Automated Grading with Rapid Feedback for SOLIDWORKS Files

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Abstract

SOLIDWORKS is a frequently used CAD program in various engineering disciplines. Generating solid models allows students to develop the skills necessary to become proficient in the software. The traditional grading method of the student submitting their work and their teaching assistant or professor grading is time-consuming, with delayed feedback for the student. One solution for the instructor is Graderworks, which reduces the grading time for the faculty by comparing students' files with the solution file using a rubric. While this helps the professor, students usually cannot redo their assignments to learn from their mistakes. Because of this, an automated grading program has been developed. With the program, students email their work to a dedicated email, and the program grades their work, sending them the grading rubric with their score. The program currently can grade SOLIDWORKS models and assemblies, including different configurations. In addition to the grading, the program also checks for plagiarism by comparing the features in each student's model with the other models that other students have submitted for that assignment, alerting the instructor if the program finds a match. Students at California Baptist University used the program in CAD classes for two different majors. Assignments included tutorials included in SOLIDWORKS and other drawing assignments based on an engineering drawing. At the end of the semester, the students completed a survey concerning their experiences with the program. Overall, the students liked using the program and appreciated the instant feedback and the chance to improve their scores.

Background/Introduction

Grading of 3D solid models can be a time-consuming task. Baxter and Guerci used SOLIDWORKS macros to grade 3D CAD files [1]. Kirstukas developed a file comparison program in Visual Basic to evaluate Siemens NX solid model files [2]. Ault and Fraser created an automated grading system for Creo files, which checked for the number of each feature type and overall geometry. [3] Garland and Grigg compared human and software grading in an engineering CAD course [4] using Graderworks [5], which Dr. Garland developed. He has continued improving the product and has become a Certified Solution Partner for SOLIDWORKS [6]. Graderworks can compare geometric properties such as volume, center of mass, and moment of inertia to a reference file. Such a comparison is similar to the Certified SOLIDWORKS Associate in Mechanical Design exam [7], where students generate SOLIDWORKS files and input a geometric property, such as mass or center of mass, to determine if their drawing is correct. Bojcetic et al.'s method allows for more refined grading criteria, grading features, and sketches in addition to the basic geometry [8]. Overall, the developed automated grading systems speed up the grading time for faculty, allowing for more homework. Still, they do not provide quick feedback, allowing students to learn by correcting

their mistakes. Having rapid feedback was the motivation for developing an email-based grading system.

Program Operation

The program can grade based on the geometric properties of volume, center of mass location, and mass moment of inertia. In addition, the instructor can specify points for the material and if all sketches are fully defined. The material specification is helpful since the mass moment of inertia depends on it, and students will try to figure out their geometry errors when the problem is the wrong material.

Figure 1 shows a typical response from the program. In this case, the student made several errors. One of their sketches was not fully defined since they did not constrain the center hole to

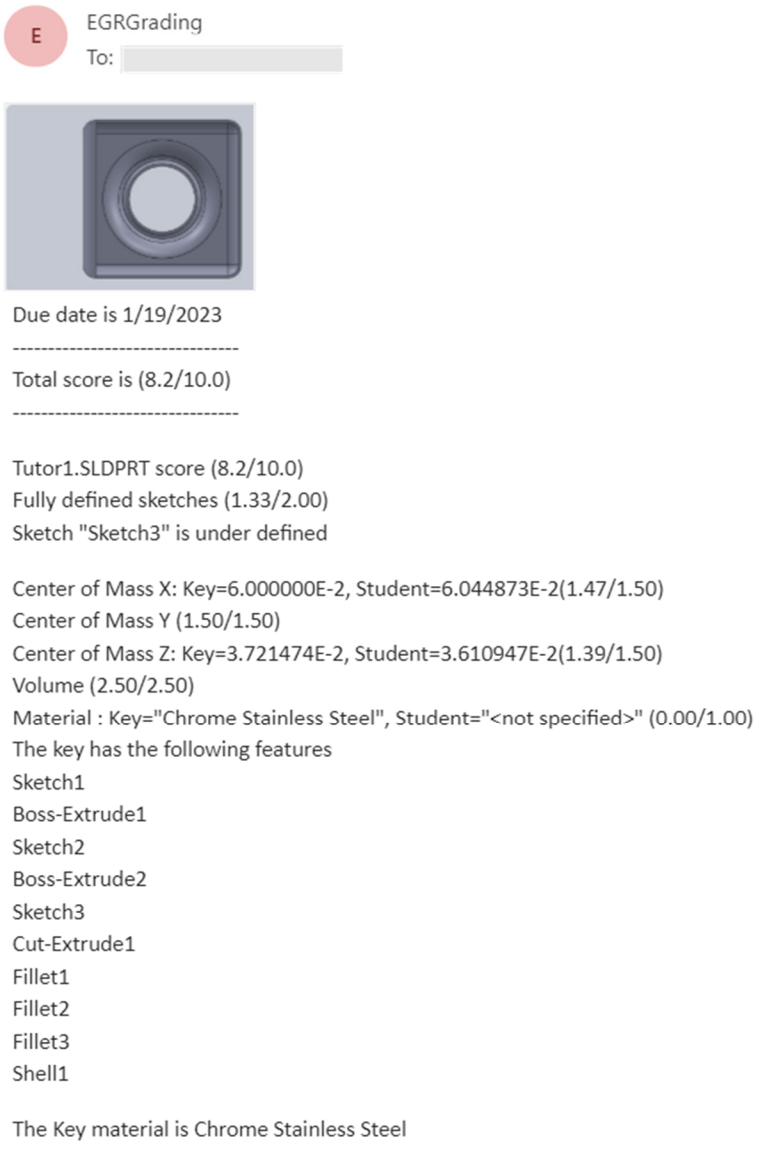

Figure 1, Typical Grading Program Feedback

be concentric with the outer cylinder. The fillets had the wrong radius, leading to an error in the center of mass. Lastly, they needed to define the material. The program also sends an image file for each part or assembly that the student submitted. The image shows whether the student submitted the correct file or forgot to include the part drawings for an assembly.

Additional Student Aids

Since the feedback is limited to overall geometry problems, to help the students understand their mistakes, the instructor provided example files for the students. For the tutorial problems, SOLIDWORKS files were included since the tutorial provides all of the steps for construction. STEP files imported into SOLIDWORKS were given for assignments from an engineering drawing. With the files, students can use the SOLIDWORKS document geometry compare to find the difference between their file and the reference file. Figure 2 shows an example of the document compare function. In this case, the fillet radius on the edge of the knob was incorrect, so SOLIDWORKS highlighted it. For some files, the document compare function did not work. In this case, a student can put both files in an assembly so they overlap. Figure 3 shows how overlapping the two parts indicates that the lower arms are not long enough.

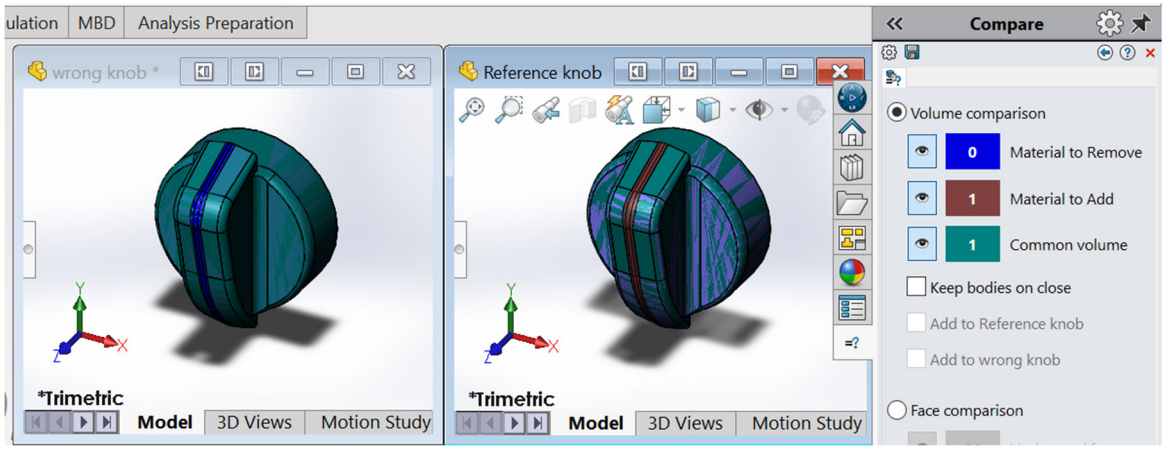

Figure 2, Document Geometry Compare Example

Figure 3, Reference Hook (Red) and Student Hook (Silver) in Assembly to See Differences.

Program Implimentation

Students used the program in CAD classes for two different majors at California Baptist University, a medium-sized private university in Southern California. The author first used automated grading in the Spring Semester of 2020 in his section of a required junior-level mechanical engineering SOLIDWORKS/ CAD-CAM/FEA class. Students in the other section had the option of using the program as well. After the successful first year of using the autograder, students used it in both course sections. In the Fall semester of 2021, another professor adopted the program for a required sophomore-level biomedical engineering class for SOLIDWORKS. Both classes used some of the tutorials provided with SOLIDWORKS to introduce the students to SOLIDWORKS. The instructors of the classes provided videos of someone working through each tutorial, and they had access to the tutorial text from SOLIDWORKS. Figure 4 shows the tutorials used in the class and the corresponding email subject used for grading. The number of submissions for each assignment for each email was compiled to determine student use of the resubmission potential. Figure 5 shows the result of this

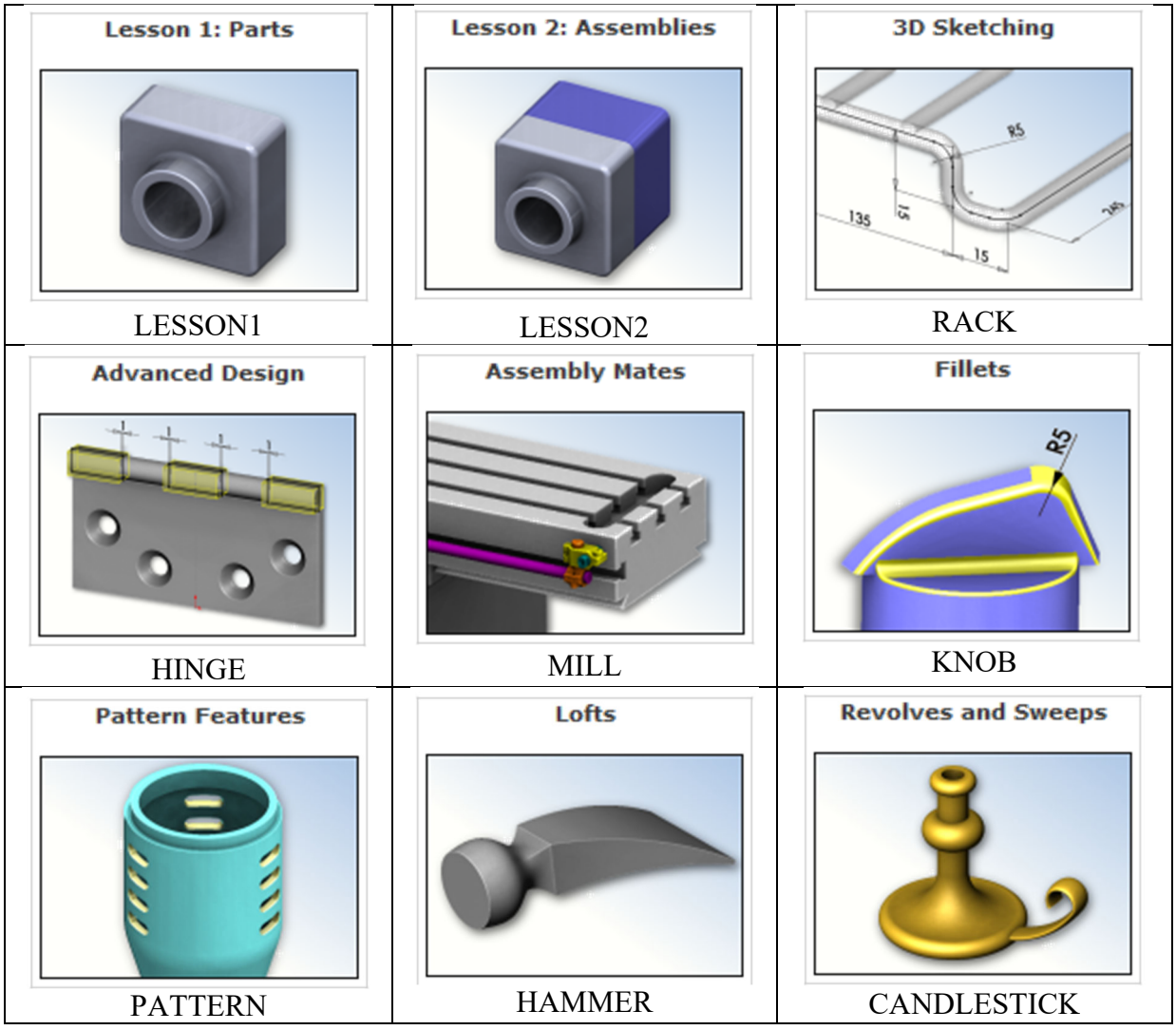

Figure 4, SOLIDWORKS Provided Tutorials with Email Subject.

compilation and the average number of submissions for the assignment. Figure 6 shows the same information for the Biomedical Engineering course. Students benefited from the ability to submit multiple times, with most of the average number of submissions being over two. The ME course graded volume and moments of inertia and required all sketches to be fully defined, while the BE course only specified the volume to match. The different specificity in grading led to the average number of submissions for the ME course being greater than that of the BE classes. The CANDLESTICK assignment has significantly lower submissions since the instructor added it during the Fall 23 semester.

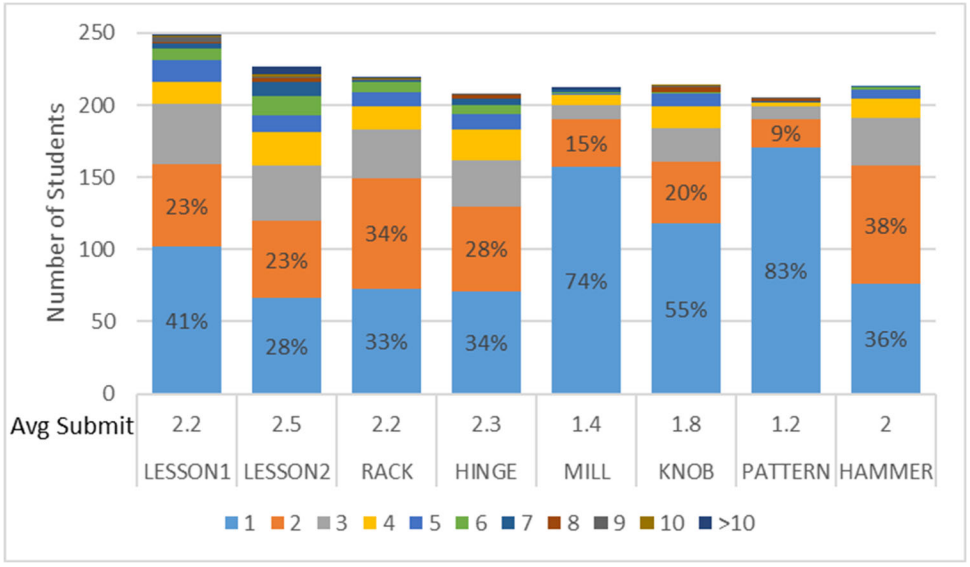

Figure 5, Mechanical Engineering Class Tutorial Submissions

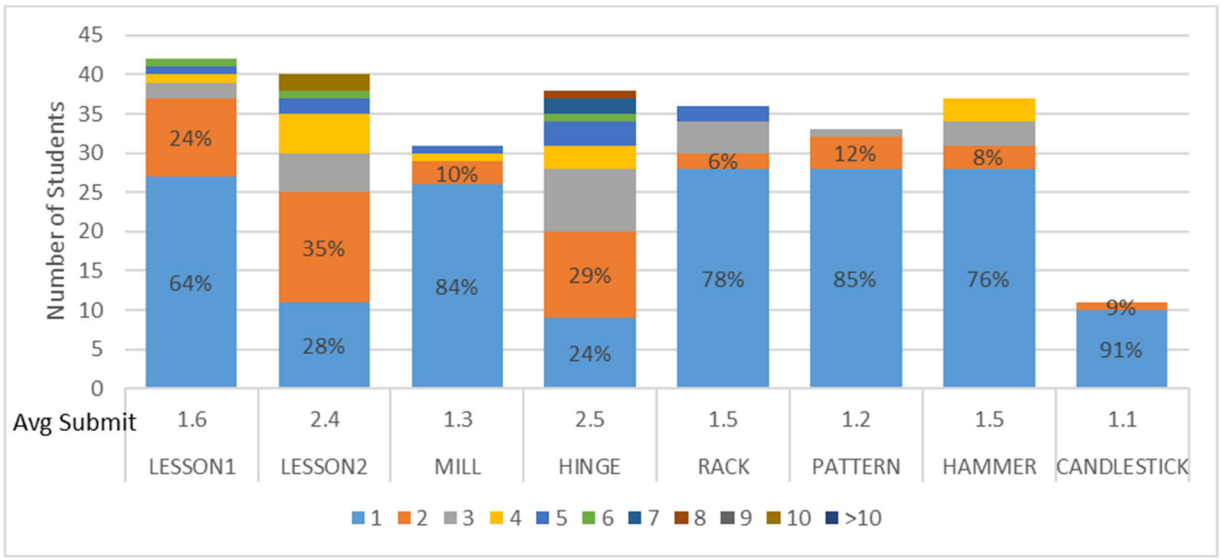

Figure 6, Biomedical Engineering Class Tutorial Submissions

Students worked on additional assignments based on an engineering drawing to help them apply the principles they learned in the tutorials. Images of the SOLIDWORKS files for the assignments for the ME class can be seen in Figure 7. Figure 8 shows the number of attempts for

each of the assignments. Over half the students needed more than two attempts for the BALL and HOOK assignments. The LOG involved creating different configurations for a part the instructor provided so it was easier for the students to complete. STARBALL involved editing the BALL file to add the star pattern, so there were few opportunities for mistakes.

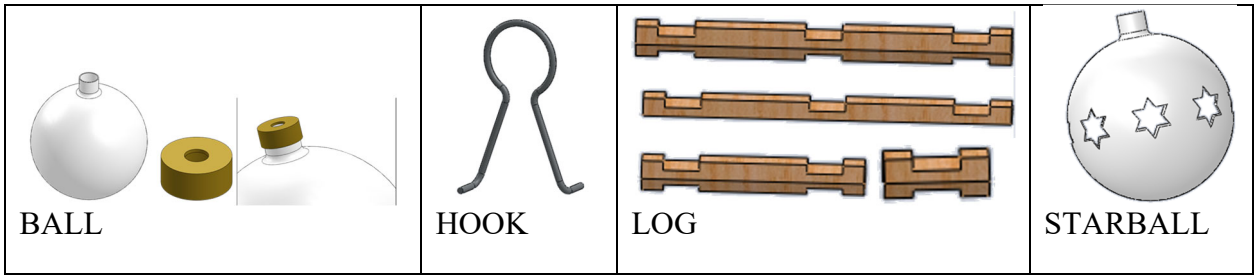

Figure 7, Mechanical Engineering Assignments

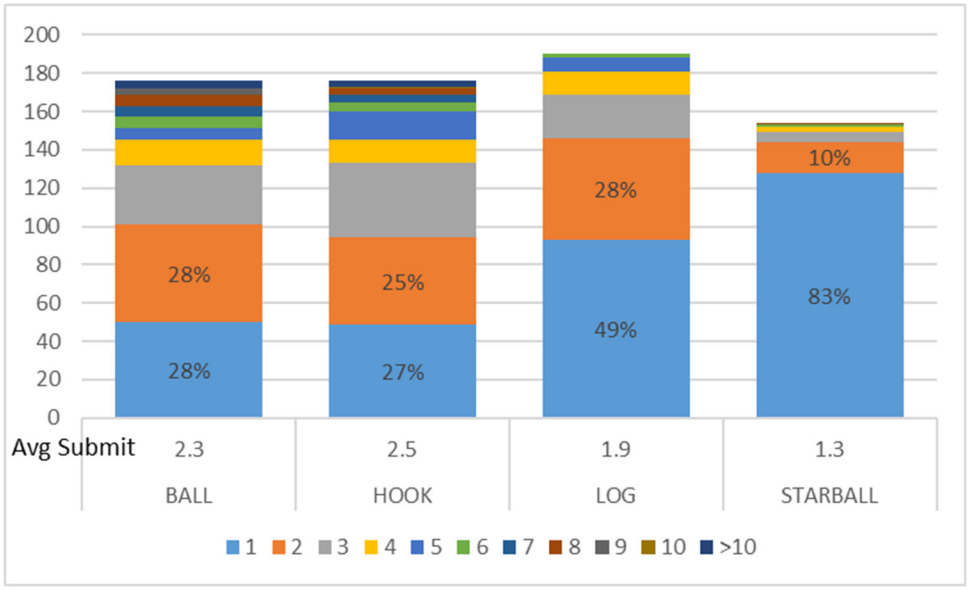

Figure 8, Mechanical Engineering Assignment Grading

Figure 9 shows the items students had to create based on a dimensioned isometric drawing in the bioengineering course. The number of attempts that the students made is seen in Figure 10. Students demonstrated their drawing skills in that most could complete their assignments on their first attempt.

Since the author was also assigning most of the auto-graded assignments before implementing the program, he analyzed the students' total scores on these assignments before and after implementing the computer grading. Table 1 shows the groupings of the grades. Grades were limited to the sections the author instructed, as students could request the instructor or TA to grade their work in the other sections of the mechanical engineering course. One complicating factor in comparing grades was the global pandemic, where classes went remote during the spring semester of 2020 and were taught remotely in Spring 2021. These grades were lower than the human-graded ones. However, when classes were back in person in 2022, the grade distribution was similar to before the implementation of the grading program. The similar grade

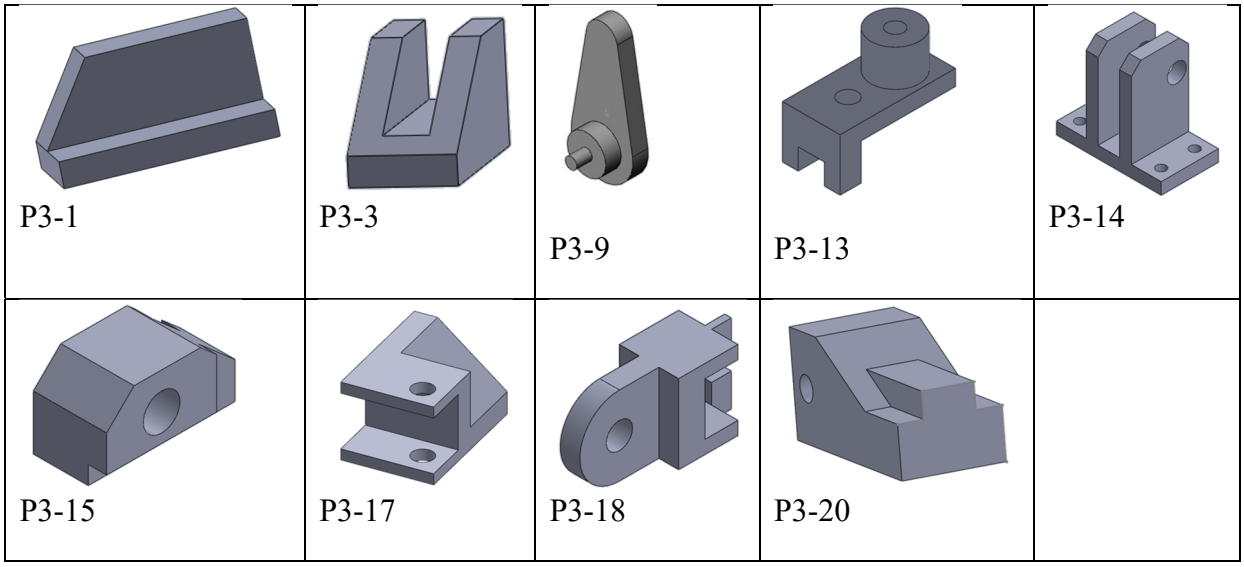

Figure 9, Biomedical Engineering Assignments

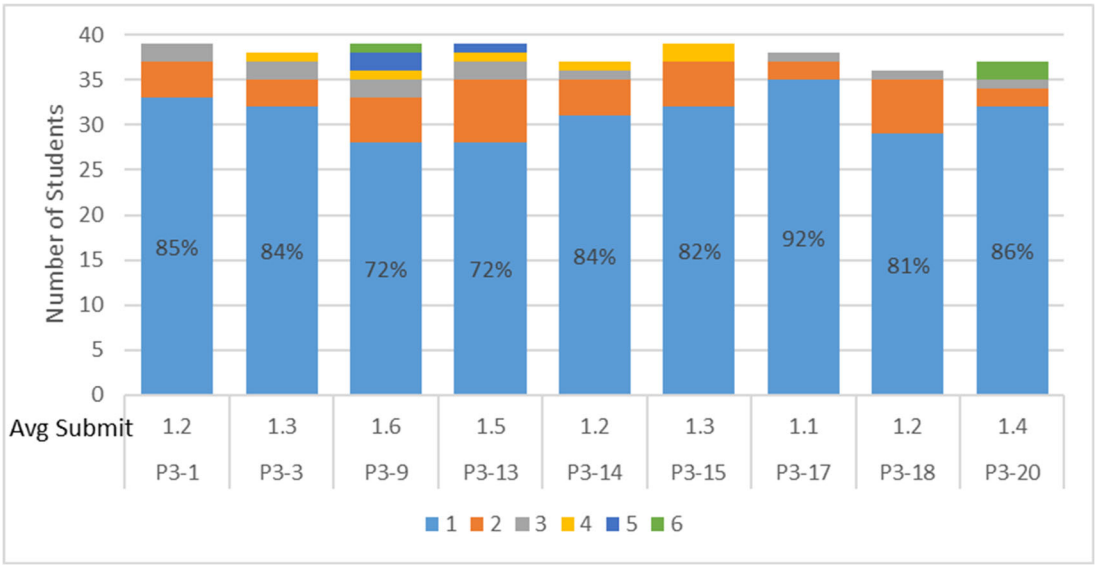

Figure 10, Biomedical Engineering Assignments Number of Submissions

range confirmed the author's assumption that the ability to resubmit their assignment balanced out the computer offering less partial credit than a human instructor.

Table 1, Grade Groupings

Lable	Range
A	$score \geq 90\%$
B	$80\% \leq score < 90\%$
C	$70\% \leq score < 80\%$
D	$60\% \leq score < 70\%$
F	$score < 60\%$

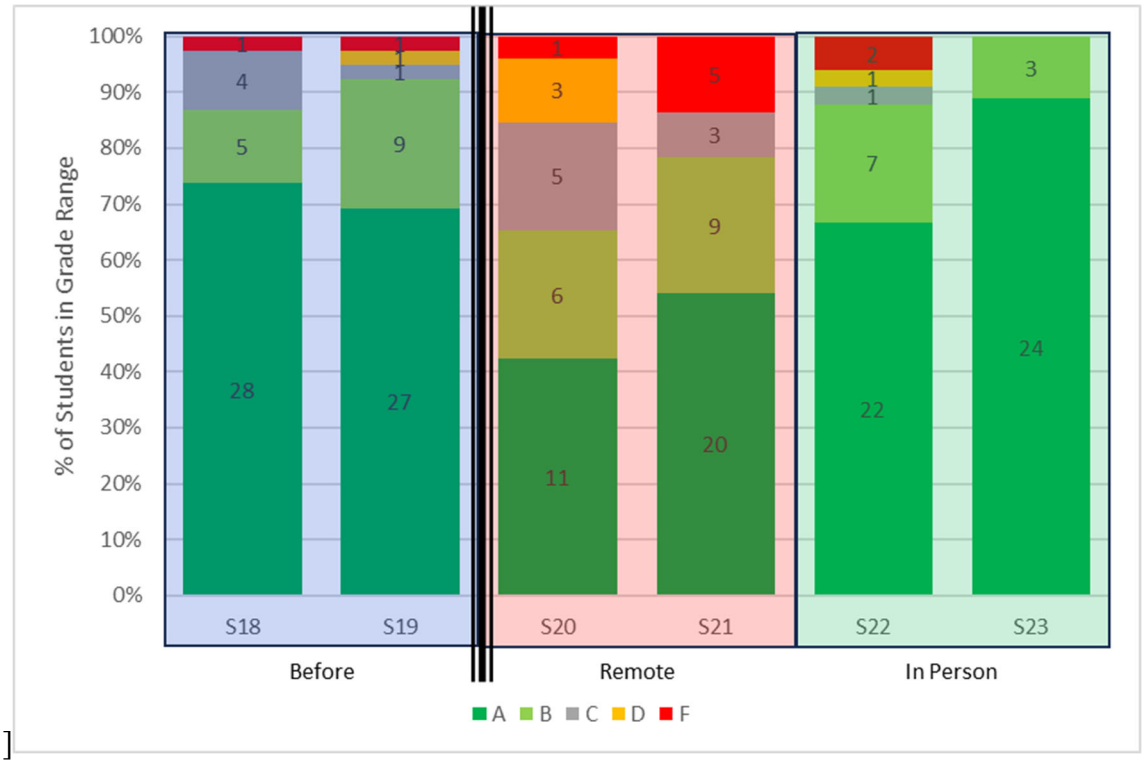

Figure 11, Students' assignment grades before and after auto-grading implementation

Professors' and Students' Opinions of the Program

The instructors have appreciated the reduced time spent grading, as the courses do not always have a teaching assistant. The program shows the students that they are making a mistake, leading them to ask for help from other students or the professor. The instructors teach their courses in a flipped manner, where students go through the tutorials in class independently, so the instructor can help individual students when they have difficulties. Checking for fully defined sketches encourages good habits in the students.

To discover the students' thoughts about the program, after receiving IRB approval, at the end of the semester, students were asked to take a survey concerning their experience using the automated grading for a small amount of extra credit. Students ranked the following items on a Likert scale.

- I found the program helpful.
- I found the text description of the errors easy to understand.
- I found the text description of the errors helpful.
- I used the reference models and the compare function in SOLIDWORKS.
- I found the compare function in SOLIDWORKS helpful.
- I found the program easy to use.
- The program improved my SOLIDWORKS modeling skills.
- The grading reply from the program came in a timely manner.

- Based on my experiences with the program, I would rather use the grading program instead of having a TA grade my homework by hand.

Figure 12 presents the results of the mechanical engineering survey. Only six out of fourteen students responded to the survey in the biomedical engineering class, which distorts the data. The figure also shows the percentage of students who responded positively (Strongly Agree or Agree). Overall, the students found the program helpful and timely. The text description of the errors was expected to score lower, as it only says something is wrong but not exactly what is wrong. The second year of use was rated higher than the first, as some of the kinks were worked out for the first year. The percentage of students using the reference models could be lower because students only had errors in fully defined sketches, not part geometry. Since it involves extra effort, students may resort to it only if they cannot find their mistakes on their own. Most students prefer automated grading to having a TA grade their work, so the college continues to use the program.

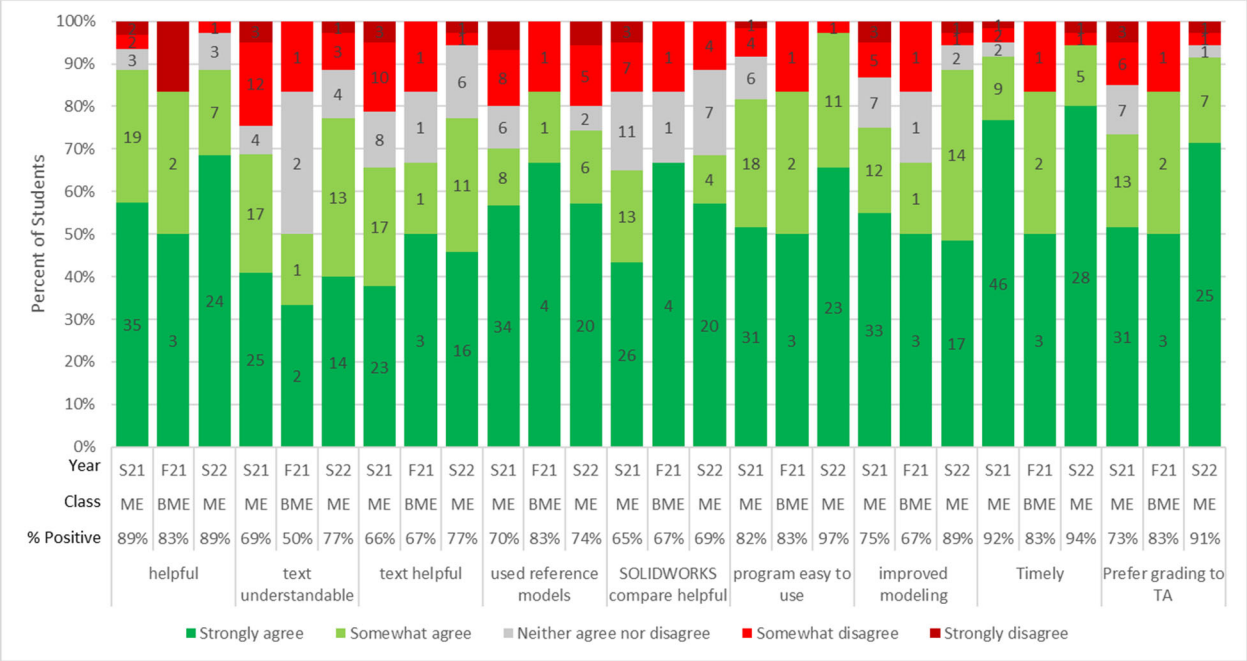

Figure 12, Student Survey Results

Conclusion and Future Work

In conclusion, an email-based automated grading program with rapid feedback for SOLIDWORKS files has been developed. The program calculates the score from the model's geometric properties, similar to the SOLIDWORKS certification exam grades. Students email their files, and the program emails back their scores. Submission data shows students taking advantage of multiple submissions. A survey of students revealed they found the program helpful and preferred using it to have their work graded by a TA. The author developed a web interface for the program, and the college used it in the Spring semester of 2024.

One further improvement to the program could include grading SOLIDWORKS drawings. Another improvement could involve grading sketches and other operations (rotate, extrude) like Bojcetic et al. [8] to give students feedback on specific mistakes they made in a tutorial problem where all the steps are specified.

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