that could influence learning.

B. LITERATURE REVIEW

1. Structured Drill and Training Methods

The drill method prioritizes practice as the primary activity to help students master specific steps or skills. In technical drawing, exercises can begin with simple geometric objects and then progress to more complex ones. Each exercise should be accompanied by a clear objective, a working example, an opportunity to try, a review of the results, and feedback to help students correct errors. Without variation and feedback, repetition can become a mechanical activity that emphasizes only memorization of procedures. Therefore, the implementation of drills in this study was combined with material explanations, visual demonstrations, discussion of errors, and reflection to enhance learning.

Evidence from systematic reviews of retrieval practice suggests that practicing recalling information can benefit classroom learning outcomes, although outcomes are influenced by the practice design, timing, materials, and form of assessment (Agarwal et al., 2021). McDermott (2021) explains that retrieval practice can help slow forgetting and support the ability to retrieve knowledge. This literature is used for general conceptual support; the study itself did not measure long-term retention.

2. 2D-3D Visualization and CAD Tools

Orthogonal projection represents a three-dimensional object through a two-dimensional view taken from a specific direction. Students need to understand the relationships between the projection planes, not simply copy the final image. Digital visualizations can help concretely demonstrate the object's form, while manual drawing exercises provide opportunities to test their understanding of the view relationships. The two can be combined so that digital media serves as a conceptual support rather than a substitute for reading and drawing skills.

Research on AR for learning technical drawing in vocational students shows that 3D visual media can support drawing comprehension, with outcomes also influenced by students' spatial abilities (Awuor et al., 2024). Fraile et al. (2021) developed a mobile application for learning standard mechanical assembly drawings, while Vergara et al. (2021) integrated technical drawing with industrial radiology through an ICT-based tool. These studies support the relevance of visual media, but their context, media, and design differ from this study. A review of CAD for vocational education also emphasized that the benefits of technology depend on integration with competency objectives, pedagogical support, device access, and task-relevant assessments (Telaumbanua & Zalukhu, 2026). In this study, Autodesk Inventor was used as a visual aid; available data do not separate the contribution of software from that of drill methods.

3. Technical Drawing Learning Outcomes and Competency Completion

Learning outcomes in technical drawing instruction should be understood as outcomes encompassing knowledge of representation rules, the ability to interpret shapes, and the accuracy of applying drawing procedures. In orthogonal projection, students are not only required to recognize the terms front, side, and top views, but also to consistently determine the relationships between the positions, sizes, and shapes of these views. A single view error may indicate that students have not established an adequate mental connection between a three-dimensional object and its two-dimensional representation. Therefore, assessment should refer to explicit learning objectives and use tasks that truly represent these competencies. Merzdorf

et al. (2024), through a systematic review of sketch assessment in engineering education, demonstrated the importance of paying attention to how representation skills are assessed. The implication for learning in vocational schools is that test results should be interpreted based on clear indicators, rather than simply based on the impression that a drawing appears correct or incorrect.

In the context of classroom action research, mastery is a practical indicator for assessing whether learning is moving toward established targets. The percentage of students exceeding the mastery threshold provides insight into the extent of learning success at the classroom level, but it does not reflect the entire distribution of achievement. Two learning stages can have the same mastery percentage even though their average scores and error patterns differ. Conversely, changes in mastery percentage can occur when a number of students move slightly beyond the threshold, without all students experiencing uniform improvement. Therefore, mastery data need to be read in conjunction with the context of the action, observational notes, and teacher reflections. In this study, the available data primarily consisted of the number and percentage of students exceeding the KKM; because individual scores and complete descriptive statistics were not reported, the discussion is limited to changes in class mastery and is not used to infer the magnitude of individual score increases.

4. Feedback, Step-By-Step Practice, and Learning Reflection

Repeated practice is more meaningful when students receive information about the quality of their answers and how to improve them. Feedback can be directed at specific errors, such as mismatched shapes between views, incorrect viewing direction, inconsistent lines, or view placement that does not follow learned projection rules. Feedback that simply states a correct or incorrect answer tends to provide limited information; in contrast, explaining the location of the error and corrective steps helps students connect the work to proper procedures. This principle is relevant to the retrieval practice discussed by Agarwal et al. (2021) and McDermott (2021): opportunities to retrieve knowledge from memory can support learning, but its benefits depend on how the practice is designed and followed up. Therefore, drill in technical drawing learning should not simply be about producing more worksheets, but rather about developing a series of tasks with a purpose, level of difficulty, and a planned correction mechanism.

The sequence of exercises could begin with simple object recognition and visual field identification, continue with matching three-dimensional objects to two-dimensional images, then draw several views based on the provided objects, and conclude with a task that requires students to complete the representation more independently. This sequencing is a principle of instructional design that can help teachers observe the types of difficulties that arise at each stage. If some students still misplace their visual direction, the teacher can return to the demonstration and provide brief practice on that aspect before increasing the complexity of the task. If errors are more prevalent in placement or consistency between views, the exercises can focus on spatial relationships and checking the results. The stepwise approach also provides a basis for reflection in CAR: teachers not only record whether scores improve but also identify areas of learning that need improvement in the next cycle. However, because this research source does not provide detailed logs of individual errors, these examples are positioned as pedagogical implications, rather than as types of errors that have been shown to be dominant among the study participants.

5. CAD as a Visual Aid in Projection Learning

Computer-aided design (CAD) software provides a way to display, rotate, and examine the shape of objects that, in conventional instruction, might only be shown through static images. In orthogonal projection instruction, the display of three-dimensional models can help

teachers demonstrate that each view is a representation of a particular viewing direction, rather than a stand-alone image. CAD tools also allow the same object to be viewed from multiple directions, allowing students to compare visible and hidden changes in shape. However, visual access to three-dimensional models does not automatically translate into students' ability to produce orthogonal drawings independently. Students still need to translate visual information into lines, proportions, positions, and geometric relationships on a two-dimensional plane. A systematic review by Koziar et al. (2025) discussed the role of CAD software in teaching engineering graphics and emphasized that technology needs to be understood as part of the instructional design, not as an end in itself.

Studies on spatial abilities and virtual environments also highlight the importance of learning outcomes for students, as they are influenced by the characteristics of the task and the form of interaction provided by the medium. Gittinger and Wiesche (2024) examined the relationship between spatial abilities and virtual reality, while Suparman et al. (2024) examined CABRI 3D-assisted geometry learning and spatial visualization. While neither context is identical to the use of Autodesk Inventor in vocational high school technical drawing classes, they provide a basis for viewing visualization as a support for spatial reasoning. Awuor et al. (2024) examined the use of mobile augmented reality-based 3D stereograms in technical drawing instruction, while Fraile et al. (2021) developed a learning tool for understanding standard mechanical assembly drawings. A commonality across these literatures is the need to connect visual representations to learning activities that require students to interpret or produce technical representations. Differences in media, participants, and research designs mean these findings cannot be considered direct evidence of the effectiveness of Autodesk Inventor in these studies.

In this study, Autodesk Inventor was positioned as a tool to make three-dimensional shapes easier to observe when the teacher explained orthogonal projection. The learning focus remained on technical drawing competency, while the software served to clarify the relationship between models and elevations. This placement is important because the use of CAD can produce two different orientations: students may be skilled at operating software features, but not necessarily understand technical drawing principles; or students may understand projection principles but require media to see spatial relationships more concretely. To ensure learning objectives remain consistent, software use activities need to be followed by questions or assignments that require students to explain the reasons for selecting elevations, check consistency between representations, and produce drawings according to principles. Luthfansyah et al. (2026) examined digital flipbook media in vocational technical drawing education, while Hidayat and Widiyanti (2025) discussed project-based learning for cognitive and psychomotor CAD competencies. This literature demonstrates that learning media and strategies can be designed in various forms; media choices need to be tailored to competency achievement, student activities, and the assessment methods used.

6. Research Position and Conceptual Framework of Action

Previous studies referenced indicate several pathways for developing technical drawing learning, including the use of CAD, augmented reality, modules, digital media, and project-based approaches. This study takes a more limited focus, namely the application of the drill method supported by Autodesk Inventor visualization to orthogonal projection material in class X TKRO 2. This focus combines two components that have different functions: structured exercises provide opportunities to repeat procedures and receive corrections, while 3D visualization helps clarify the shape of objects that must be translated into two-dimensional views. Thus, the conceptual framework does not assume that software alone improves learning outcomes, but rather that the integration of media with a sequence of exercises and corrective actions has the potential to support student understanding. Koziar et al. (2025) provide context

for the use of CAD in teaching technical graphics; Martín Erro and Nuere Menéndez-Pidal (2024) highlight the development of visual literacy in an engineering graphics course; while Afriardhy et al. (2025) and Sobah et al. (2017) provide context for the use of the drill method in engineering education. Because the contexts of these studies differ, this research does not claim novelty in each component, but in the application of classroom actions that combine drills and Autodesk Inventor visual support in the learning contexts studied.

Operationally, the learning process can be understood through the relationship between demonstration, practice, feedback, and reflection. Demonstration provides an initial model of how objects are observed and projected; practice requires students to apply procedures; feedback helps them identify discrepancies between work results and criteria; and reflection is used by teachers to determine adjustments for the next cycle. This relationship is consistent with the nature of CAR, which utilizes observations to gradually improve actions. The outcome indicators in this study were the number and percentage of students achieving scores above the KKM (Minimum Completion Criteria) of 75 at each stage. These indicators are sufficient to illustrate the development of class mastery as reported, but inadequate to test the mechanisms of change, isolate the influence of Autodesk Inventor, or compare the effectiveness of drills with other methods. This limitation provides an important basis for interpreting the results and formulating recommendations for further research.

7. Digital Media Design and Suitability to Competencies

Digital media in vocational learning should be selected based on a clear instructional function. Visually appealing media may not necessarily help students achieve competency if they simply observe without interpreting or producing. Conversely, simple media can be beneficial when used to direct attention to concepts that are difficult to observe directly. In technical drawing, the primary function of visualization is to help students connect the shape of an object, the direction of observation, and the graphical representation. Therefore, the use of Autodesk Inventor needs to be placed within a sequence of activities that move students from observing the model to reasoning and creating the drawing. Literature on developing technical drawing modules for vocational students, including Arfianti (2022) and Riyadi and Wibowo (2023), demonstrates the importance of structured teaching materials to support learning drawing competencies. Falah and Pramono (2023) also developed a module on basic 3D AutoCAD drawing. These works provide context for the need for technology-assisted learning to be supported by easy-to-follow materials and procedures, not just access to software.

The alignment between media and competency also concerns student access and readiness. CAD software can require computing devices, time to familiarize themselves with the interface, and adequate user guidance. If too much learning time is spent understanding application menus or features, students' attention can be diverted from the purpose of reading and drawing projections. Therefore, teachers need to limit the features used to suit the needs of the material and provide focused demonstrations. Research on vocational students' technological literacy in CAD learning by Saputra et al. (2025) provides context for the importance of paying attention to students' technological readiness. In classroom practice, teachers can prepare the models to be displayed, ensure the necessary viewpoints are available, and provide brief instructions on which parts of the object to observe. This step does not replace drawing practice, but rather reduces the burden of device use so that students' attention is more focused on the concept of projection.

Augmented reality-based media, three-dimensional models, and digital applications also differ in the level of interaction they offer. Some media simply present visual representations, while others allow users to change perspectives or manipulate objects. Gittinger and Wiesche (2024) emphasized the relevance of interaction when reviewing spatial

skills and virtual reality, while Sabila et al. (2025) reviewed augmented reality in vocational mechanical engineering education. This literature does not imply that one technology is always superior to another; its pedagogical value depends on the objectives, task design, and participant characteristics. For orthogonal projection materials, the ability to observe objects from different angles can be a relevant support, but students still need to demonstrate their understanding through self-constructed drawings. Thus, technology is positioned as a support for understanding objects, not as a substitute for targeted cognitive processes.

8. Considerations in Reading Previous Research Evidence

Comparisons with previous research should consider differences in design, subject matter, materials, and outcome indicators. Studies using augmented reality, virtual reality, CAD, modules, or project-based learning can provide a basis for explaining why visual representations and structured activities are relevant for engineering learning. However, results from one medium cannot be directly transferred to another, nor can findings from engineering students or geometry materials be considered identical to orthogonal projection learning in vocational high schools. Martín Erro and Nuere Menéndez-Pidal (2024) position visual literacy as part of engineering graphics learning, while Merzdorf et al. (2024) point out that the assessment of engineering sketches is a field with diverse approaches. These two aspects remind us that learning and outcome measurement need to be considered simultaneously: students need to gain experience interpreting representations, while assessment instruments need to capture the skills being taught.

In classroom action research, the strength of evidence comes primarily from documenting changes in instructional practices and outcomes observed in a specific classroom context. An increase in completion rates after an action can justify maintaining or refining an instructional strategy, but it does not, in itself, prove a causal relationship in isolation. Without a comparison group, individual scores, and controls for other factors, change could be attributed to several concurrent elements, such as teacher explanations, repeated practice, use of visualizations, test-taking experiences, or adjustments to subsequent cycles. Therefore, this study uses descriptive language and positions the results as contextual evidence for instructional improvement. Future research could add a visual analytic rubric, error type analysis, instrument reliability testing, and a comparison design to more robustly assess the contribution of each component. These considerations ensure practical recommendations remain useful without overpowering the reported data.

C. METHOD

This study employed a classroom action research (CAR) design implemented in two cycles. Each cycle included planning, action, observation, and reflection. The goal of this design was to improve classroom learning practices through iterative action and adjustment, rather than estimating causal effects with a control group. The CAR framework was used to identify learning needs, implement a drill method assisted by Autodesk Inventor, observe the learning process, and then use the reflection results to refine the next cycle.

The research was conducted at SMK Negeri 1 Kepanjen in the 2024/2025 academic year. The research subjects were 36 students of class X TKRO 2. The class identity was written consistently as X TKRO 2 following the dominant mention in the presentation of results and learning tools in the sources.

The learning activities focused on orthogonal projection material. The learning implementation plan included a time allocation of 2 x 50 minutes, the use of laptops, mobile phones, LCD/projectors, learning videos, Autodesk Inventor, internet access, and Google Forms. In cycle I, the teacher conveyed the objectives, introduced the concept of orthogonal projection, displayed visuals of three-dimensional objects through Autodesk Inventor, used

videos/tutorials, provided exercises, and discussed any errors that arose. Two colleagues acted as observers. Reflections on cycle I were used to adjust the plan and instruments in cycle II, then the corrected actions were followed by observation and evaluation.

Data were collected through tests, observations, and documentation. The tests were used to describe students' cognitive understanding of orthogonal projection. The source states that the pre-test and post-test each consisted of 20 questions. The similarity in the number of questions does not necessarily indicate that the two tests have equivalent difficulty levels or psychometric characteristics. The source does not provide complete specifications of the grid, equivalence of the test format, rubric, or validity and reliability coefficients. Observations were conducted during the lesson to record the implementation of the drill stages and student responses. Documentation includes photos of activities, lesson plans, and a summary of grades. The instrument was reportedly reviewed by a content expert, but validation results were not reported.

Data analysis was conducted using quantitative descriptive analysis. Test data were summarized as the frequency of students scoring above the minimum completeness criterion (KKM) of 75 and the frequency of students scoring ≤ 75 at each stage. Frequencies were converted to percentages by dividing the number of students in the corresponding category by the number of subjects ($N = 36$), then multiplying by 100%. Changes between stages are presented as percentage differences (percentage points), not as relative percentage increases. Because individual scores, means, standard deviations, and inferential test results were not available in verifiable sources, the article did not recalculate statistical significance, gain scores, or effect sizes. Thus, the analysis shows descriptive changes in class completion and does not isolate the causal influence of the drill method from other learning components.

Table 1. Data Analysis Formulas and Procedures

Indicator	Formula	Information
Percentage of categories	$P = (f / N) \times 100\%$	P = percentage of category; f = number of students in category; N = total number of students (36).
Percentage difference between stages	$\Delta P = P_2 - P_1$	ΔP = change in percentage points; P_2 = percentage in the subsequent stage; P_1 = percentage in the previous stage.
Frequency difference	$\Delta f = f_2 - f_1$	Δf = change in the number of students who obtained a score >75 ; f_2 and f_1 are the frequencies at the two stages being compared.

Example calculation: in the post-test cycle II, 35 out of 36 students obtained a score >75 . The percentage is $(35/36) \times 100\% = 97.2\%$. Compared to the post-test cycle I ($27/36 = 75.0\%$), the change in completeness is $97.2 - 75.0 = 22.2$ percentage points, or an increase of 8 students. This calculation uses the frequency reported by the source and not individual score data.

D. RESULTS AND DISCUSSION

1. Pre-Cycle Completion Results

In the pre-cycle conditions, technical drawing learning was reported to still tend to be teacher-centered and use limited media. Of the 36 students, 21 students (58.3%) exceeded the KKM of 75, while 15 students (41.7%) did not. This condition became the basis for implementing the action. The pre-cycle data only provided the number of students in two completion categories; individual scores and value distributions were not presented, so the variation in achievement within each category could not be explained.

Results of cycle I

In the pre-test of cycle I, 24 students (66.7%) exceeded the KKM and 12 students (33.3%) did not exceed the KKM. After the learning action using the drill method with the help of Autodesk Inventor visuals, the post-test results showed that 27 students (75.0%) exceeded the KKM and 9 students (25.0%) did not exceed the KKM. Thus, the number of students who exceeded the KKM increased by three people, equivalent to an increase of 8.3 percentage points between the pre-test and post-test of cycle I. This change is a descriptive picture at the class level and not the result of a significance test.

Results of cycle II

In the cycle II pre-test, 30 students (83.3%) exceeded the Minimum Competency (KKM) and 6 students (16.7%) did not. After adjusting the learning cycle II based on the reflection of cycle I, the post-test results showed that 35 students (97.2%) exceeded the Minimum Competency (KKM) and one student (2.8%) did not. The number of students exceeding the Minimum Competency (KKM) increased by five people, or 13.9 percentage points, between the cycle II pre-test and post-test. This final achievement exceeds the class success indicator of 75% mentioned in the source.

Table 2. Completion of technical drawing learning outcomes at each stage

Measurement stage	Value > KKM (n)	Value ≤ KKM (n)	Value > KKM (%)	Value ≤ KKM (%)
Pre-cycle	21	15	58.3	41.7
Pre-test cycle I	24	12	66.7	33.3
Post-test cycle I	27	9	75.0	25.0
Pre-test cycle II	30	6	83.3	16.7
Post-test cycle II	35	1	97.2	2.8

Note: n = 36; KKM = 75. Percentages are rounded to one decimal place.

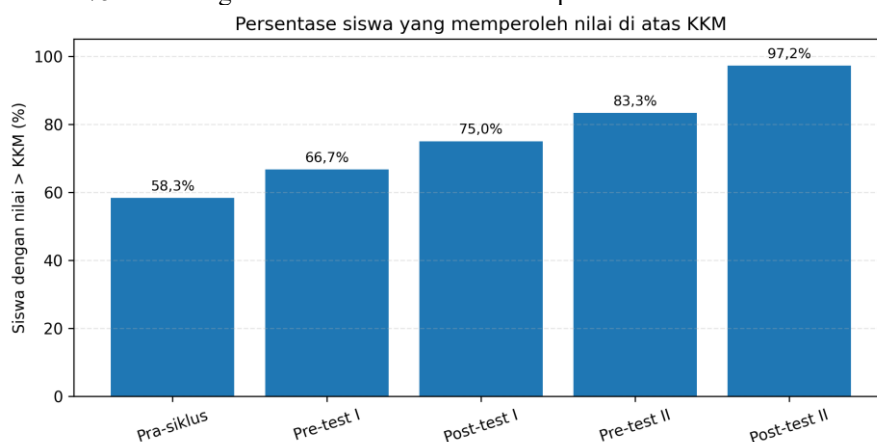


Figure 1. Percentage of students who exceeded the KKM at each stage

Figure 1 reproduces the reported completion rates, not the reconstructed individual scores. The pre-test phase of cycle II represents a subsequent measurement of cycle I, so the patterns between phases reflect the development of classroom processes. Without additional information about instrument equivalence, these phases should not be treated as fully equivalent measurements for estimating statistical effects.

A systematic review of engineering graphics learning indicates that CAD and BIM tools can enhance visualization, analysis, and revision processes, but the learning impact remains dependent on how the technology is integrated into the curriculum and student activities (Koziar et al., 2025). This finding is relevant to the use of Autodesk Inventor in this study: the software helps visualize three-dimensional objects, but it does not replace the need for students to actively read, draw, and examine orthogonal views. Because the study design did not

separate the action components, the results cannot be attributed solely to the software or solely to the drill.

The relationship between spatial visualization and technical drawing learning also needs to be interpreted with caution. Ripoll Chacón's (2025) systematic review found a reciprocal relationship between technical drawing experience and spatial visualization skills, but highlighted the limited research specifically in secondary education. Studies on spatial skills in engineering design also caution that spatial abilities should not replace mastery of practical skills such as sketching and using CAD (Gittinger & Wiesche, 2024). Therefore, the use of 3D models in this learning is best viewed as a support for understanding representations, not as evidence that students' spatial abilities are improving—this variable was not directly measured.

Research on the development of visual literacy through engineering graphics courses indicates that curricula generally emphasize graphic representation and technical communication, while the cognitive aspects of visualization may receive less attention (Martín Erro & Nuere Menéndez-Pidal, 2024). The implication for vocational high school contexts is the need to link object demonstrations with questions that require students to explain the rationale for their chosen appearance, identify relationships between planes, and generate their own drawings. This study reports the use of demonstrations and exercises, but does not provide a detailed rubric to measure these visual reasoning processes.

Engineering drawing assessment needs to have clear criteria. A systematic review by Merzdorf et al. (2024) found significant variation in the assessment of engineering sketches and identified accuracy, perspective, line quality, annotation, and aesthetics as frequently used criteria. Studies on AI-assisted engineering drawing analysis also emphasize the importance of rubrics and consistency of assessment when drawings are assessed against technical standards (Munguia, 2026). Although this study used cognitive tests rather than product drawing assessments, the literature reinforces the need to report grids, definitions of completeness, and evidence of instrument quality in more detail in future research.

More comparable evidence for vocational education comes from studies of digital media and project-based approaches in learning engineering drawing/CAD. Luthfansyah et al. (2026) reported improved scores in digital flipbook-assisted engineering drawing learning, while Hidayat and Widiyanti (2025) examined cognitive and psychomotor competencies in project-based CAD learning. Afriardhy et al. (2025) also reported higher learning outcomes in groups using the drill method in basic vocational program subjects. These three studies differed in design, participants, materials, and treatment; therefore, their results provide context supporting the relevance of developing drill strategies and media, rather than direct numerical comparisons for this CAR.

Regular practice and testing can serve as opportunities for students to revisit learned knowledge. Agarwal et al.'s (2021) systematic review indicates that retrieval practice is often beneficial in school contexts, and studies of retrieval practice also support the importance of repeated opportunities to revisit knowledge. However, tests were used in this study to measure achievement at each stage, and the sources did not specify the time intervals, item equivalence, or retrieval practice settings. Therefore, this literature supports the general rationale for using repeated practice and assessment, but does not demonstrate that retrieval practice mechanisms specifically cause the observed improvements in mastery.

A study of CABRI-assisted 3D geometry visualization also found that the impact of 3D-assisted learning on spatial visualization needs to be interpreted based on the characteristics of the intervention and the study context (Suparman et al., 2024). Furthermore, a review of CAD in vocational education by Telaumbanua and Zalukhu (2026) emphasized that drawing accuracy and projection understanding can be supported by 2D/3D visualization, provided there is adequate instructional design, teacher competence, and technology access.

Collectively, these sources support the feasibility of using visual media as part of technical drawing instruction, but do not eliminate the limitations of inferences from single-class action research.

The main finding of the study was a descriptive increase in the number of students exceeding the Minimum Competency (KKM) during the two cycles of action. Completion was recorded at 58.3% in the pre-cycle, 75.0% in the post-test of cycle I, and 97.2% in the post-test of cycle II. In each cycle, the proportion of students exceeding the KKM also increased from pre-test to post-test: 66.7% to 75.0% in cycle I and 83.3% to 97.2% in cycle II. This pattern is consistent with the practical goal of CAR, which is to monitor changes in class achievement while making adjustments to learning practices.

Pedagogically, the drill method can provide space for repeated practice in skills that require procedural precision. In orthogonal projection, students need to establish relationships between front, top, and side views and identify how 3D shapes are represented on a 2D plane. Step-by-step practice, discussion of errors, and opportunities for retry can help teachers identify concepts that students may not yet grasp. Studies on retrieval practice support the use of knowledge retrieval drills in learning, although the cognitive drills examined in the literature are not identical to technical drawing drills (Agarwal et al., 2021; McDermott, 2021). The results of this study therefore provide contextual support for planned practice, not verification of specific cognitive mechanisms.

Autodesk Inventor's role in this activity is primarily as a visual aid. Displaying three-dimensional objects allows teachers to associate the object's shape with a two-dimensional projection before students practice creating or interpreting drawings. Recent literature on CAD for vocational education suggests that 2D/3D visualization can aid technical drawing learning, but its benefits depend on integration with competency objectives and teaching strategies (Telaumbanua & Zalukhu, 2026). Research on the development of an augmented reality-assisted technical drawing module also positions object visualization as a support for drawing interpretation at the vocational high school level (Mizian et al., 2025a). However, the medium used here is Autodesk Inventor, not AR; the study serves only as a conceptual comparison, not direct evidence that the two media are equivalent.

Research on CAD module development for vocational students also highlights the importance of providing instructional materials that support engineering drawing competencies. Arfianti (2022) developed an engineering drawing module for construction program students, Falah and Pramono (2023) developed a basic 3D AutoCAD drawing module, and Riyadi and Wibowo (2023) developed a manufacturing drawing module for vocational students. These studies focused on the development and feasibility of instructional materials, while this study focuses on changes in mastery through CAR. The similarity of topics suggests the relevance of visual support and exercises to engineering drawing competencies, but the research designs and outcomes differ, making the results indirect comparisons.

Research on the drill method in technical drawing in other schools provides context that structured exercises have been used to address students' difficulties reading and drawing (Sobah et al., 2017). However, similar patterns do not prove that the drill method always produces the same impact in all classes. Differences in student characteristics, materials, number of exercises, duration of activities, media, and assessment criteria can influence the results. Because this study involved only one class, the findings are more appropriately viewed as evidence of local practices that can inform teacher reflection, rather than estimates of effects that can be generalized to all vocational schools.

Improvements in cycle II were made following reflections on cycle I, and the percentage of completion in the post-test of cycle II was higher than in cycle I. In CAR, this pattern may reflect the benefits of learning adjustments, but several components changed sequentially: students received additional learning, practiced more, took follow-up tests, and

studied with an improved lesson plan. Without a comparison group and individual data, the separate contributions of drills, Autodesk Inventor visualization, additional study time, test-taking experience, and learning adjustments cannot be determined. Guidelines for reporting classroom interventions emphasize the importance of describing the action components and context in detail so that interpretation of results does not go beyond the research design (Hill et al., 2026).

Changes in completion rates are not the same as changes in mean scores. Students can move beyond the KKM threshold without knowing the extent of the score change, and two classes with the same percentage of completion rates can have different score distributions. Because individual and mean data are not available in the auditable summary, this study can only state the increase in the number of students exceeding the KKM. The word "significant" in some source descriptions is not retained as a statistical term, as no inferential tests, p-values, confidence intervals, or effect sizes are reported. The correct interpretation is that completion rates increased descriptively over the two cycles.

Practically, teachers can start with simple geometric shapes, present 3D visuals, ask students to identify orthogonal views, and then provide independent practice and specific feedback. Afterward, students can be asked to redraw the figures manually to check whether they understand the spatial relationships, rather than simply following the software's display. This strategy is consistent with the idea that digital tools should be integrated with directed learning activities and competency assessments, rather than simply used as presentations. However, the effectiveness of each sequence of activities has not been tested separately in this study.

E. CONCLUSION

Classroom action research on 36 students of class X TKRO 2 SMK Negeri 1 Kepanjen showed an increase in descriptive completeness of technical drawing learning outcomes on orthogonal projection material during two cycles of implementing the Autodesk Inventor-assisted drill method. In the pre-cycle, 21 students (58.3%) obtained scores above the KKM of 75. In cycle I, the number of students who obtained scores above the KKM increased from 24 students (66.7%) in the pre-test to 27 students (75.0%) in the post-test. In cycle II, the number increased from 30 students (83.3%) in the pre-test to 35 students (97.2%) in the post-test.

The findings indicate that class completion rates increased following the actions and instructional improvements in the subsequent cycle. The final results of cycle II exceeded the 75% completion indicator used in the source. However, because the available analysis is descriptive, this study does not prove statistical significance or isolate the causal effects of the drill method from visual supports, additional practice, testing experience, and instructional adjustments. Conclusions are limited to the classes, materials, and data reported.

Practically, drills incorporating Autodesk Inventor visualizations, step-by-step exercises, error discussions, and reflection can be considered as orthogonal projection learning strategies. Applications to other classes should be accompanied by contextual adjustments and evaluation. Future research should present more comprehensive individual score data, instrument details, evidence of validity and reliability, and ethical procedures.

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