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Enhancing Efficiency and Creativity in Mechanical Drafting: A Comparative Study of General-Purpose CAD Versus Specialized Toolsets

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Abstract: Computer-Aided Design (CAD) plays a critical role in modern engineering education by supporting technical accuracy and fostering innovation in design. This study compares the performance of beginner CAD users employing general-purpose AutoCAD 2025 with those using the specialized AutoCAD Mechanical 2025. Fifty undergraduate mechanical engineering students, all with less than one year of CAD experience and no prior exposure to AutoCAD Mechanical, were randomly assigned to complete six mechanical drawing tasks using one of the two software environments. Efficiency was evaluated through command usage, frequency, and task completion time, while creativity was assessed using a rubric covering originality, functionality, tool proficiency, and graphical quality. Results show that AutoCAD Mechanical significantly improved workflow efficiency, reducing task execution time by approximately 50%. Creativity scores were also notably higher among users of AutoCAD Mechanical, particularly in functionality and tool usage. These gains are attributed to automation features such as parametric constraints, standard part libraries, and automated dimensioning, which lower cognitive load and support iterative design. The findings suggest that integrating specialized CAD tools into engineering curricula can enhance both technical and creative outcomes. Limitations and future research directions include longitudinal studies, diverse user populations, and exploration of student feedback and tool adaptation.

Keywords: general-purpose drafting software; specialized tools; CAD automation; mechanical drafting; engineering creativity

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1. Introduction

Computer-Aided Design (CAD) has become an essential tool in engineering education and professional practice, significantly shaping mechanical design, drafting, and product development [1]. As CAD technology advances, modern software integrates automation [2], parametric modeling [3], and artificial intelligence-driven features [4,5], enhancing both design efficiency and creative exploration [6]. Among widely used CAD software, AutoCAD serves as a general-purpose drafting tool, while AutoCAD Mechanical extends functionality with automated dimensioning, parametric components, and standardized mechanical part libraries, optimizing workflows in engineering applications [7]. Given the increasing reliance on CAD in industry, research has focused on how different software configurations impact learning, efficiency, and creativity in engineering education [8].

CAD tool efficiency is often evaluated in terms of workflow optimization and cognitive load reduction. Studies indicate that manual drafting in CAD software leads to longer

task completion times and higher cognitive demands, particularly for beginners navigating complex command structures [9]. In contrast, automation features in CAD, such as those in AutoCAD Mechanical, help reduce design complexity, allowing users to focus on problem-solving and iterative design. These tools enhance accuracy and efficiency, making AutoCAD Mechanical particularly beneficial for engineering students and novice designers by enabling faster iteration cycles and improved visualization of mechanical components.

While efficiency is critical, creativity in design education is equally important. CAD tools should not only streamline workflows but also raise innovation and creative problem-solving [10]. Research suggests that incorporating creativity-focused methodologies into CAD-based learning enables students to develop diverse design solutions and adapt to real-world engineering challenges [11]. For instance, integrating marketing strategies in industrial drawing courses enhances creative thinking and ideation skills [12]. Likewise, 3D CAD modeling in STEM education has been shown to improve spatial reasoning, design flexibility, and conceptual understanding—key skills for engineering problem-solving [13].

A fundamental aspect of CAD education is transitioning from freehand sketching to digital modeling [14]. Some studies emphasize that sketching helps reduce cognitive inhibition in novice designers, enabling more fluid ideation before transitioning to digital models [15]. Additionally, instructional approaches significantly influence students' ability to use CAD effectively, highlighting the educator's role in fostering creativity within engineering design courses [8]. Active learning experiences and interdisciplinary exposure further enhance innovation and problem-solving skills [16], preparing students to tackle complex engineering challenges [17].

As CAD tools continue to evolve, research increasingly explores their role in conceptual design and knowledge representation [6]. Emerging challenges and developments in CAD emphasize the need for intuitive interfaces, automated design suggestions, and real-time collaboration features [7]. Structured frameworks have also been proposed to assess creativity and innovation in CAD-based projects, offering quantitative methods for evaluating different design strategies [18]. The continued development of intelligent CAD environments is reshaping how students and professionals interact with design software, balancing efficiency with creative freedom [19].

Beyond traditional CAD learning, immersive technologies such as virtual and augmented reality are transforming engineering education [20]. Studies suggest that natural and virtual environments significantly enhance creative performance in CAD-based design by improving spatial reasoning and ideation processes [21]. Research indicates that virtual environments advance unconventional design exploration [20], while structured sketching and visualization interventions help reduce inhibition in novice designers [15]. Similarly, 3D descriptive geometry methodologies reinforce the role of immersive learning in problem-solving and creativity [22].

Despite extensive research on CAD tools and creativity, empirical studies quantifying the impact of automation on both efficiency and creative performance remain limited. While CAD research has extensively examined usability and functionality, fewer studies have rigorously measured how automation influences user performance, learning outcomes, and creative thinking in CAD environments [23]. This research gap highlights the need for quantitative evaluations of automated CAD tools, particularly in assessing their impact on student workflows. Additionally, developing teaching approaches that balance technical competence with creativity is crucial, given the diversity of CAD education methodologies among instructors [21]. Creativity assessment frameworks for engineering students have been introduced to quantify the impact of CAD training on design thinking and product innovation, offering structured evaluations of CAD's role in promoting creative problem-solving [19].

This study compares the performance of beginner CAD users in AutoCAD and AutoCAD Mechanical, focusing on command usage, task completion time, and creative design output. By analyzing command execution logs, tool usage frequency, and workflow improvements, the research provides a quantitative assessment of workflow optimization in AutoCAD Mechanical. Furthermore, through rubric-based evaluation—commonly used in CAD-related studies [24,25]—the study examines how automation influences creativity and problem-solving in mechanical drafting.

This study addresses a critical gap in the literature concerning the combined impact of specialized CAD toolsets on both user efficiency and creative performance. Although prior research has examined aspects of CAD usability and automation, few works have quantitatively compared general-purpose and specialized drafting tools in terms of their influence on workflow optimization and design innovation. By analyzing command usage, task duration, and creative outcomes using a structured rubric, this work offers a comprehensive evaluation of how automation-integrated environments affect novice users. The main contribution lies in demonstrating that specialized CAD software not only enhances operational efficiency but also fosters more innovative and functional design solutions. Distinct from previous studies that typically focus on technical or educational outcomes in isolation, this research provides an integrated perspective that highlights the pedagogical and practical advantages of automation-driven tools in mechanical design training.

The paper follows a systematic structure: Section 2 details the methodology for evaluating efficiency and creativity, including the experimental setup and assessment criteria. Section 3 presents results, comparing AutoCAD and AutoCAD Mechanical in command usage, workflow efficiency, and creativity scores. Section 4 discusses the implications of the findings for engineering education and professional design workflows. Finally, Section 5 summarizes key insights and outlines future research directions in CAD innovation.

2. Materials and Methods

2.1. Evaluation of the Efficiency of AutoCAD and AutoCAD Mechanical

The evaluation of the efficiency of AutoCAD and AutoCAD Mechanical for undergraduate mechanical engineering students being beginner CAD users, was performed by analyzing command usage, access frequency, and task completion time. To conduct the study, fifty students, beginner CAD users with less than one year of experience, were selected. All participants were undergraduate mechanical engineering students enrolled in the same academic program and had completed a single introductory CAD module using standard AutoCAD. They were classified as beginners based on having less than one year of CAD experience and no prior exposure to AutoCAD Mechanical. This status was confirmed through course records and self-reporting. Although no formal pre-test was conducted to quantify initial skill levels, the shared curricular background and recent uniform training ensured a comparable baseline of CAD proficiency across all participants. To avoid bias, the fifty students were randomly assigned into two groups of twenty-five. Group 1 only drew with AutoCAD 2025, while group 2 drew exclusively with AutoCAD Mechanical 2025. In both cases, the student versions of the software were used. Each participant completed six predefined mechanical drawing tasks in computers with the following specifications: Intel® Core™ i5-12400F, 2500 MHz, RAM memory 16.0 GB and graphic card NVIDIA GeForce GT 1030. The drawing tasks included screw connections, shaft drawings, hidden geometry creation, enlarged view detailing, mechanical symbols and notes, and balloons and parts lists. The selection of these tasks was based on their relevance in mechanical drafting and their potential for efficiency improvements when using AutoCAD Mechanical. A short description of each one is provided in the next Section 2.1.1.

2.1.1. Predefined Drawing Tasks

- Screw connection.

Figure 1 represents a technical drawing of a flanged screw connection, depicted through orthographic views, including a top view and sectional view (A-A). It follows standard engineering drawing conventions to illustrate the assembly, fastening, and internal structure of the connection. The top view (left) contains a circular flange geometry with four equally positioned bolt holes for securing the assembly. There is bored hole or shaft clearance, for fluid flow, alignment, or mechanical coupling. The bolted joint assembly is detailed in the sectional view A-A, including hexagonal bolts, washers, and nuts securing the flange.

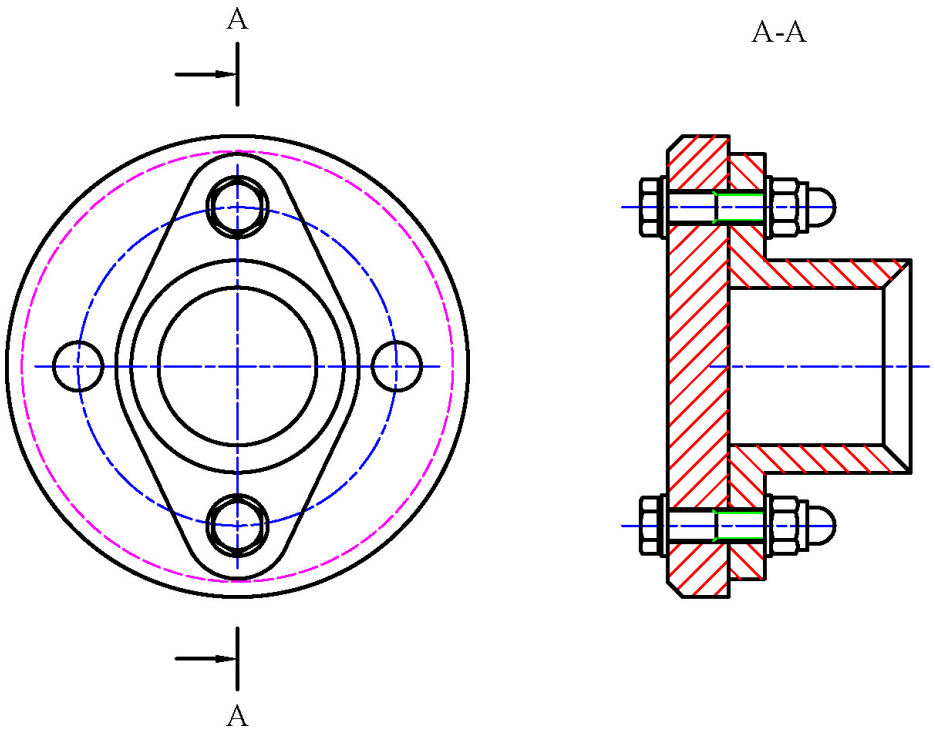


Figure 1. Screw connection.

This flange connection drawing serves a critical role in piping systems, mechanical assemblies, and structural supports. Designed with a bolted joint configuration, it ensures secure fastening while minimizing the risk of loosening under mechanical loads. The sectional view provides a detailed representation of internal features, offering machinists and engineers a clear understanding of otherwise hidden components essential for precise fabrication and assembly.

- Shaft assembly.

This task involves the creation of an engineering drawing of a shaft assembly, represented through two orthographic projections: a side view and a front view (Figure 2). The drawing follows established technical drafting standards, incorporating centerlines and sectional details to enhance clarity and precision.

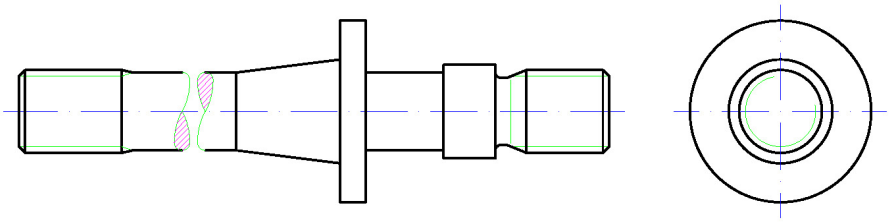


Figure 2. Shaft assembly.

Shaft drawings are essential in the design and manufacturing of rotary machinery, transmission systems, and mechanical couplings. The inclusion of sectional views and threading details highlights key interfaces where the shaft interacts with other mechanical components. By using orthographic projection, sectional views, and centerlines, the drawing ensures accuracy in fabrication and assembly, allowing for seamless integration within complex mechanical systems.

- Hidden geometry.

Figure 3 represents a detailed top view of a mechanical flange assembly, with extensive use of hidden lines and centerline references. It depicts a flanged connection with bolted holes, which could be part of a pipe fitting, rotary machine, or structural component. Hidden line drawings like this are essential in mechanical and structural engineering, providing detailed internal geometries without requiring a sectional view.

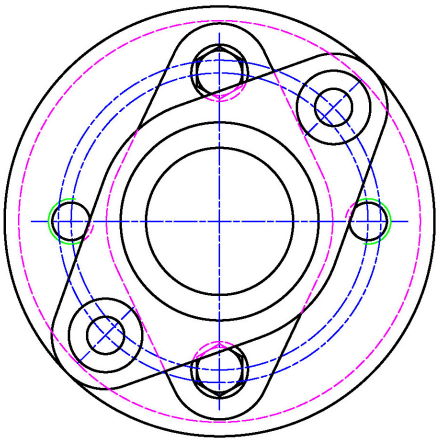


Figure 3. Hidden geometry.

This type of drawing is common in flange couplings, rotary equipment housings, and pressure vessel connections. The inclusion of hidden lines and reference geometry focuses on precise machining, assembly, and mechanical fit.

- Enlarged view.

This case presents a sectional view with an enlarged detail of a flanged mechanical component (Figure 4). The illustration consists of two distinct views. The enlarged sectional view on the left, labeled “B (2:1)”, is displayed at twice the original size to enhance the visibility of intricate details. The main sectional view on the right, labeled “B”, provides the full cross-sectional profile of the component. A green circular highlight marks the specific area of focus for the enlarged view, ensuring a detailed examination of critical features.

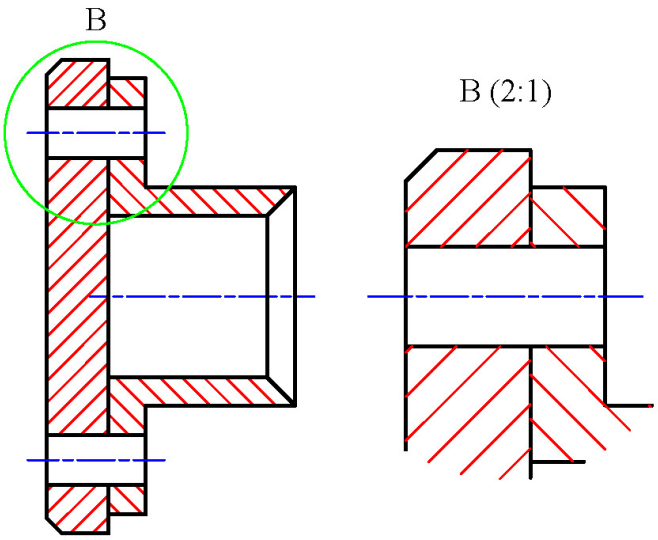


Figure 4. Enlarged view.

Enlarged views play a crucial role in technical drawings, as they emphasize fine details, machining tolerances, and precision features that might not be clearly visible at the standard scale. They are particularly valuable for components such as flanges, couplings, rotating machinery, and precision mechanical parts, where accurate detailing is essential for manufacturing and assembly.

- Dimensioned and annotated machined shaft.

Figure 5 presents a fully dimensioned and annotated technical drawing of a machined shaft, incorporating geometric dimensioning and tolerancing, machining specifications, and manufacturing details. Adhering to established engineering drawing standards, this illustration ensures manufacturability, precision, and quality control. The main view provides a longitudinal profile of the shaft, detailing key dimensions, machining features, and specified tolerances. On the right, a sectional view (C-C) reveals internal cross-sectional features, employing hatching to distinguish solid material.

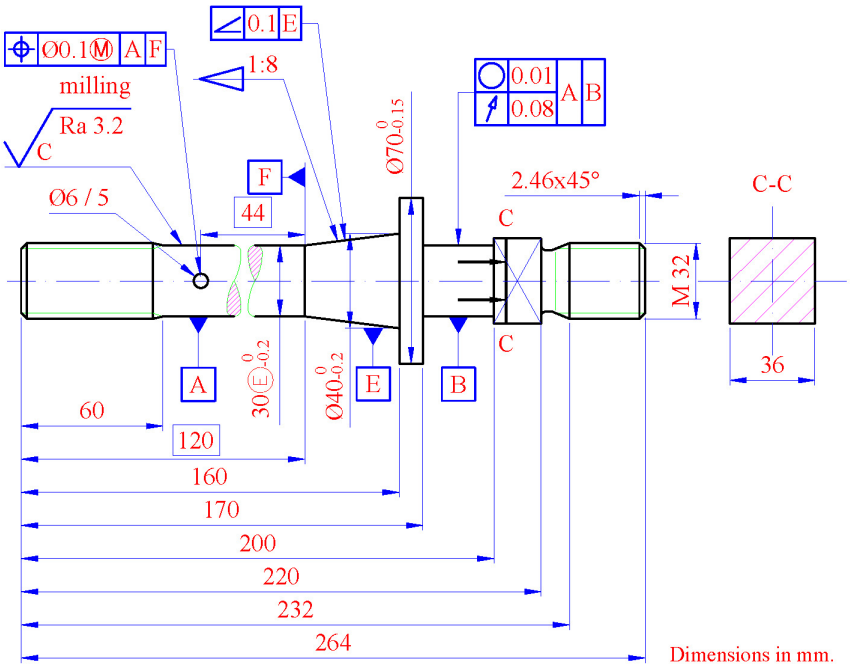
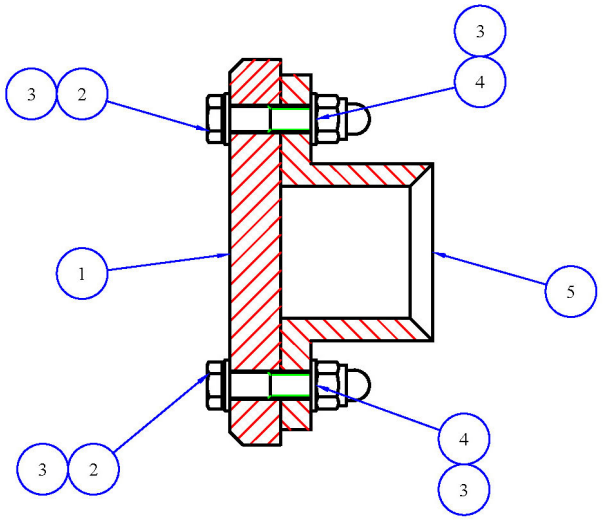


Figure 5. Machined shaft.

Comprehensive technical drawings of this nature play a crucial role in precision machining, mechanical design, and quality assurance. The integration of geometric dimensioning and tolerancing, surface roughness specifications, and machining notes guarantees manufacturability and performance consistency. Furthermore, this drawing serves as an essential reference for computer numerical control programming, part inspection, and assembly integration—particularly in mechanical and automotive engineering. The use of layering, color coding, and sectional representation enhances clarity, facilitating accurate interpretation within manufacturing documentation.

- Adding balloons and parts list.

A detailed sectional assembly drawing is presented in Figure 6, featuring an annotated bill of materials (BOM) and balloon callouts for component identification. This technical illustration adheres to engineering drawing standards for mechanical assembly documentation, with a particular focus on fastening systems and part differentiation. The primary component depicted is a flange assembly with bolted connections, incorporating bolts, nuts, and washers. Balloon callouts, numbered 1 through 5, correspond to individual components listed in the BOM, providing clear reference points for manufacturing and assembly processes. These callouts are strategically placed to indicate specific physical locations within the assembly, ensuring precision and ease of interpretation. Positioned at the bottom of the drawing, the BOM is a structured parts list that includes the item number, which matches the balloon callouts, the quantity of each component used in the assembly, a description identifying the type of component, the applicable standard such as ISO or DIN specifications, and the material, such as stainless steel or cast iron.



Item	Qty	Description	Standard	Material
5	1	Cylinder		Cast Iron
4	2	Cap nut	DIN 986 - M5	Stainless Steel A2
3	4	Washer	ISO 7091 - 5 - 100 HV	Stainless Steel A2
2	2	Hex head bolt	ISO 4014 - M5 x 25	Stainless Steel A2
1	1	Body		Cast Iron

Figure 6. Balloons and parts list.

Balloon callouts and BOMs are fundamental in technical drawings for manufacturing, procurement, and assembly. Their inclusion ensures standardization, compatibility, and ease of part replacement. This drawing methodology is particularly valuable in mechanical assemblies, piping systems, and industrial equipment, where clarity and precision are critical for successful fabrication and integration.

2.1.2. Analyzing Command Usage, Access Frequency, and Task Completion Time

The methodology for collecting command usage and access frequency involved enabling the logging function at the start of each task by entering LOGFILEON in the command line. This function allowed for the recording of every command executed throughout the task. Upon task completion, the logging session was terminated using LOGFILEOFF, which saved all recorded command entries in a *.log file. This process was systematically applied to each task in both AutoCAD and AutoCAD Mechanical, ensuring a direct and consistent comparison of user behavior across both software environments. To eliminate potential biases, all log files were collected anonymously. These *.log files were analyzed to extract two key metrics: the number of unique commands used and the total frequency of command executions. This analysis was conducted through a combination of manual review and automated scripts that parsed the log data. For instance, if a log file contained commands such as LINE, CIRCLE, TRIM, and DIMLINEAR, with multiple instances of LINE and TRIM, the analysis would determine both the total count of unique commands and the frequency of their usage.

Task completion times were measured using a stopwatch-based approach, supplemented by automation scripts that logged task start and end times. The recorded times were then processed to compute the average task duration for both AutoCAD and AutoCAD Mechanical. To evaluate the statistical significance of any observed differences, paired *t*-tests were conducted. The null hypothesis assumed no difference in efficiency between the two software environments, while the alternative hypothesis proposed that AutoCAD Mechanical significantly reduced task completion time and command repetition. The results were deemed statistically significant if the *p*-value was less than 0.05.

It is important to note that no formal optimization algorithms or dedicated optimization software were used in this study. The evaluation of efficiency was based exclusively on empirical metrics, including the number and frequency of command executions and task completion times. Statistical significance of observed differences between the AutoCAD and AutoCAD Mechanical groups was assessed using paired *t*-tests, with *p*-values reported to determine the likelihood that differences occurred by chance. This approach provides a robust comparative framework without relying on model-based optimization techniques.

2.2. Evaluating Potential Creativity Improvement When Using AutoCAD Mechanical

This study aimed to evaluate the potential enhancement of creativity when using AutoCAD Mechanical compared to standard AutoCAD by analyzing the design variations produced by beginner CAD users. A structured methodology was implemented to assess how the use of automated mechanical design tools influences creative problem-solving in technical drawing.

The research involved the same fifty beginner CAD users from previous studies, each assigned the task of designing a mechanical assembly using AutoCAD or AutoCAD Mechanical, depending on which group they belong to. To ensure consistency, all participants worked from the same reference design (Figure 7)—a standard mechanical assembly represented as a fully dimensioned and annotated engineering drawing. This drawing incorporated detailed sectional views, geometric dimensioning and tolerancing, machining specifications, and a BOM, providing all necessary manufacturing and assembly information for precise fabrication.

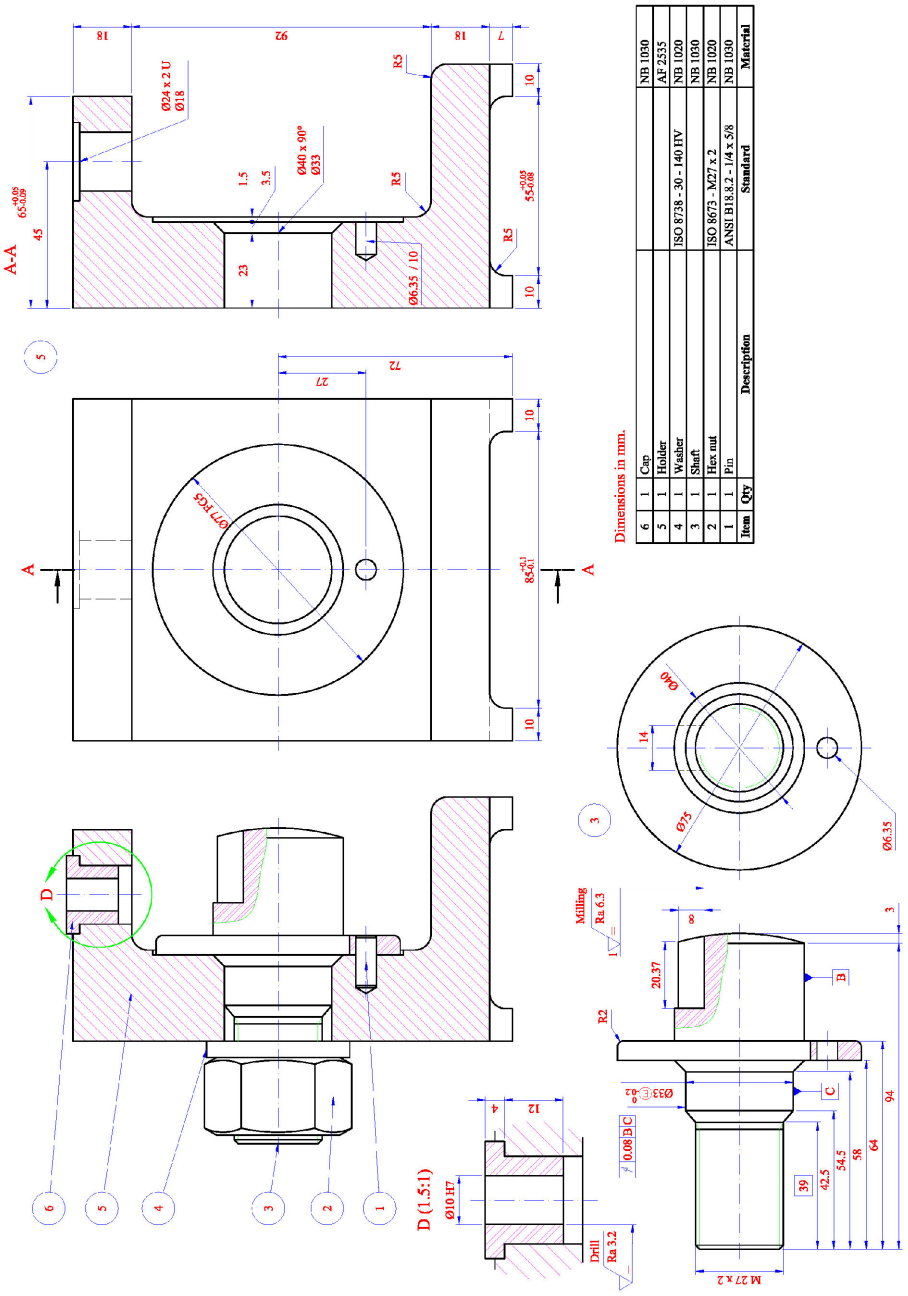


Figure 7. Reference design given to the participants to evaluate creativity.

Participants were instructed to create a variation of the given design based on specific improvement strategies. These strategies included geometrical optimization, which focused on improving material efficiency while maintaining structural integrity; feature enhancement, which introduced additional mechanical features to enhance functionality; simplification for production, which aimed to reduce complexity for more efficient manufacturing; modular assembly, which redesigned components for easier assembly and disassembly; and advanced mechanical integration, which incorporated industry-standard mechanical features into the design. The objective was to explore how different CAD tools influence creativity in technical design. Participants belonging to group 1 completed their designs using AutoCAD, relying on traditional drafting tools, such as basic 2D drawing commands, manual dimensioning, and standard constraints. Group 2 performed the same design tasks using AutoCAD Mechanical, which provided parametric constraints, standard part libraries, automated dimensioning, and mechanical-specific tools. This comparison

highlighted the differences between manual drafting methods and automated mechanical design tools in fostering creative technical solutions.

To evaluate the creative outcomes, a rubric-based assessment was applied based on four key criteria: (i) originality measured the degree of innovation in the design approach; (ii) functionality assessed the feasibility and appropriateness of the solution for manufacturing; (iii) efficient use of CAD tools evaluated proficiency in applying the relevant commands in AutoCAD or AutoCAD Mechanical; and (iv) graphical quality examined the clarity, precision, and completeness of the technical drawings. These criteria provided a structured framework for assessing the impact of different CAD tools on creativity in mechanical design.

Each design was independently evaluated by experienced CAD instructors, who assigned scores on a scale from one to five for each criterion, resulting in a maximum possible score of twenty points per design. The average creativity score was then calculated for each design variation to assess the impact of AutoCAD versus AutoCAD Mechanical on creative output. To ensure consistency and objectivity, a structured evaluation rubric was developed, as shown in Table 1, which provides a systematic framework for assessing the quality of CAD-generated designs based on the previously defined key criteria.

To ensure objectivity during the evaluation of design creativity, all student submissions were anonymized and presented in randomized order, preventing evaluators from identifying whether a design was created using AutoCAD or AutoCAD Mechanical. The assessment was carried out by experienced CAD instructors who were trained in advance to apply the rubric consistently. A calibration session was conducted using a subset of sample designs to align evaluators' interpretations of the criteria and scoring scale. Although inter-rater reliability was not formally measured using statistical indices, this preliminary session helped to harmonize the evaluation approach and reduce scoring variability across raters.

Although formal validation of the rubric was not conducted using statistical measures, the criteria were adapted from published CAD education frameworks [24,25] and refined in consultation with experienced instructors to ensure relevance to mechanical drafting tasks. The rubric was intended to capture not only the technical correctness of the design but also the degree of conceptual innovation and workflow efficiency demonstrated. While AutoCAD Mechanical's automation tools may enhance scores in functionality and tool proficiency, these tools do not produce creative outcomes autonomously. Rather, they provide users with the means to implement more advanced design ideas, which are still conceived, structured, and executed by the participants. As such, the observed differences in creativity reflect the participants' ability to exploit available tools in original and functional ways, consistent with contemporary understandings of creativity in engineering design.

When assigning weights to evaluation criteria in a rubric-based assessment, certain aspects of design play a more significant role in determining the overall effectiveness of a CAD-generated model. In this context, not all criteria contribute equally to the final evaluation, as some factors are more critical for practical engineering applications than others.

To ensure a balanced and meaningful assessment, the criteria can be weighted according to their relative importance in mechanical design workflows. This approach allows for a more accurate reflection of the impact of each design element on functionality and manufacturability. Below, Table 2 presents the proposed weighted distribution for the four key assessment criteria, aligning the evaluation process with the priorities of professional mechanical design.

Table 1. Rubric for evaluating the creativity output.

Criteria	1—Poor	2—Fair	3—Satisfactory	4—Good	5—Excellent
Originality (degree of innovation)	The design lacks creativity, showing a direct replication of the reference without any modifications. No new features are introduced.	Minimal innovation is present. Some minor modifications or additional elements are included but do not contribute significantly to improvement.	A moderate level of creativity is demonstrated. The design includes new features, but they are not fully integrated into a unique or innovative solution.	The design shows a strong level of innovation, introducing original modifications that enhance functionality or aesthetics.	Highly creative and innovative design that introduces entirely new elements, optimizes material usage, and enhances functionality beyond conventional expectations.
Functionality (feasibility and appropriateness for manufacturing)	The design is impractical for manufacturing. It contains errors in dimensions, tolerances, or assembly features that prevent real-world application.	Some aspects of the design are functional, but there are major manufacturability concerns, such as incorrect tolerances or missing critical details.	The design is generally manufacturable, but minor issues (e.g., suboptimal material selection, excessive complexity) reduce its efficiency.	The design is well-structured for manufacturing with only minor refinements needed. It considers realistic tolerances and assembly constraints.	The design is highly optimized for manufacturability, incorporating appropriate tolerances, material efficiency, ease of assembly, and industry-standard best practices.
Efficient use of CAD tools (proficiency in AutoCAD/AutoCAD Mechanical commands)	The design was created inefficiently with excessive manual operations, improper use of tools, and lack of automation. Frequent errors requiring correction.	Basic CAD tools are used, but there is minimal understanding of advanced features. The workflow is slow and inefficient.	The design demonstrates moderate proficiency with CAD tools, making use of fundamental commands but with room for optimization.	CAD commands and features are used efficiently. Parametric tools, constraints, and standard libraries are properly integrated for a streamlined workflow.	Highly proficient use of AutoCAD/AutoCAD Mechanical tools. The designer effectively uses automation, constraints, standard libraries, and advanced features to maximize efficiency.
Graphical quality (clarity, precision, and completeness of technical drawings)	The drawing is unclear, lacks dimensions, and contains inconsistencies in views and projections. The layout is disorganized.	The drawing includes basic dimensions but has errors in scaling, projection alignment, or clarity. Annotation placement is poor.	The drawing is mostly clear with accurate projections and proper annotations but lacks refinement in line weights, hatching, or notation consistency.	The drawing is precise, well-organized, and correctly dimensioned. Proper use of line weights, section views, and annotations enhances readability.	The drawing is of professional quality, adhering to all drafting standards with perfect clarity, precise dimensions, appropriate annotations, and highly detailed visualization of features.

Table 2. Assigned weights to each key criterion.

Criteria	Weight (%)	Rationale for Weighting
Originality	20%	While creativity is important, it must be balanced with functionality. In mechanical design, excessive innovation without feasibility can lead to impractical solutions. Thus, originality is valued but not prioritized over functionality.
Functionality	35%	Functionality is the most critical factor in mechanical design because even the most innovative and visually appealing design is useless if it cannot be manufactured or assembled correctly. It must adhere to realistic tolerances, material considerations, and practical engineering constraints.
Efficient use of CAD tools	30%	CAD proficiency is essential for an efficient workflow. Mastery of automation tools, parametric design, and feature libraries directly impacts productivity and quality. Using CAD tools effectively minimizes design errors and accelerates modifications.
Graphical quality	15%	While essential, graphical quality has less impact than functionality or efficient CAD use. Aesthetics and drawing clarity enhance communication but do not directly affect manufacturability. A design can be functional even if the drawing is slightly imperfect, if it is interpretable.

This approach ensures that designs emphasize manufacturability and CAD efficiency while still recognizing the importance of creativity and clarity. The methodology applied in this study can be further expanded to include advanced CAD users, various engineering applications, and real-world manufacturing constraints, allowing for a more comprehensive assessment of creativity beyond beginner-level proficiency.

3. Results

3.1. AutoCAD vs. AutoCAD Mechanical Efficiency

Table 3 provides a comparison between AutoCAD and AutoCAD Mechanical based on the average number of commands used, their standard deviations, the average frequency of command access, and the corresponding standard deviations across various mechanical drafting tasks. These results offer valuable insights into the workflow efficiency and productivity improvements that AutoCAD Mechanical offers over standard AutoCAD.

In terms of command usage, AutoCAD consistently requires more commands to complete each task compared to AutoCAD Mechanical. For example, in the "shaft assembly" task, AutoCAD users employ an average of 22 commands, whereas AutoCAD Mechanical users only require 11. Similarly, in the "dimensioned and annotated shaft" task, AutoCAD uses 23 commands, while AutoCAD Mechanical reduces this to 13. This pattern is consistent across all tasks, highlighting that AutoCAD Mechanical simplifies the design process by reducing the number of commands needed to achieve the same outcomes.

Table 3. Comparison of command usage and access frequency between AutoCAD and AutoCAD Mechanical for several drawing tasks.

	AutoCAD				AutoCAD Mechanical			
Task	**Avg. Commands Used**	**Std. Dev. (Commands)**	**Avg. Command Access**	**Std. Dev. (Access)**	**Avg. Commands Used**	**Std. Dev. (Commands)**	**Avg. Command Access**	**Std. Dev. (Access)**
Screw connection	18	2	42	5	9	2	20	2
Shaft assembly	22	3	55	7	11	2	25	3
Hidden geometry	19	2	38	5	8	2	18	2
Enlarged view	21	3	50	6	12	2	27	3
Dimensioned and annotated shaft	23	3	58	7	13	3	28	3
Balloons and parts list	20	3	53	6	11	2	24	3

The frequency of command access follows a similar trend. AutoCAD users access commands more often, indicating a higher number of repetitive manual operations. In the "dimensioned and annotated shaft" task, AutoCAD users access commands an average of 58 times, while AutoCAD Mechanical users access them only 28 times. The "shaft assembly" task shows a reduction from 55 accesses in AutoCAD to 25 in AutoCAD Mechanical. These findings emphasize that AutoCAD Mechanical significantly reduces the number of interactions required, leading to a more efficient and less labor-intensive workflow.

The standard deviation values further illuminate the consistency of the workflow. The standard deviation of command usage in AutoCAD Mechanical is consistently lower than in AutoCAD, suggesting a more predictable and optimized workflow. In contrast, AutoCAD has higher standard deviation values, reflecting greater variability in user input and execution. For instance, the standard deviation of command access in AutoCAD reaches up to seven in both the "shaft assembly" and "dimensioned and annotated shaft" tasks, while in AutoCAD Mechanical, the maximum recorded standard deviation for command access is only three. This indicates that AutoCAD workflows are more prone to fluctuations due to manual inputs, whereas AutoCAD Mechanical offers a more structured and automated approach, reducing unpredictability.

The efficiency gains with AutoCAD Mechanical are evident throughout the data. The reduction in command usage and command access frequency leads to significant time savings and a reduced workload for users. With fewer commands required and fewer interactions needed, users can complete tasks more quickly while maintaining accuracy. The lower standard deviations in AutoCAD Mechanical suggest that it provides a more consistent and optimized user experience, minimizing inconsistencies and reducing manual effort.

In conclusion, Table 3 clearly demonstrates how AutoCAD Mechanical outperforms AutoCAD in terms of efficiency, reducing both the number of commands needed (by 40–50%) and the frequency of command access across all tasks. The data confirms that AutoCAD Mechanical offers a streamlined, more consistent, and automated drafting process, making it a superior choice for mechanical design workflows. The lower standard deviations in command usage and access further reinforce the idea that AutoCAD Mechanical leads to more predictable and standardized workflows, ultimately improving productivity and reducing the cognitive load on users.

A comparative analysis of task completion times between AutoCAD and AutoCAD Mechanical, including average time, standard deviation, time reduction percentage, and statistical significance through *p*-values, is provided in Table 4. The data underscore the efficiency gains that AutoCAD Mechanical offers in reducing the time required for various drafting tasks.

Table 4. Evaluation of task completion times and efficiency gains between AutoCAD and AutoCAD Mechanical.

	AutoCAD		AutoCAD Mechanical			
Task	**Avg. Time (min)**	**Std. Dev. (min)**	**Avg. Time (min)**	**Std. Dev. (min)**	**Time Reduction (%)**	***p*-Value (*t*-test)**
Screw connection	15.20	2.45	7.40	1.85	51.32	0.0001
Shaft assembly	16.00	2.90	8.00	2.10	50.00	0.0002
Hidden geometry	13.50	2.20	6.30	1.75	53.33	0.0001
Enlarged view	14.60	2.55	7.10	1.90	51.37	0.0003
Dimensioned and annotated shaft	17.00	3.00	8.50	2.30	52.32	0.0003
Balloons and parts list	16.50	2.85	8.30	2.10	49.70	0.0004

The results indicate that AutoCAD requires significantly more time to complete tasks compared to AutoCAD Mechanical. For example, in the "screw connection" task, the average completion time in AutoCAD is 15.20 min, whereas AutoCAD Mechanical completes the same task in just 7.40 min. Similarly, in the "dimensioned and annotated shaft" task, AutoCAD users take an average of 17.00 min, while AutoCAD Mechanical reduces this time to 8.50 min. Across all tasks, AutoCAD Mechanical consistently reduces task completion time, with time savings ranging from 49.70% to 53.33%.

The standard deviation values highlight the variability in task completion times. AutoCAD exhibits higher standard deviations across all tasks, ranging from 2.20 to 3.00 min, indicating greater inconsistency in task execution. In contrast, AutoCAD Mechanical shows lower standard deviations, ranging from 1.75 to 2.30 min, suggesting a more predictable and structured workflow. This reduction in variability implies that AutoCAD Mechanical offers more uniform drafting experience, likely due to its automation features and specialized mechanical tools.

The time reduction percentage quantifies the improvement in efficiency, with all tasks showing reductions of approximately 50% or more. The greatest time reduction occurs in the "hidden geometry" task, where AutoCAD Mechanical achieves a 53.33% reduction in task completion time compared to AutoCAD. The smallest, yet still substantial, reduction is observed in the "balloons and parts list" task, with a 49.70% improvement. These findings confirm that AutoCAD Mechanical consistently outperforms AutoCAD in reducing task execution times.

The *p*-values from the *t*-test analysis further validate the statistical significance of these results. All *p*-values are below 0.05, confirming that the differences in task completion times between AutoCAD and AutoCAD Mechanical are not due to random variation. The lowest *p*-value is observed in the "screw connection" and "hidden geometry" tasks (0.0001), indicating that the time savings in these tasks are particularly strong and statistically significant.

Overall, the data confirms that AutoCAD Mechanical provides substantial efficiency improvements over standard AutoCAD by reducing task completion times, decreasing variability, and ensuring statistically significant time savings. These findings support the adoption of AutoCAD Mechanical for mechanical drafting tasks, particularly for users seeking to optimize workflow efficiency and minimize manual effort. The lower standard deviations further indicate that AutoCAD Mechanical offers a more structured and predictable design environment, reinforcing its advantages for engineering applications.

3.2. Impact of Using AutoCAD and AutoCAD Mechanical on Creativity

The statistical comparison between AutoCAD and AutoCAD Mechanical reveals significant differences in creativity-related criteria (see Table 5), highlighting the impact of automated CAD tools on beginner users. The mean scores indicate that AutoCAD Mechan-

ical outperforms AutoCAD across all four evaluated dimensions: originality, functionality, efficient CAD use, and graphical quality.

Table 5. Average creativity criteria scores for AutoCAD and AutoCAD Mechanical.

	AutoCAD		AutoCAD Mechanical		
Criteria	**Average**	**Std. Dev.**	**Average**	**Std. Dev.**	***p*-Value (*t*-test)**
Originality	2.93	0.88	3.80	0.77	0.0080
Functionality	3.00	0.93	4.20	0.86	0.0010
Efficient CAD use	3.27	0.70	4.07	0.88	0.0107
Graphical quality	3.20	0.86	3.67	0.62	0.1004
Average weighted creativity score	**12.56**	3.41	**16.24**	2.89	0.0007

The most notable improvement is observed in functionality, where AutoCAD Mechanical achieved an average score of 4.2, compared to 3.0 in AutoCAD. This suggests that the advanced mechanical-specific features in AutoCAD Mechanical facilitate the creation of more feasible and practical design solutions.

In terms of originality, AutoCAD Mechanical users scored 3.8, significantly higher than the 2.93 recorded for AutoCAD users. This finding suggests that access to parametric constraints, mechanical part libraries, and automation tools enables designers to explore more innovative solutions without the limitations of manual drafting. The *t*-test results support this observation, with a *p*-value of 0.008, confirming a statistically significant difference between the two groups. The impact of AutoCAD Mechanical on originality is likely due to its ability to facilitate rapid modifications and iterations, allowing users to experiment with multiple design variations efficiently.

The efficient use of CAD tools category also shows a notable improvement, with AutoCAD Mechanical users scoring 4.07 on average, compared to 3.27 in AutoCAD. The *p*-value of 0.0107 confirms a statistically significant difference, demonstrating that automation reduces the time and effort required to create precise technical drawings. The integration of automated dimensioning, standard mechanical symbols, and intelligent part management enhances workflow efficiency, making it easier for beginner users to execute complex tasks.

The graphical quality scores exhibit a smaller gap, with AutoCAD users averaging 3.2 and AutoCAD Mechanical users scoring 3.67. Although the difference suggests improvement, *p*-value of 0.1004 indicates that this difference is not statistically significant. This could be attributed to the fact that both software environments allow users to achieve similar levels of visual clarity and precision through manual adjustments, even though AutoCAD Mechanical provides automated tools for refinement.

The overall creativity score for AutoCAD Mechanical (16.24 out of 20) compared to AutoCAD (12.56 out of 20) confirms that AutoCAD Mechanical enhances creativity and efficiency in technical drawing and mechanical design. Additionally, the lower standard deviation in AutoCAD Mechanical (2.89 vs. 3.41 for AutoCAD) suggests that its automation tools contribute to more consistent performance across users. In contrast, AutoCAD users exhibit greater variability in creativity scores, likely due to manual drafting challenges. The *p*-value of 0.0007, which is well below the standard significance level of 0.05, confirms that the difference in creativity scores between the two software environments is statistically significant. This indicates that the observed improvement in creativity when using AutoCAD Mechanical is not due to random variation but is instead attributable to the design advantages provided by automation and engineering-specific tools.

4. Discussion

The findings of this study demonstrate that specialized CAD toolsets such as AutoCAD Mechanical significantly enhance both efficiency and creativity compared to standard AutoCAD, for undergraduate mechanical engineering students, being beginner CAD users, engaged in mechanical drafting tasks. The analysis of command usage, access frequency, and task completion times clearly indicates that AutoCAD Mechanical provides a more streamlined and optimized workflow, reducing the number of commands required by nearly 50% across various drawing tasks. Furthermore, the reduction in command repetition and task execution time confirms that the automation features embedded in AutoCAD Mechanical lead to higher productivity and lower cognitive load for users.

The comparison of creativity metrics further underscores the advantages of AutoCAD Mechanical. The results show that designs created using AutoCAD Mechanical scored higher in originality, functionality, and efficient CAD tool usage, with statistically significant differences in these categories compared to standard AutoCAD. The ability to leverage parametric constraints, automated dimensioning, and standard part libraries allows users to focus more on design innovation rather than manual drafting, leading to better-optimized and more functional solutions. The graphical quality scores, while slightly higher for AutoCAD Mechanical, did not show statistical significance, suggesting that manual drafting techniques in standard AutoCAD can still achieve similar visual precision. This outcome merits additional discussion. One possible explanation is that graphical quality—as defined by clarity, precision, and adherence to drafting standards—depends more on users' general drawing discipline and less on the specific toolset employed. Both software environments offer the essential functionalities required to produce technically correct drawings, such as line control, annotation, and layout tools. As such, even beginner users using standard AutoCAD can produce high-quality visuals when guided by consistent instructional standards. Moreover, the rubric criterion for graphical quality may involve less cognitive abstraction compared to creativity or functionality, allowing students to achieve comparable results regardless of the software used. This may explain why the scores in this category showed a smaller and statistically non-significant difference. These findings suggest that while automation enhances workflow and innovation, visual precision may be more influenced by instructional emphasis and drawing conventions than by tool complexity alone.

The findings of this study align with and extend previous research on the impact of automation in creative design environments. Prior studies have shown that automation-supported tools can enhance creative output by reducing cognitive load and facilitating iterative exploration. For instance, it has been demonstrated that CAD tools integrating automation features contribute to improved problem-solving strategies and increased ideation diversity among engineering students [10]. Similarly, it has been found that simulation-enabled CAD environments promote design thinking and innovation through real-time feedback mechanisms [19]. Our results corroborate these observations by showing that beginner users equipped with automated CAD functionalities—such as parametric constraints and standardized part libraries—achieved higher scores in originality and functionality. Unlike many prior studies that rely on qualitative observations, the current research contributes a quantitative framework for evaluating creativity in CAD-based tasks, thus offering a more structured comparison of tool impact.

A key insight from the study is that automation in CAD software advances greater creativity by allowing users to explore multiple design variations more efficiently. The closely 30% increase in average weighted creativity score obtained for AutoCAD Mechanical reinforces the idea that automation not only improves efficiency but also enhances design exploration and problem-solving capabilities. The structured workflow and integrated

mechanical tools in AutoCAD Mechanical enable users to iteratively refine their designs, resulting in more functional and innovative outcomes.

The observed improvements in both efficiency and creativity among users of AutoCAD Mechanical can be attributed to specific functional enhancements embedded in the software. Automation features such as parametric constraints, automated dimensioning, and standard part libraries reduce the cognitive load associated with repetitive drafting tasks, allowing users to redirect mental resources toward problem-solving and iterative design. This shift from procedural to conceptual engagement promotes a more exploratory and inventive design process, particularly beneficial for novice users who may struggle with command memorization and manual operations. Moreover, AutoCAD Mechanical's contextual toolsets and design validation features enable rapid feedback and real-time adjustments, which support creative experimentation without compromising technical accuracy. These affordances help bridge the gap between technical execution and creative ideation, aligning with theories of cognitive offloading and scaffolding in design learning environments.

Although the current study did not include a dedicated measure of user perception or transition difficulty, the findings offer indirect evidence regarding the usability of AutoCAD Mechanical for students previously trained in standard AutoCAD. All participants had foundational experience in AutoCAD, and yet those introduced to AutoCAD Mechanical—despite having no prior exposure—achieved superior results in both efficiency and creativity. This performance gap suggests that the transition was intuitive and that the specialized toolset did not pose a barrier to entry. The structured features, automation support, and design-specific functions in AutoCAD Mechanical likely facilitated learning by reducing the cognitive burden associated with manual drafting. Future research could explore students' subjective experiences during such transitions, including any reluctance or adaptation challenges, to inform curriculum development and software integration strategies. While student feedback was not collected in this study, future research should incorporate surveys or interviews to capture user perceptions of tool usability, learning experience, and adaptation. Such qualitative insights would complement the performance data and inform curriculum design by highlighting how students engage with and respond to different CAD environments.

Future research should also explore how the benefits of specialized CAD tools evolve as users progress from novice to advanced proficiency levels. While the present study focused on beginners to isolate the immediate effects of tool functionality and automation, experienced users may exhibit different patterns of efficiency gains, creative exploration, and tool adaptation. Investigating how expert users leverage advanced features of specialized software could reveal whether the initial advantages observed among beginners persist, amplify, or diminish with continued use. Such analysis would contribute to a more comprehensive understanding of the role of CAD tools in skill development, design innovation, and professional practice over time.

5. Conclusions

From both an educational and industrial perspective, these findings underscore the importance of integrating specialized CAD toolsets for drafting into mechanical engineering curricula and professional workflows. By reducing manual drafting efforts and promoting an automated, standardized approach to technical drawing, these toolsets facilitate faster learning, improved design efficiency, and increased creative potential. The results suggest that undergraduate mechanical engineering students benefit significantly from automation, as it reduces the complexity of design tasks while ensuring high standards of accuracy and feasibility. By analyzing the impact of AutoCAD and AutoCAD Mechanical

on efficiency and creativity, this study provides strong evidence that AutoCAD Mechanical is a drafting tool that offers tangible improvements in workflow efficiency and design innovation. As engineering design continues to advance, embracing automation-driven CAD solutions will be key to streamlining processes, enhancing creativity, and ensuring high-quality technical drawings in both academic and professional settings. The findings contribute to a broader understanding of how specialized CAD tools expand both the technical and creative aspects of mechanical design, ultimately leading to improved productivity and innovation in engineering applications. Future research could explore these findings by examining the long-term impact of specialized toolsets on advanced CAD users, real-world manufacturing applications, and collaborative design environments. Understanding these aspects could provide even deeper insights into how automation-driven CAD tools shape the way engineers work, learn, and innovate.

While the findings of this study provide valuable insights into the immediate effects of specialized CAD tools on beginner performance, the analysis is limited to short-term task execution and does not account for long-term learning outcomes or knowledge retention. The impact of repeated tool use, progressive skill acquisition, and the transferability of efficiency and creativity gains over time remain unexplored. As such, future research should incorporate longitudinal designs to assess how sustained exposure to automation-enhanced CAD environments influences cognitive development, design proficiency, and the durability of creative problem-solving abilities. These investigations could also examine how students adapt to increasingly complex design challenges and whether early advantages observed with specialized tools persist or evolve with experience. Furthermore, while the drawing tasks were selected to reflect common mechanical drafting practices, some task elements may inherently align more closely with the automated features of AutoCAD Mechanical. This alignment could have contributed to the observed performance advantages and should be considered when interpreting the results. Future research with larger, more diverse populations and longitudinal follow-up is needed to confirm and extend these findings.

This study is also subject to several limitations. The sample size, while adequate for exploratory statistical analysis, was relatively small and limited to beginner-level participants from a single academic program, which may constrain the generalizability of the findings. Moreover, individual differences in creativity and prior exposure to technical drawing conventions were not controlled, potentially introducing variance in design outcomes. These factors, along with the short-term nature of the experiment, suggest that the results should be interpreted as indicative rather than conclusive. Future research with larger, more diverse populations and longitudinal follow-up is needed to confirm and extend these findings.

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