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Improving CSWA Performance and CAD Proficiency through Automated Feedback and Iterative Design

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Introduction:

Computer-aided design (CAD) proficiency is a foundational skill for mechanical engineering students, serving as both a core technical skill and a primary medium for engineering communications [1], [2]. Introductory engineering graphics courses are typically responsible for developing students' abilities in freehand sketching, three-dimensional solid modeling, and technical drawings using commercially available CAD software [3], [4]. These courses often culminate in design projects intended to reinforce the modeling concepts introduced in the classroom within an applied engineering context [5].

In addition to meeting curricular objectives, introductory engineering graphics courses play a critical role in preparing students for professional practice. For many undergraduates, the next stage following graduation is employment in industry, where CAD tools are leveraged across design, manufacturing, and product development roles [6]. Hiring managers in these sectors frequently seek evidence of CAD proficiency beyond course grades alone, motivating the integration of industry-recognized, third-party credentials into academic programs [7].

The Certified SolidWorks Associate (CSWA) credential is an entry-level certification that is particularly appropriate for students enrolled in introductory engineering graphics courses with SolidWorks being their preferred CAD platform. This credential serves both as a benchmark of foundational proficiency and as a stepping-stone toward more advanced certifications. A natural progression following the CSWA is the Certified SolidWorks Professional (CSWP) and the Certified SolidWorks Expert (CSWE); typically earned in that order [7]. These credentials provide an externally validated measure of CAD competency that is well aligned with the learning objectives of engineering graphics courses. Post-graduation, these certifications also provide a competitive edge in the hiring process, helping secure interviews and stand out from non-certified peers [8].

Expanding the number of learning opportunities within a course promotes deeper understanding of the material. This is particularly true in engineering graphics courses, where students are not only acquiring conceptual knowledge but also developing technical skills that require sustained practice, time, and effort to master [9]. Providing sufficient opportunities for practice and feedback, however, presents a persistent challenge in these courses. Manual evaluation of CAD models, assemblies, and/or drawings are time intensive, often limiting the number of graded exercises that can be reasonably assigned [10], [11]. As a result, students may receive fewer modeling assignments and/or delayed feedback, reducing their ability to practice, identify, and correct modeling errors before progressing to more complex operations.

To address these limitations and increase students' preparedness for the certification exam, two complementary instructional changes were introduced in an introductory engineering graphics course. The first involved the adoption of automated CAD grading software to enable an increase in the number of assigned modeling exercises while also allowing for rapid, detailed feedback [10], [11]. This feedback was paired with concise "how-to-design" videos, enabling students to identify mistakes and learn proper modeling techniques before progressing to the next assignment. The second was the introduction of a reverse-engineering, 3D printed design project centered on the disassembly, modeling, and physical reproduction of a commercially manufactured mortise lock. In this project, students were challenged to apply their newly acquired CAD skills to create individual part models based on physical measurements, virtually assemble those components, and then 3D print them to produce a functional mechanical lock; all with an instructional emphasis on iterative learning.

This paper describes the implementation of automated CAD assessment with a reverse-engineering, 3D printed design project in an introductory engineering graphics course and its effect on CAD skill development and certification preparedness.

Methods:

Instructional Change I: Automated Grading

This course is traditionally structured around two weekly lectures (75 minutes each) and one weekly recitation (75 minutes), totaling 3.75 hours of in-class work per week. Lectures are primarily used to introduce new modeling techniques and are predominately instructor-led, while recitation sessions focus more on design challenges intended to reinforce lecture material and progressively prepare students for the Certified SolidWorks Associate (CSWA) examination.

The course is led by Instructor A in the Fall semesters and by Instructor B in the Spring semesters, which enabled this intervention to be implemented in one offering (Spring 2025) while the others served as a comparison (Fall 2024 and Fall 2025). To maintain consistency between semesters, similar lecture materials and course schedules were used, resulting in comparable lecture content and pacing. The principal distinctions between the two offerings were the quantity of assigned recitation exercises and the course project. Any modeling exercises introduced during lectures or assigned as homework were not included in this analysis, as these were kept largely consistent throughout the three semesters.

Automated grading was implemented with the adoption of GraderWorks. Developed by Garland Industries LLC, a Certified SolidWorks Solution Partner, GraderWorks facilitates the automated assessment of CAD files using customizable rubrics [10]. By comparing student submissions against a master solution file, the software evaluates specific parameters efficiently. In this study, the rubric was configured to assess volume, material assignment, feature usage, center of mass, and fully defined sketch definitions. Additionally, a shape similarity score was enabled to calculate partial credit based on geometric resemblance.

Beyond geometric analysis, this software enabled the automation of administrative tasks. Late submissions were automatically penalized based on file modification dates, while plagiarism was detected through metadata analysis specifically by flagging files with identical creation timestamps or creation dates predating the assignment. Finally, the mail merge function was utilized to generate and provide personalized, detailed feedback emails for each student rapidly. This software was essential to managing the increased volume of recitation exercises and models related to the course project.

Instructional Change II: Reverse Engineering, 3D Printed Design Project
The reverse engineering, 3D printed design project required students to disassemble, measure, model, virtually assemble, and ultimately physically fabricate and assemble a functional replica of a commercially manufactured mortise lock (as shown in *Fig. 1a*). Each student was equipped with a mortise lock (Prime-Line, Model #E2294), digital caliper, and the CAD knowledge/skills needed to complete the project. As this course is typically one of the first mechanical engineering courses taken by students, the project was scaffolded into multiple segments to avoid cognitive overload. The release of each project section was intentionally aligned with newly introduced modeling practices covered in lecture. Early project tasks focused on simple sketches and basic solid modeling features, while later tasks required students to model more complex components such as springs and fasteners and create a dynamic assembly.

In total, ten components were modeled with varying complexity. Subsequent project phases required the creation of functional assemblies (*Fig. 1b*) using advanced mates to replicate the kinematic motion of the lock and latch mechanisms (*Fig. 1c*), as well as the generation of engineering drawings incorporating exploded views with an embedded bill of material table and balloon annotations.

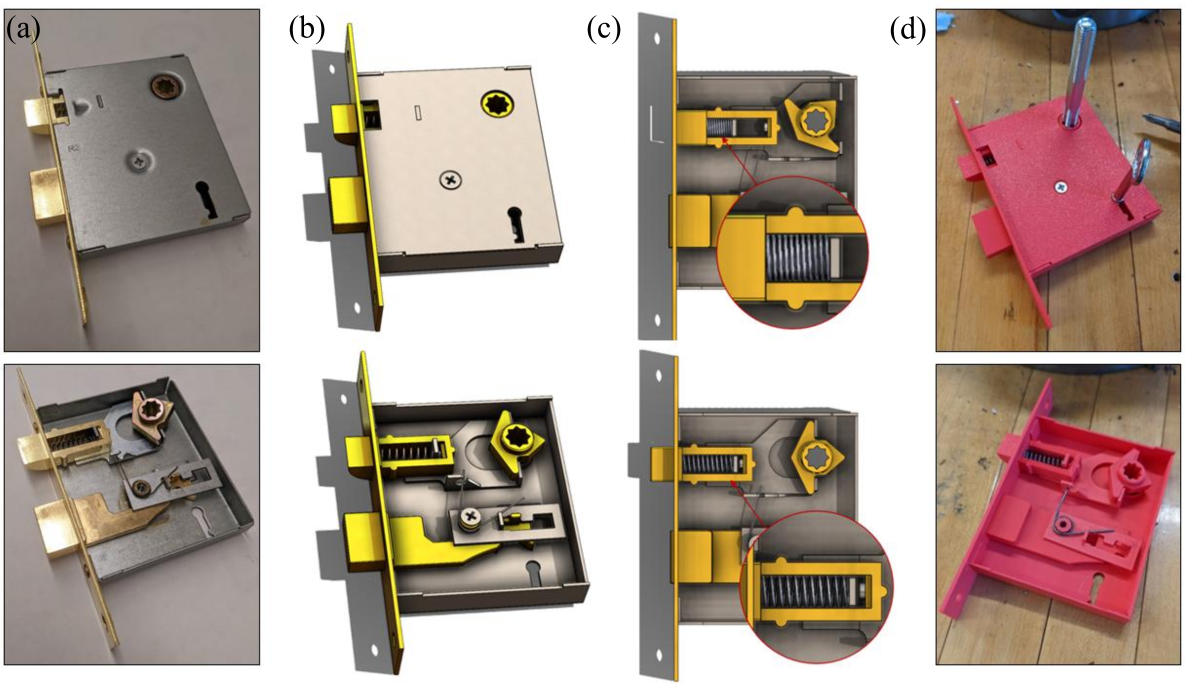

Fig. 1: The figure above illustrates the project lifecycle. From left to right, it displays: (a) the physical mortise lock students were tasked with reverse engineering, (b) the completed virtual assembly of all ten components, (c) the application of advanced mates and in-context assembly modeling techniques to simulate the spring's mechanical behavior, and (d) the resulting 3D-printed functional prototype (with corresponding deadbolt key and spindle attached).

Due to the considerable effort required by the students to complete this project, it accounted for 25% of the overall course grade and, more importantly, was also evaluated on a pass/fail basis. To receive a course grade (i.e. avoid an incomplete course grade), students were required to submit a fully functional, 3D printed mortise lock by the end of the semester. Lock functionality was assessed by the instructor using the manufacturer-provided deadbolt key and a generic spindle (*see Fig. 1d*). Additionally, to ensure parts were modeled accurately with respect to the metal mortise lock, select 3D printed components were interchanged with their metal counterparts and tested for fit and function (*see Fig. 2*). This assessment process and the instructor's feedback were formally documented via submission-specific video recordings that were made available to each student through the course webpage.

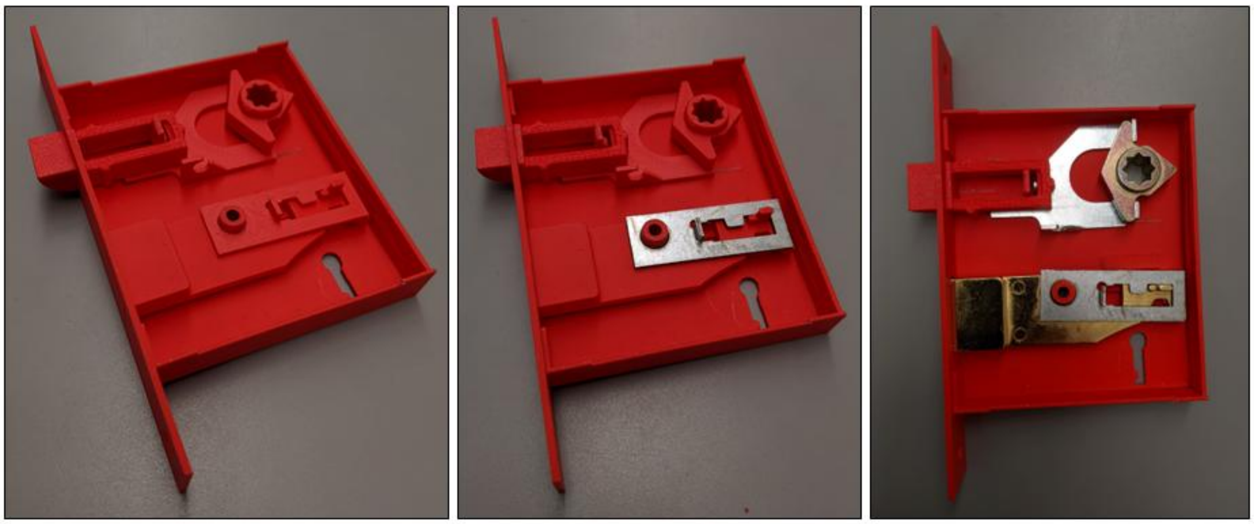

Fig. 2: From left to right, this figure illustrates the validation process which involved substituting the 3D-printed parts with their original metal counterparts to confirm the dimensional accuracy of the replica.

To ensure that students allocated enough time for iteration and refinement, a "false ending" was introduced three weeks prior to the end of the term, providing students with an additional three-week window to address deficiencies identified in their designs and assemblies.

Certified SolidWorks Associate Certification Examination

The CSWA exam is typically administered as a single, three-hour, online assessment. In academic settings, however, an academic version of the exam is commonly adopted to better align with instructional schedules. This academic version, which was used in this study, divides the exam into two, 90-minute parts (totaling three hours). Part I assesses basic part modeling, intermediate part modeling, and assembly, while Part II evaluates drafting competencies, assembly, and advanced part modeling. Each part is scored out of 120 points, for a total score of 240 points. A minimum score of 80 points (67%) must be achieved on each part to pass and earn the CSWA credential; achieving a 67% or greater average across both parts is insufficient for certification. Starting in the Fall of 2024, students enrolled in this course were given the opportunity to earn the CSWA credential and their score has since been counted towards their final exam grade. The percentage of students earning the CSWA credential from the three course offerings (Fall 2024, Spring 2025, and Fall 2025) was used as the primary outcome measure for this study.

Results:

When isolating recitation-specific exercises, Instructor A assigned an average of 10 modeling problems, whereas Instructor B assigned 65. This 6.5x increase in practice problems is largely attributed to the performance improvements observed in the categories below.

As shown in *Fig. 3a*, the percentage of students earning the CSWA credential (referred to as "CSWA pass rate") were compared across three consecutive course offerings (Fall 2024 – 98 students, Spring 2025 – 50 students and Fall 2025 – 99 students). To further examine differences in student performance, average scores (with ±1 standard error of the mean) across the five CSWA problem categories (*Fig. 3b*) and the distribution of time allocated to Part I and Part II were analyzed (*Fig. 4*). The results from the three courses will be referred to as Instructor A (F24 – red colored), Instructor B (S25 – blue colored), and Instructor A (F25 – green colored). To ensure a fair comparison, students with extra time accommodations (exam durations exceeding the standard 90-minute limit per part) were excluded from the analysis. This controls for external variables unrelated to course instruction and structure.

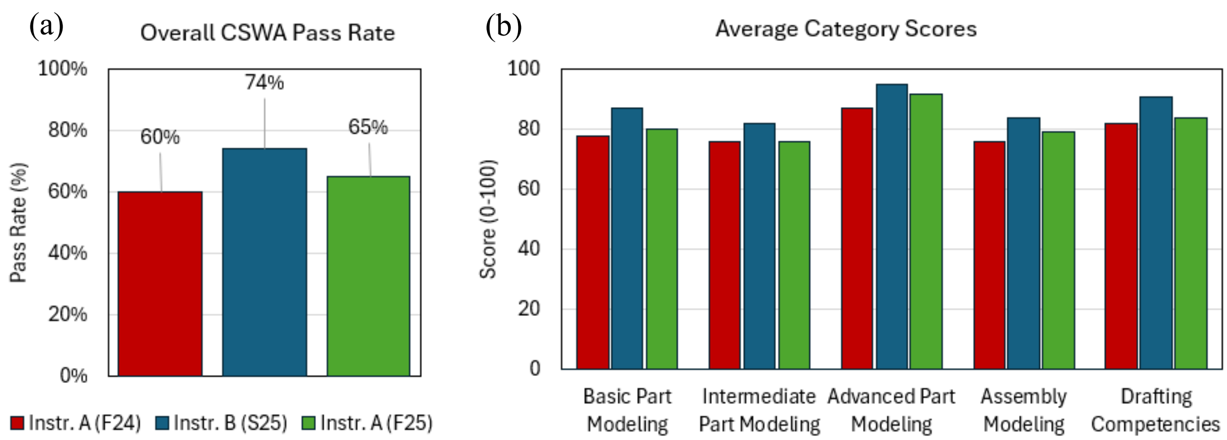

Fig. 3: (a) Semester-specific summary results of the CSWA examination performance across three introductory engineering graphics course offerings (Fall 2024, Spring 2025, and Fall 2025) and (b) the variability in performance by problem type (basic part modeling, intermediate part modeling, advanced part modeling, drafting competencies, and assembly).

The Spring 2025 semester exhibited a 14-point increase in the CSWA pass rate relative to Fall 2024 and a 9-point increase relative to Fall 2025. A chi-square test of independence was performed to examine the relation between the course offering and the overall CSWA pass rate. The relation between these variables was not statistically significant, $\chi^2(2, N = 232) = 2.24$, $p = 0.33$.

Across all five categories, students in the Spring 2025 offering achieved higher average scores than those in Fall 2024 and Fall 2025 (*Fig. 3b*). Improvements were observed in both foundational skills (basic and intermediate part modeling) and more complex competencies (advanced part modeling, assembly, and drafting). In addition, standard deviations were generally lower in Spring 2025, most notably in drafting competencies (Fall 2024: 25, Spring 2025: 16, and Fall 2025: 24) and advanced part modeling (Fall 2024: 26, Spring 2025: 18, and

Fall 2025: 21), indicating reduced variability in student performance. Although the observed standard deviations are relatively large across all semesters, this variability is characteristic of the CSWA exam structure, which does not award partial credit. As a result, a single modeling error can lead to a zero score on an individual problem, inflating score dispersion. As assessed via a one-way ANOVA, no statistically significant difference was found in student scores for any category (all $p > 0.05$).

A consistent performance trend was observed across all course offerings: students scored highest in the advanced part modeling category and lowest in the intermediate part modeling category (*Fig. 3a*). Specifically, average scores in the advanced category were 87, 95, and 82 for the Fall 2024, Spring 2025, and Fall 2025 offerings, respectively, while average scores in the intermediate category were 76, 82, and 76 for the same terms. This discrepancy appears to be more strongly related to the structure of the academic version of the exam than to differences in student ability.

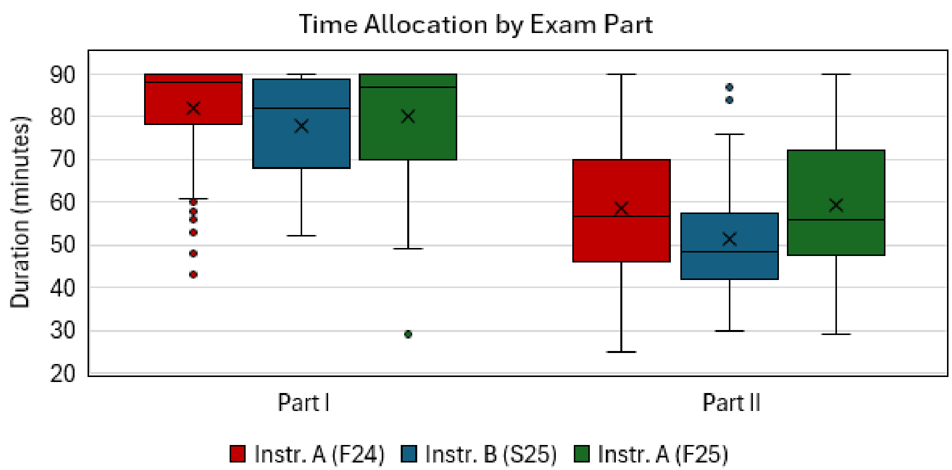

Fig. 4: Distribution of the time spent on Part I and Part II of the CSWA exam across three introductory engineering graphics course offerings (Fall 2024, Spring 2025, and Fall 2025). Note: maximum exam time is capped at 90-minutes per part.

A comparison of the time allocated to Part I and Part II of the exam supports this interpretation (see *Fig. 4* above). Although each part is limited to a maximum of 90 minutes, Part II, which includes the advanced part modeling category, typically allows students more time for modeling and troubleshooting, whereas Part I, which includes the intermediate part modeling category, imposes greater time pressure. As a result, students may have less time to recover from minor errors in their intermediate part modeling problem, resulting in a lower reported score as compared to the advanced part modeling problem. Comparing all three semesters, students in the Spring 2025 offering not only achieved higher average scores across the five categories (see *Fig. 3b*) but also completed the exam in the shortest amount of time (see *Fig. 4*).

Statistical analysis confirmed that while pass rates and category scores were generally higher for Instructor B (S25), these differences were not statistically significant (all $p > 0.05$). However, a significant difference was found in efficiency via a one-way ANOVA, followed by Tukey's

Honestly Significant Difference (HSD) post-hoc test. Students in the Instructor B (S25) cohort completed Part II of the exam significantly faster (7.7 minutes faster, $p = 0.016$ and 7.2 minutes faster, $p = 0.028$) than students in both Instructor A cohorts (Fall 2024 and Fall 2025, respectively).

Discussion:

While the direct contribution of the design project to the CSWA pass rate is difficult to isolate from the increased recitation exercises, the project contributed to an increase in student engagement with the CAD software. The project's iterative structure dramatically increased the students' "time-on-task", a critical factor in CAD proficiency. By requiring students to create, refine, and troubleshoot ten distinct components, the project ensured that exposure to the software extended far beyond the constraints of the weekly lectures and recitation sessions. This targeted practice via recitation exercises, combined with the application of newly acquired CAD skills to a more open-ended project, created the compound effect responsible for the observed increase in certification rates for the Spring 2025 cohort. These curricular modifications were effectively executed largely due to the adoption of the automated grading software (i.e. GraderWorks).

The project requirement of physically manufacturing a functional mechanism addressed a critical gap found in students enrolled in introductory engineering graphics courses: the disconnect between virtual representation and physical reality. In a purely virtual environment, seemingly minor modeling errors, such as poor feature definition, improper constraints, or ignored tolerances, often go unnoticed. However, these deficiencies become immediately apparent when parts are 3D printed and fail to assemble. The implementation of a strict pass/fail functionality requirement was instrumental in mitigating the students' tendency to accept "good enough" approximations, a mindset that conflicts with parametric modeling workflows. By confronting the realities of physical assembly, students were transitioned from simple feature creation to advanced modeling workflows that integrate considerations of fit, form, function, and manufacturability (i.e. Design for Manufacturing or "DFM").

Beyond geometric accurateness, the project emphasized the creation of robust parametric models that adhere to industrial best practices. A common pitfall for novice modelers is the creation of models that "break" when dimensions or constraints are altered. The project mirrored engineering workflows by requiring iterative revisions, a context where poorly constrained models require significant rework. By confronting students with the need to modify their designs to achieve physical functionality, the project reinforced the importance of design intent, structuring feature trees and parent-child relationships which allow for future alterations. This approach ensured that students were not merely learning to replicate shapes but were developing the strategic modeling skills necessary for professional engineering practice.

It is necessary to acknowledge the limitations of this study, particularly the variables introduced by utilizing different instructors across cohorts and the natural fluctuations in section sizes between semesters.

Conclusion:

Overall, the integration of automated grading software circumvented traditional resource constraints, enabling both a substantial increase in assigned modeling exercises and the inclusion of a complex design project. This shift allowed students to apply their CAD skills to open-ended design challenges, which stood in stark contrast to standard, prescriptive recitation exercises. Ultimately, the combination of high-volume practice and immediate, detailed feedback contributed to a significant increase in the CSWA pass rate.

References:

[1] K. Jaakma and P. Kiviluoma, "Nine Years of Systematic CAD Course Development: What Did We Learn?," in *European Society for Engineering Education (SEFI)*, European Society for Engineering Education (SEFI), 2023, pp. 2203–2210. doi: 10.21427/6YZM-F274.

[2] F. Mandorli and H. E. Otto, "Negative Knowledge and a Novel Approach to Support MCAD Education," *Comput. Aided. Des. Appl.*, vol. 10, no. 6, pp. 1007–1020, Jan. 2013, doi: 10.3722/cadaps.2013.1007-1020.

[3] M. Guerci and D. Baxter, "Automating An Introductory Computer Aided Design Course To Improve Student Evaluation," in *2003 Annual Conference Proceedings*, Nashville, TN: ASEE Conferences, 2003, pp. 8.258.1-8.258.9. doi: 10.18260/1-2--11479.

[4] N. Veurink and G. Hein, "Modifying an Assembly Project to Improve Student Dimensioning Skills," in *2014 ASEE Annual Conference & Exposition Proceedings*, ASEE Conferences, pp. 24.913.1-24.913.12. doi: 10.18260/1-2--22846.

[5] S. Anwar and E. Granlund, "Enhancing A Freshman Level Engineering Design Course Through Project Based Learning," in *2003 Annual Conference Proceedings*, ASEE Conferences, 2003, pp. 8.515.1-8.515.10. doi: 10.18260/1-2--11803.

[6] J. Langenbach, A. Deiters, A. Hortop, R. Lachmayer, A. Lohrengel, and T. Vietor, "Improving Engineering Education Through Distributed Development Projects," in *Proceedings of the 16th International conference on Engineering and Product Design Education*, Netherlands, 2014, pp. 213–219.

[7] R. Webster and R. Ottway, "Computer-Aided Design (CAD) Certifications: Are They Valuable to Undergraduate Engineering and Engineering Technology Students?," *J. Eng. Technol.*, vol. 35, no. 2, pp. 22–32, 2018, [Online]. Available: https://docs.lib.purdue.edu/soetfp

[8] Z. Rofiq, M. B. Triyono, Surono, and H. Pratiwi, "The effect of BNSP CAD competency test certification on the acceptance of mechanical engineering graduates from vocational high school in the machining industry," in *AIP Conference Proceedings*, AIP Publishing, Sep. 2025, p. 020009. doi: 10.1063/5.0292630.

[9] R. F. Hamade, H. A. Artail, and M. Y. Jaber, "Evaluating the learning process of mechanical CAD students," *Comput. Educ.*, vol. 49, no. 3, pp. 640–661, Nov. 2007, doi: 10.1016/j.compedu.2005.11.009.

[10] A. Garland and S. Grigg, "Evaluation of Humans and Software for Grading in an Engineering 3D CAD Course," in *2019 ASEE Annual Conference & Exposition Proceedings*, Tampa, Florida: ASEE Conferences, 2019. doi: 10.18260/1-2--32764.

[11] K. Hekman, "Automated Grading with Rapid Feedback for SOLIDWORKS Files," in *2024 ASEE Annual Conference & Exposition Proceedings*, Portland, OR: ASEE Conferences, 2024. doi: 10.18260/1-2--46631.