Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #47498

Development of a Web-Based Automated Grading System

Dr. Keith Hekman, California Baptist University

Dr. Keith Hekman is a full professor in Mechanical Engineering. He has been at California Baptist University for sixteen years. Prior to teaching at CBU, he has taught at Calvin College and the American University in Cairo. His Ph.D. is from the Georgia Institue of Technology

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Abstract

Automated grading is helpful for students, providing them with rapid feedback, which allows them to increase their learning by providing the opportunity to learn from their mistakes. Automation also assists professors by reducing the time they spend grading student work. Previous work showed that students preferred using an automated grading system to having a TA grade their work.

A web-based system has been developed based on the email-based system currently used at the university. Interfaces were developed to grade AutoCAD, SOLIDWORKS, Excel, and LabVIEW files. From the student perspective, students choose the assignment they are submitting and then upload the appropriate file(s). The back end of the web page grades the student's work, providing textual and graphical feedback on their submission. On the web page, students can review their scores for each assignment and access the scoring report and submitted files for each submission.

From the professor's perspective, classes are created by uploading a file with the problems and corresponding due dates and the class lists from the learning management for each section. Once the professor makes a class, they can access the students' view to practice submitting assignments. In addition, they can view each student's grades on each assignment in a section. By clicking on a student's score, they can retrieve each student's submitted files and the grading feedback that the student received.

Students in one class with four sections used the web page for AutoCAD and Excel. One class with two sections used the SOLIDWORKS grading function. One class used the LabVIEW grading interface. An additional class used the Excel grading feature. At the end of the semester, students were surveyed concerning their experience utilizing the grading web page. Students had similar opinions for both email and web-based grading.

Another benefit of shifting to the web is having multiple machines process grading requests, speeding up grading time and increasing reliability.. Having multiple machines processing requests speeds up the response for the students and leads to possible collaboration with other institutions.

Introduction

Manual grading is probably not the favorite part of a teaching job for some professors. They could spend their time and effort on more productive work, such as searching for new applications and developing new lecture topics. In addition, manual grading does not provide instant feedback to the students on their performance and understanding. More and more homework has moved online in recent years, and many textbooks come with online homework assignments with automated grading.

Some research has shown that automated grading is helpful for students, while others show a more neutral effect. Arura *et al.* show that online homework significantly improved students' grades in a statics course [1]. Multiple attempts at homework problems have been shown to prove the scores in an economics class [2]. Magalhães *et al*. [3] provide a literature review of the

benefits and pitfalls of online homework. They noted that others found that the ability for students to try again may encourage students to practice to achieve mastery [4] and that randomization of exercises is likely to reduce cheating [5]. One drawback of online homework that they reported is that it emphasizes the final answer rather than the process. [6] Cooke and Al Faruque saw mixed results in implementing Mastering Engineering in a Strength of Materials course [7]. O'Neill *et al.* [8] saw a slight improvement in students' test scores when using Mastering Engineering. Overall, online grading reduces the faculty workload and can benefit the students.

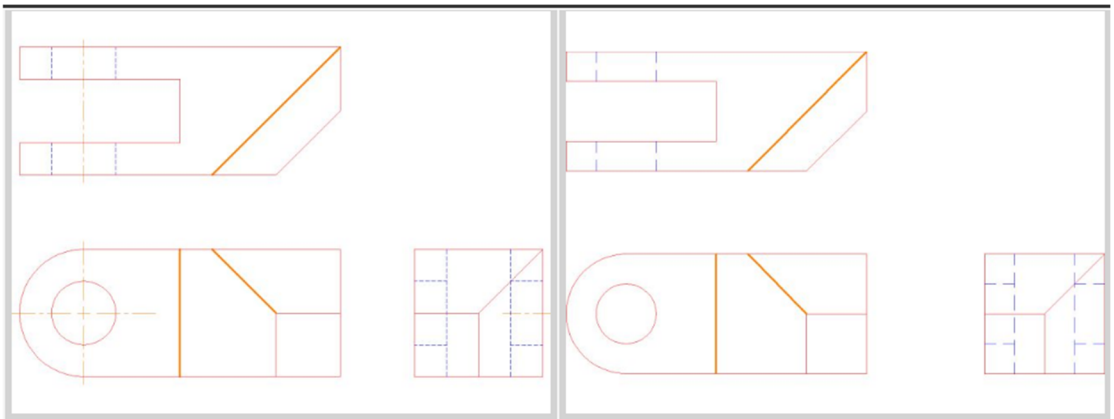
Previous work at the author's university has developed automated grading for AutoCAD [9] [10], Excel [11], SOLIDWORKS [12], and LabVIEW [13]. It was shown that students appreciated the rapid feedback, allowing them to see their mistakes and fix them while working on their homework. The course instructors appreciated the reduced time spent grading the students' work. Details of the grading procedures are provided in these papers. A limitation of the grading applications was that they were email-based and ran on a dedicated computer. This paper describes the transition of the grading programs to a web-based system running in the cloud.

Student Interface

When students start using the web grading system, they create an account using their email and tie it to their student ID. Students can then check their grades or submit work to be graded. When checking their grades, if they click on their grade, they can access all their scores for the previous submissions with a link to the file they submitted for that assignment. Clicking on a score brings up the scoring feedback for that submission, so they do not need to resubmit their work to see their errors.

When students submit their work, they select the assignment they are submitting from a drop-down menu and then upload their file(s) associated with the corresponding assignment. The program backend then grades their work and shows them their score along with feedback on grading, including mistakes that they made. Students are allowed multiple submissions so that they can learn from their mistakes.

For AutoCAD, students are graded based on the degree of matching of lines, circles, arcs, center lines, dimensions, arrays, and hatching compared to an instructor-provided solution drawing. An example of the feedback response from the program can be seen in Figure 1. The top images show the solution and student drawings, with the differences highlighted in orange. Below the image is the text description of the grading and the errors. Students can scroll down to see all of the text. In this case, the student did not draw the diagonal lines with the 45° angle snap, so the delta X did not equal the delta Y. The vertical line should be on the hidden layer, while the student had it on the visible layer. In addition, the student is missing the center marks and center lines.



Solution drawing | Student drawing

Feedback

Due Date is 10/9/2024 at 11:59 PM

Total score is 17.69/20.0

The following items are in the key

Item	Matching Items	Total in key
LINE	31	34
CIRCLE	1	1
ARC	1	1
ARRAYS, CENTERLINES, CENTERMARKS	0	3

For an item to be correct, it needs to be on the correct layer and have the correct size.

The program grades based on item length (deltaZ,deltaY) rather than the absolute position. For grading, the program combines short connected colinear lines into one line. If it appears the program is not grading properly, it may have found a match with another line in your drawing.

The following items do not have a match between the file you submitted and the key

Student Extra Combined Lines

Tab	Layer	Delta X	Delta Y	start point	end point	# of lines
Layout1	Visible	0.9744	-1.0000	(3.0256,0.4708)	(4.0000,-0.5292)	1
Layout1	Visible	0.0000	2.0000	(2.5000,-1.5292)	(2.5000,0.4708)	1
Layout1	Visible	1.9744	2.0000	(5.0000,3.8518)	(3.0256,1.8518)	1

Key Extra Combined Lines

Tab	Layer	Delta X	Delta Y	start point	end point	# of lines
Layout1	Visible	1.0000	-1.0000	(3.0000,2.0000)	(4.0000,1.0000)	1
Layout1	Visible	2.0000	2.0000	(3.0000,3.1542)	(5.0000,5.1542)	1
Layout1	Hidden	0.0000	2.0000	(2.5000,0.0000)	(2.5000,2.0000)	1

Key Extra Center Marks

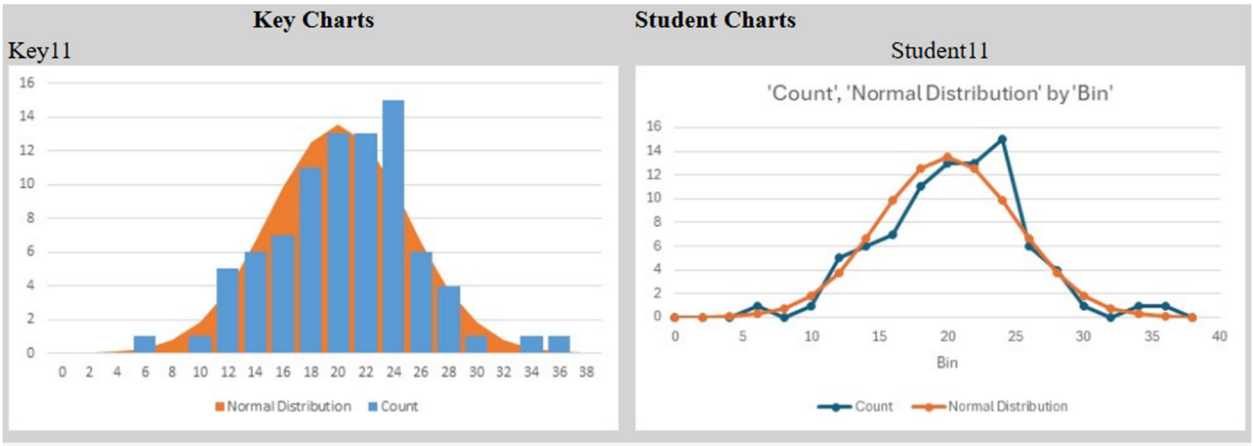
Tab	Layer	Center	Radius
Layout1	Center	(1.0000, 1.0000)	1.0000

Key Extra CenterLines

Tab	Layer	Delta X	Delta Y	start point
Layout1	Center	0.5000	0.0000	(1.0000,4.9042)
Layout1	Center	0.0000	0.0000	(7.9042,1.0000)

Figure 1, Example AutoCAD Feedback

For Excel grading, the program grades worksheets by comparing a solution file to the student's submission. Things like formula values and cell borders can be checked. Similarly, charts can be graded by chart type, titles, data, and many other options. An example of the feedback for Excel charts can be seen in Figure 2. Images of the correct figure and the student's figure are provided at the top of the page. Below the figures is the textual feedback indicating the grading items for this assignment. In this case, the student's data was correct, but they chose the XY-Scatter charts rather than the key values of Colum Clustered and Area. At the bottom of the page, students can download their submitted file with comments in each cell where points were deducted indicating their mistakes.



Feedback

Due Date is 11/5/2024 at 11:59 PM

Total Assignment Score (8.00 / 10.00) (80.0%)

Key Worksheet 1: "normal"
(40.0% / 40.0%) Worksheet

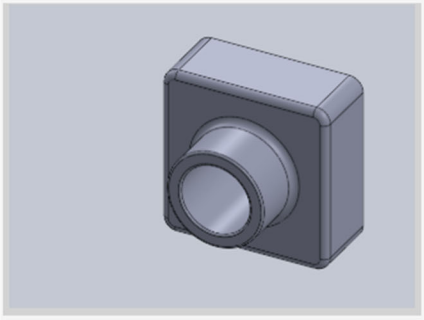
Key Chart 1: "" (40.0% / 60.0% total)
(0.0% / 10.0%) Chart series 1, Chart Type: You had [XYScatterLines] and the key had [ColumnClustered]
(0.0% / 10.0%) Chart series 2, Chart Type: You had [XYScatterLines] and the key had [Area]
(10.0% / 10.0%) Chart series 1, series name
(10.0% / 10.0%) Chart series 2, series name
(10.0% / 10.0%) XY data: Key chart series Count
(10.0% / 10.0%) XY data: Key chart series Normal Distribution

Your file with comments should have automatically downloaded if you have allowed popups for this page. You can also download it by right clicking on this link here

Figure 2, Example Excel Feedback

SOLIDWORKS is graded by comparing the geometric properties of the student's file(s) with the solution files. These include center of mass, volume, and moments of inertia. Material and fully constrained sketches can also be checked. Figure 3 displays an example of the feedback screen.

Below are the images of your files. If they do not look like you expected, check to see if you submitted the correct files



Feedback

```
--------------------------------
Total score is (8.5/10.0)
--------------------------------

Tutor1.SLDPRT score (8.5/10.0)
Fully defined sketches (2.00/2.00)

Center of Mass X (1.50/1.50)
Center of Mass Y (1.50/1.50)
Center of Mass Z: Key=3.721474E-2, Student=4.208620E-2(1.04/1.50)
Volume (2.50/2.50)
Material : Key="Chrome Stainless Steel", Student="<not specified>" (0.00/1.00)
The key has the following features
Sketch1
Boss-Extrude1
Sketch2
Boss-Extrude2
Sketch3
Cut-Extrude1
Fillet1
Fillet2
Fillet3
Shell1

The Key material is Chrome Stainless Steel
```

Figure 3, SOLIDWORKS Feedback

LabVIEW is graded by comparing the student's file with the solution file. Both the objects in the program and the wires between the objects are checked for accuracy compared to the solution provided by the instructor. An example of the textual feedback for LabVIEW grading can be seen in Figure 4. In the feedback, an example of the ability to set a satisfactory score is that if students reach it, they get full credit. This is used for tutorials to have the students do them but not spend too much time to get them perfect. Also seen is the late penalty, which encourages students to keep up with the work. In this example, the student used a control named thermometer (Demo) instead of the supplied VI. Because of this, any wires connected to these elements are wrong. In addition to this, the student did not wire the file pointer to the Write to Text File block. Finally, the student has the error wire have two connections to the while loop.

Feedback

Raw score of 4.30 is below than the minimum satisfactory score of 4.75 (95%)

Keep working

Due Date is 4/19/2024 at 11:59 PM, Submission Date is 1/6/2025 at 7:38 PM

Original Score is (4.30)

50 % late penalty modified score is (2.15)

More than 14 days late

For key file Temperature Monitor.vi

Objects 36/40
Wires 44/53
Total score 4.30/ 5.00

The key has the following extra items:

- SubVI named "Thermometer (Demo).vi"
- SubVI named "Thermometer (Demo).vi"

Your submission has the following extra items:

- Control named "Thermometer (Demo).vi"
- Control named "Thermometer (Demo).vi"

The key has the following extra wires:

Wires between:

- SubVI [Thermometer (Demo).vi] (Terminal 1), While Loop [While Loop] (Right Shift Register Inside terminal 0), CompoundArithmetic [Compound Arithmetic] (Terminal 5), Bundler [Bundle] (Terminal 3), FormatScanString [Format Into String] (Terminal 5)
- Function [Write to Text File] (Terminal 0), While Loop [While Loop] (Tunnel Inside terminal 0), Function [Or] (Terminal 2)
- Function [Write to Text File] (Terminal 2), While Loop [While Loop] (Tunnel Inside terminal 0)
- While Loop [While Loop] (Tunnel Inside terminal 0), Function [Write to Text File] (Terminal 6)
- SubVI [Thermometer (Demo).vi] (Terminal 1), While Loop [While Loop] (Terminal 1), While Loop [While Loop] (Terminal 2), While Loop [While Loop] (Terminal 4), While Loop [While Loop] (Terminal 3)

Your submission has the following extra wires:

Wires between:

- While Loop [While Loop] (Tunnel Inside terminal 0), While Loop [While Loop] (Tunnel Inside terminal 0)
- Control [Thermometer (Demo).vi] (Control), While Loop [While Loop] (Right Shift Register Inside terminal 0), Bundler [Bundle] (Terminal 3), CompoundArithmetic [Compound Arithmetic] (Terminal 5), FormatScanString [Format Into String] (Terminal 5)
- Function [Or] (Terminal 0), While Loop [While Loop] (Loop End)
- Control [Thermometer (Demo).vi] (Control), While Loop [While Loop] (Terminal 1), While Loop [While Loop] (Terminal 2), While Loop [While Loop] (Terminal 3), While Loop [While Loop] (Terminal 4)

Figure 4, LabVIEW Textual Feedback

In addition to the textual feedback, the program highlights the differences between the key file (Figure 5) and the student's file (Figure 6). The title of the missing subVI and the extra control are highlighted. The wires that these are connected to are also highlighted. The wires connected to the *Write to Text File* are highlighted as well. The two error wire outputs are not apparent from the block diagram, as the wires are on top of each other.

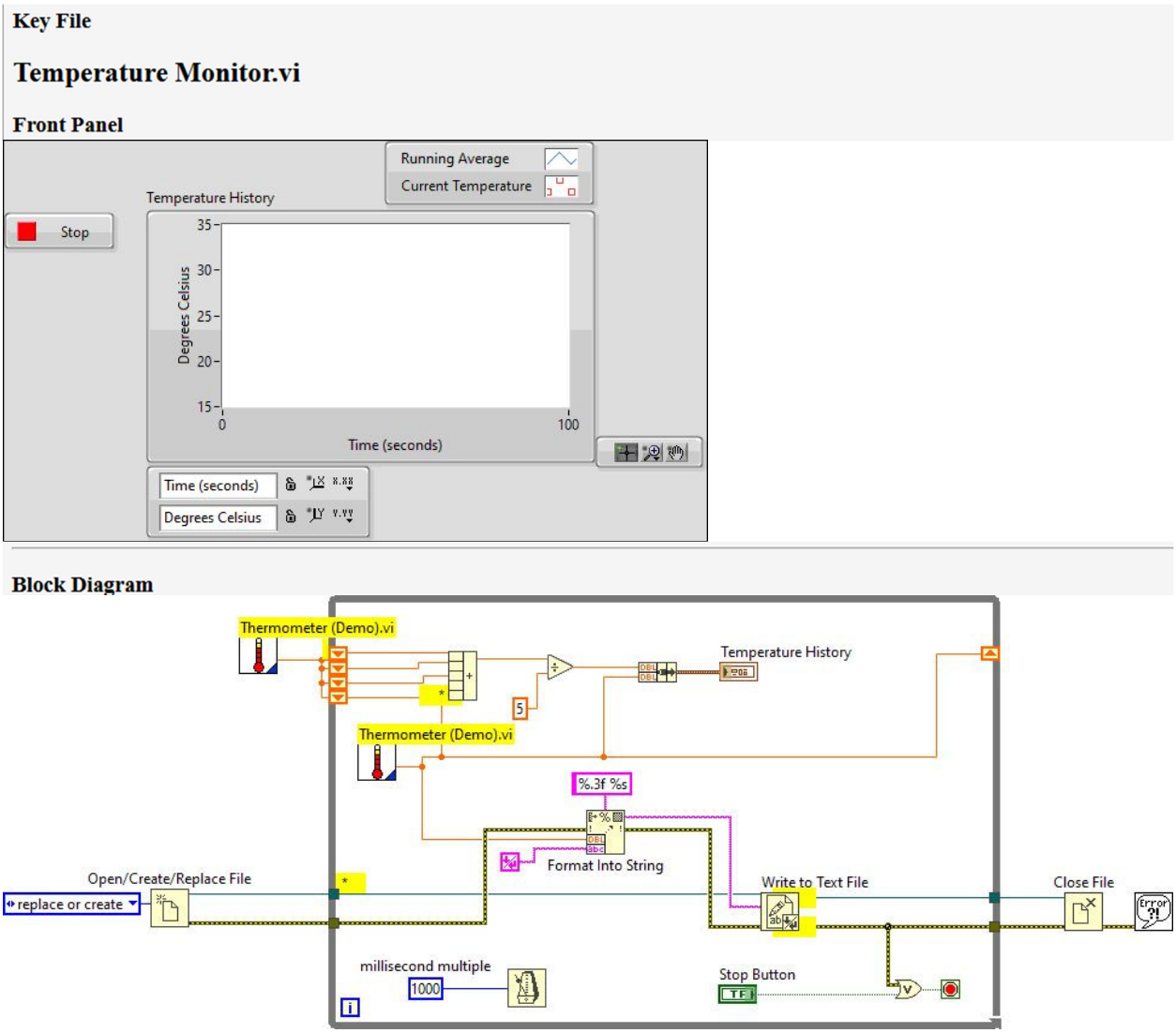
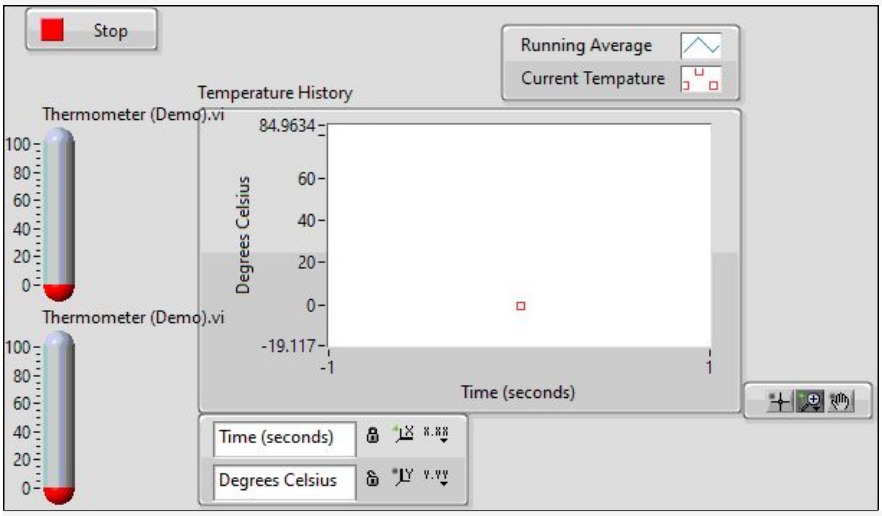


Figure 5, LabVIEW Key with Highlighting

Student File

Temperature Monitor example 9-2.vi

Front Panel



Block Diagram

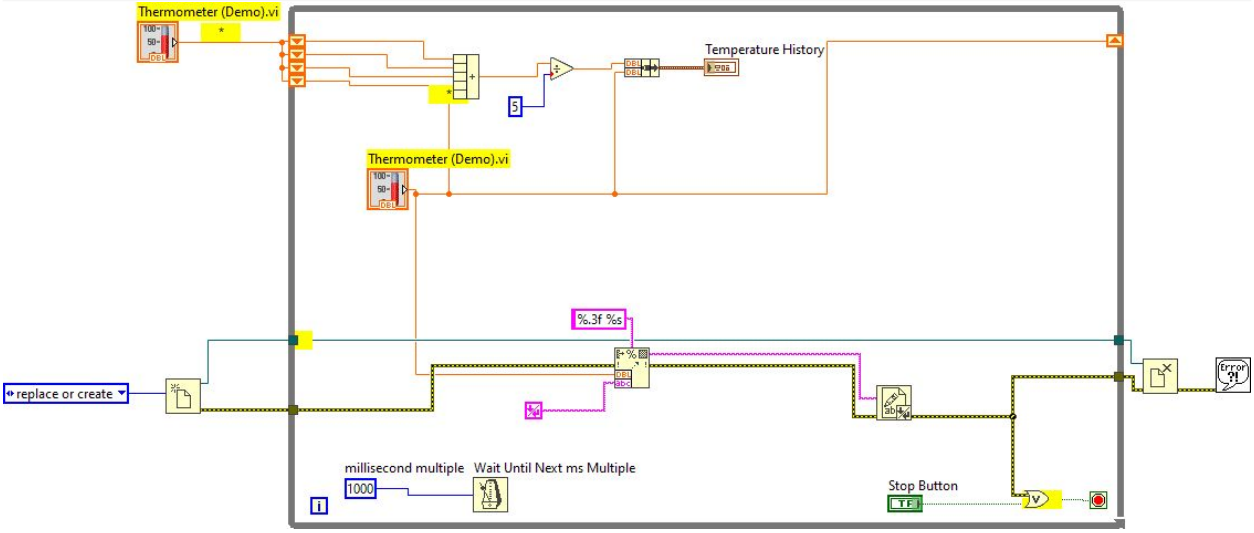
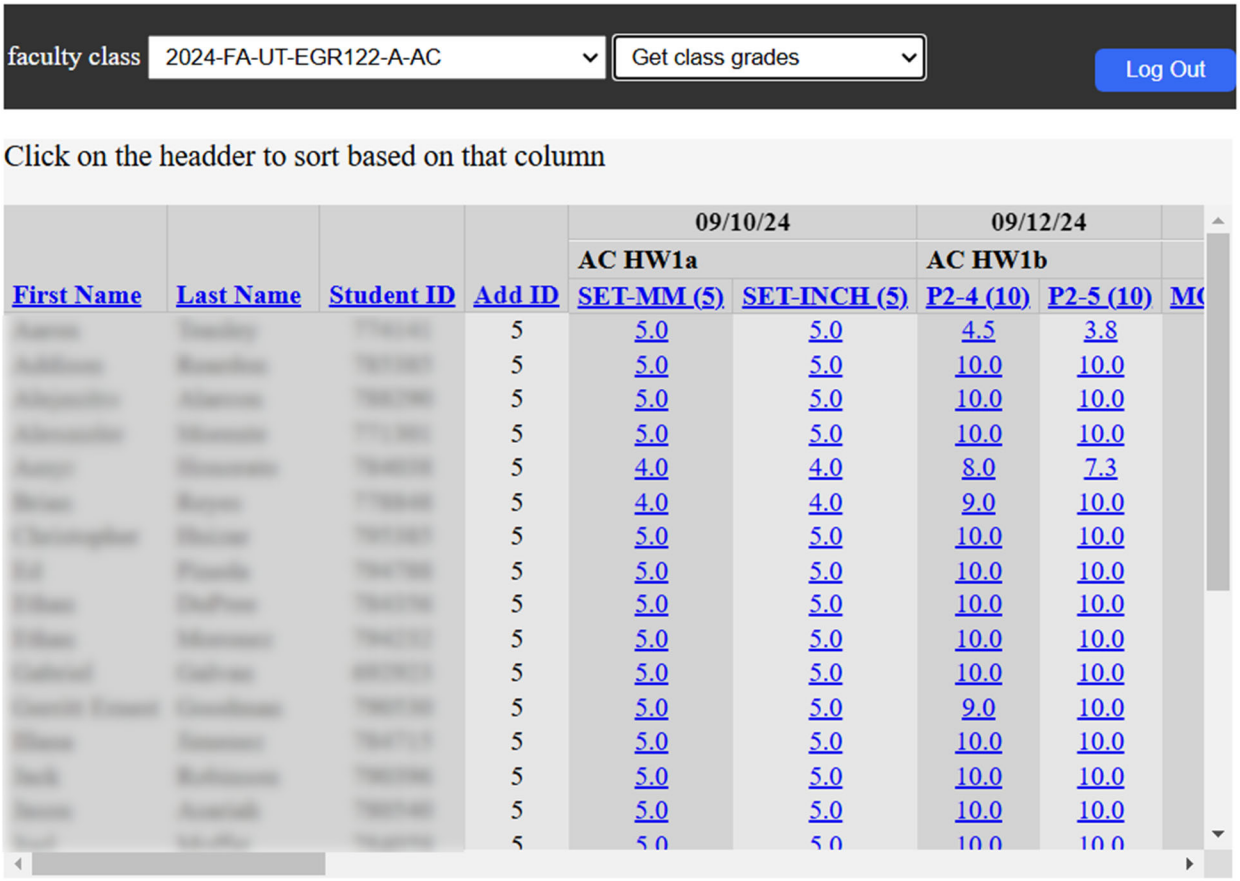


Figure 6, Student LabVIEW file with Highlighting

Faculty Interface

For the faculty interface, a class is created by providing a CSV file with the points, homework grouping, and due dates for the selected assignments, along with the class lists from Blackboard for each section of the class and the section instructor's email. Instructors can then add and remove problems and change due dates from another screen as needed during the semester. When a class is created, students with IDs in the Blackboard Class List are added to the class and can access the assignments.

Once a class is created, faculty can access the grade book for the class. Assignments are grouped by their due date. Clicking on a column header will sort based on that column. The Add ID column has 5 points if the student has created an account, allowing the professor to follow up with students who still need to create an account. Clicking on a student's grade for an assignment will bring up a page with each of the student's submissions. The instructor can either download the submitted file or click on the submission score to see the grading feedback for that submission. This has proven helpful when diagnosing what a student is doing wrong, as the instructor can access their file and feedback without having the student email them the grading details from the email-based system.



First Name	Last Name	Student ID	Add ID	09/10/24 AC HW1a SET-MM (5)	09/10/24 AC HW1a SET-INCH (5)	09/12/24 AC HW1b P2-4 (10)	09/12/24 AC HW1b P2-5 (10)	MC
[redacted]	[redacted]	[redacted]	5	5.0	5.0	4.5	3.8	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	10.0	10.0	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	10.0	10.0	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	10.0	10.0	
[redacted]	[redacted]	[redacted]	5	4.0	4.0	8.0	7.3	
[redacted]	[redacted]	[redacted]	5	4.0	4.0	9.0	10.0	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	10.0	10.0	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	10.0	10.0	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	10.0	10.0	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	10.0	10.0	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	10.0	10.0	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	9.0	10.0	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	10.0	10.0	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	10.0	10.0	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	10.0	10.0	
[redacted]	[redacted]	[redacted]	5	5.0	5.0	10.0	10.0	

Figure 7, Faculty Gradebook View

Faculty retrieve the students' grades from the system by uploading the Blackboard gradebook for the class. The program then populates the gradebook with the assignments, keeping the higher grade between the Blackboard gradebook and the program's database, allowing the instructor to modify a student's grade. The instructor then downloads the updated gradebook and uploads it to Blackboard.

Implementation

The program was implemented in the Spring 24 semester at California Baptist University, a medium-sized private university. Students in four sections of a first-year Engineering Drawing/Excel course used AutoCAD and Excel grading. All engineering and computer science

students are required to take this course. The program graded AutoCAD homework, where students reproduced drawings from the textbook with a single solution. Students were allowed to resubmit until the due date, and then a 20% late penalty was applied. The exams in the course were graded by their instructor since the students were in a timed environment with a single submission. Similarly, web grading cannot evaluate open-ended projects. Similarly, the program graded the Excel homework, where there was a defined solution to the problem. An image of each calculation's location is also necessary for Excel homework, as the program matches the cell calculation result. The instructor graded the Excel tests for the classes.

Students in two sections of a SOLIDWORKS course used the SOLIDWORKS grading. This course is required for junior Mechanical Engineering students, and senior Biomedical Engineering students can take it as an elective. The program checked students' work when they followed tutorials in the SOLIDWORKS program and when they generated parts and assemblies based on engineering drawings. There was also a class project where students created and built an assembly demonstrating an engineering mechanism, which the instructor graded.

One section of a LabVIEW course used the LabVIEW grading. Third-year Electrical and Computer Engineering students are required to take the course, and senior Mechanical Engineering students take it as an elective. The program graded tutorial problems with a defined solution. The tutorials were supplemented by other homework problems that the instructor graded since the grading program shows the problem's solution in the feedback. Also, some homework requirements have different implementation methods.

Finally, a vibrations class with two sections used the grading program for a few Excel problems. These problems were data analysis for some Pasco demonstrations. [14]. For these problems, the instructor provided a CSV file, which included the data and labels to indicate the location of the calculations. Students were required to generate charts based on images of the desired charts to do the analysis.

The program was initially run on one virtual machine at the start of the semester. During the semester, a second virtual machine was added to grade students' work to reduce the wait time for the students on the evening that assignments were due. Students could select which machine they wanted to work on. Both machines used the same database for storing submissions, so it did not matter which machine students worked on.

Student Surveys

In order to compare the students' thoughts about the web grading, at the end of the semester, students were given the opportunity to complete the same surveys that were given when the program was based on email submission. Students completed surveys for Excel, SOLIDWORKS, and LabVIEW. For AutoCAD, there was no recent survey for comparison.

For Excel, the questions on the survey in the required AutoCAD and Excel class were

- I found the program helpful
- I found the email text easy to understand
- I found the email graphs easy to understand
- I found the comments in the Excel worksheet easy to understand
- I found the program easy to use

- The program improved my Excel formula skills
- The program improved my Excel graphing 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.

The data for email-based grading was compiled from the Spring 21 and Spring 22 semesters, and the web-based grading was from the Spring 24 semester. Data from the fall semesters was not included since students who enter the program and are not ready for precalculus are advised to take the course in the Fall, while those who are math-ready take the course in the Spring. Figure 8 shows the percentage of each reply on the Likert scale. The combined percent 'strongly agree' and 'agree' are indicated by '% Positive' in the table. The results from the web grading are shaded.

The responses were converted to a numerical value, with Strongly Agree being a 4 and Strongly Disagree being 0. The mean of these values is indicated on the chart for each grading modality. An independent t-test was performed to calculate the p-value that the means of the two values were the same. This probability is also indicated on the graph.

From the survey, students responded similarly to both methods of program interaction. The response to graphs was slightly higher, likely due to the images displayed in the response compared to an email attachment. None of the differences between the two methods was statistically significant at a 0.05 significance level.

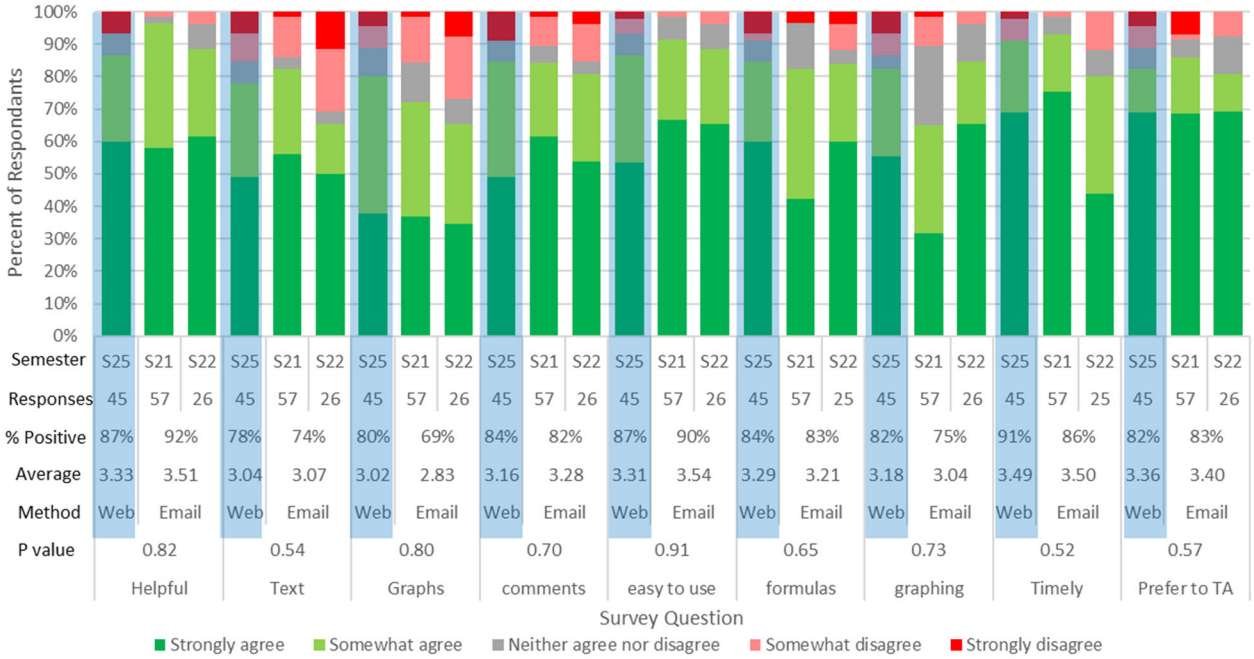


Figure 8, comparison between web and email-based grading survey responses for Excel Grading.

Similarly, the same survey for the SOLIDWORKS email grading was administered for web grading in the SOLIDWORKS class. The relevant questions students responded to on a Likert scale were

- 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.

The student's responses can be seen in Figure 9. A similar statistical analysis was also done, like in the Excel survey. Overall, the responses were similar, with the most significant difference in preferring the program to having a TA grade their work. One possible reason for this difference was that the author had always taught one of the two sections of the course but did not teach either section when the web-based grading was implemented. In these classes, students were given the option to have their work manually graded or use the computer grading.

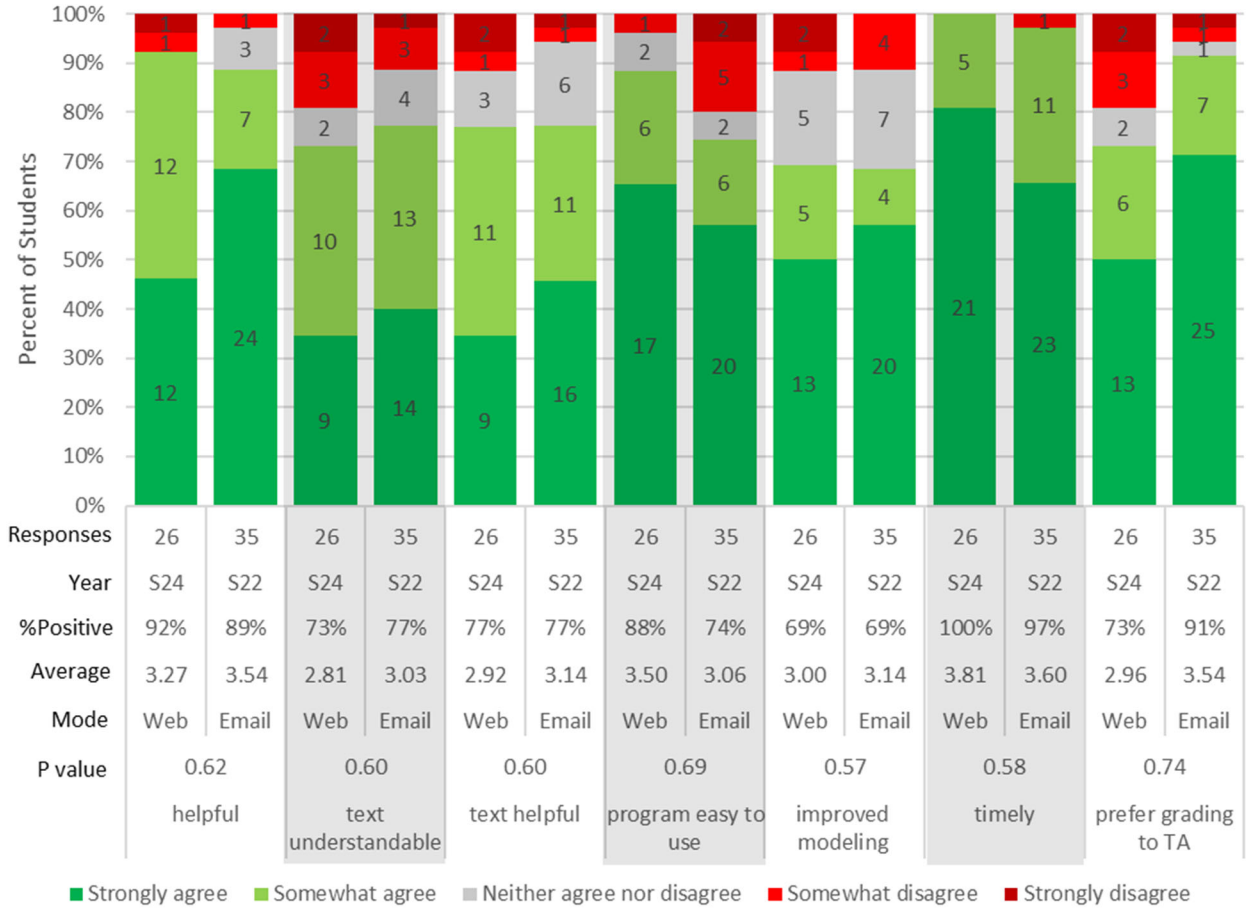


Figure 9, comparison between web and email-based grading survey responses for SOLIDWORKS Grading

Lastly, the LabVIEW course students were surveyed on their opinions of the web-based LabVIEW grading program. The students were asked to answer the following questions 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 found the highlighted LabVIEW block diagrams easy to understand
- I found the highlighted LabVIEW block diagrams helpful
- I found the program easy to use
- The program improved my LabVIEW coding 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.

The responses of the students can be seen in Figure 10. A similar statistical analysis to the Excel data analysis was used to compare the survey results. Once again, the students' opinions were not significantly different between the web-based and the email-based grading.

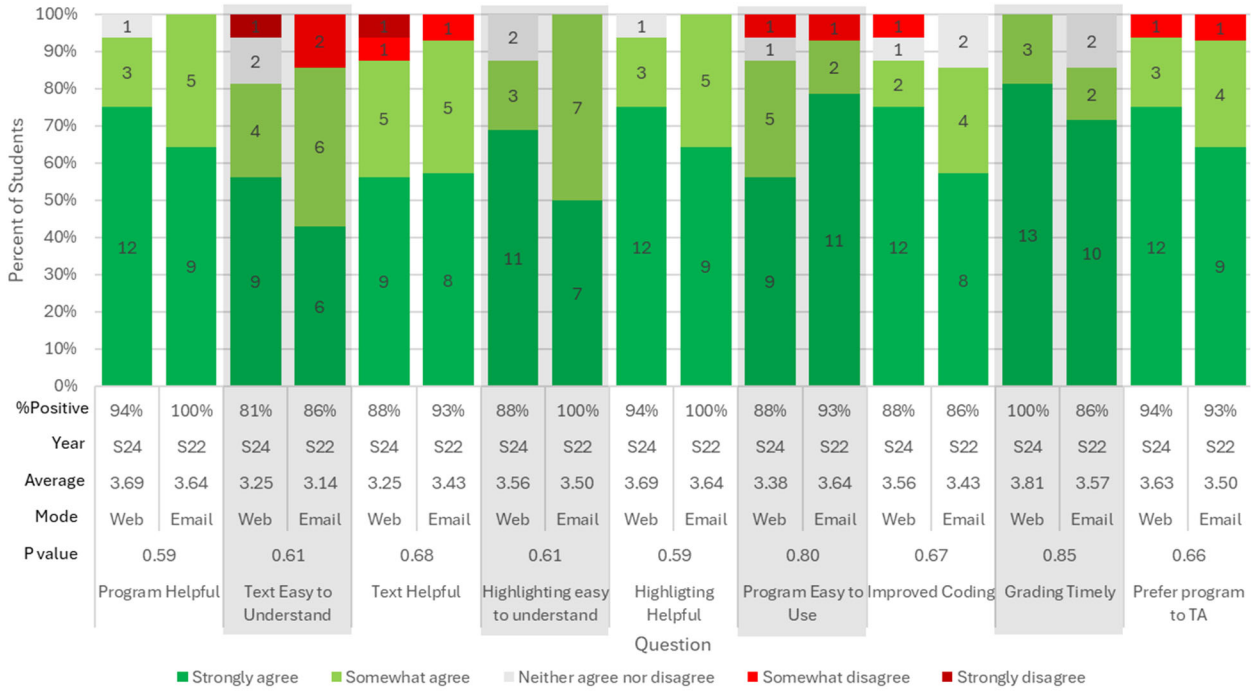


Figure 10, comparison between web and email-based grading survey responses for LabVIEW Grading

Faculty Opinions

In addition to the author, three other professors have used both email and web-based grading for AutoCAD and Excel, one professor used both email and web-based grading for AutoCAD, Excel, and SOLIDWORKS, and two professors have only used web-based grading for AutoCAD. These professors solicited their opinions about the web grading.

From a professor who has taught many sections of the AutoCAD and Excel class, both with email and web-based grading:

A. Program has so much promise, especially for teachers who are limited in time to grade CAD assignments for large classes,

B. Love the fact that you can create your own CAD.dwg file and make it part of the grading system's list of assignments to assess,

C. Has the potential to be launched via an APP and have students view their scores and mistakes

D. Feedback via grading results can be enhanced further, though it does add a bit of critical thinking to decipher the way the errors are being detected versus the correct files

E. Needs to be maintained periodically to keep up with new assignments from current CAD workbooks

Thank you so much for the awesome tool...

From a faculty member who has used both email and web-based grading for AutoCAD and Excel:

> In my opinion, based on experience with AutoCAD and Excel, this is an excellent example of an instructional tool that helps foster consistency and clear guidelines for students. This helps give baseline standards that students can ascribe to and eliminates the majority of one of the most time-consuming aspects of teaching: grading with consistently rapid feedback.
>
> I love that this tool is able to accommodate visual grading in the form of **.dwg files and textual grading in the form of .xls** files.
>
> I appreciate the ease with which an instructor can integrate with Blackboard (a simple download and upload of their grade book as a .xls file in both systems).

From one professor using the automated grading for AUTOCAD for the first time:

> I love the web grading program, and it has been a great help to me and to students (I believe). Almost instant response/feedback allows students to identify their mistake(s), if there is any, and allows them to correct them.
>
> As you know, there are some areas for improvement. When many students submit their files for grading at the same time, the program or sever gets down and does not work.
>
> Overall, I appreciate the program and your help.

From the other professor who was using the automated grading for AutoCAD for the first time:

> I would like to echo the Feedback D. Overall, I think the grading program does its purpose. It surely saves a lot of instructor time by having the grading program show the flaws of students' work and help them correct their errors. If we could improve it a bit, I wonder if we could make the feedback contain some additional information with a brief note (such as missing lines, redundant lines, incorrect coordinates, etc.). I know it cannot be totally self-explanatory, but I had a hard time locating the errors in students' drawings at times and

ended up coming to your office :-) If we would like our students to be able to correct their errors by themselves without asking their instructors for further help, the current feedback on the student's drawings works for the most part but seems a bit insufficient at times. That way, even if the students do not fully comprehend their errors, the instructors can help them find their flaws upon request. I understand we cannot make the grading program verbally elaborate on how students can locate their errors, but it would help if students got some additional feedback in addition to the highlighted errors and coordinates. I can imagine it would be very challenging. Otherwise, it could have been done in the first place :-)

From the professor who has used automated grading for AutoCAD, Excel, and SOLIDWORKS:

1. AutoCAD: overall, it is very positive for improving student learning experience through instant feedback to students. The majority of the students understand the feedback information after two or three weeks of using it. The feedback information points out the problems of each individual line, arc, or circle. Once students learn how to read the feedback information, they can locate the drawing mistakes right away. The video instructions are helpful. Students can try as many times as they want to improve their grades before the deadline.
2. Excel: It has been improved a lot during the last few years, and the feedback information is clearer than before. Overall, it is still not as clear as the feedback on the AutoCAD problems. Especially when there are multiple sheets in one file, the feedback information did not clearly point to the right tab and the right cell. Students need to go back to the original problem and guess and try. When one file with one tab, the feedback information is very clear.
3. SOLIDWORKS: This is the 2nd year of trying to use it. Overall, the experience is positive; some of my students love it because it gives quick feedback, and they use it consistently. There is one problem we discussed before. When there are problems with the 3D body's dimension or material selection, the program describes it as a wrong moment of inertia. Usually, students are confused about this feedback because it does not clearly point to the exact problem as it is in AutoCAD. It did not point to the wrong dimension or the wrong material. Students either need to check each individual dimension to figure out the mistakes or redraw it.

Overall, I liked the program because it saved a lot of grading labor and helped students get feedback right away; students have more flexibility in submitting their homework. Students' final grades were improved because of the improvements in their homework grades.

From a professor who is a regular instructor who has used both systems for AutoCAD and Excel.

I would agree with the other faculty on the grading system.

-It is very helpful for us instructors that the grading is automatic, and it provides quick feedback for students to learn from their mistakes. Especially with the web grader, having a shorter turnaround time and being able to tabulate their scores

-I think there is a bit of a learning curve for the AutoCAD grader. Students don't take the time to read through and figure out what exactly the response is telling them what they need

to fix (i.e., coordinates and prompts of extra lines, but with further experience, they know what to look back at on their drawing.

-The Excel grader is my favorite because it provides specific feedback for individual cells. The only drawback is the need to avoid merged cells.

Conclusion and Future Work

An email-based grading system has been successfully transferred to a web-based interface. The system can grade AutoCAD, Excel, SOLIDWORKS, and LabVIEW files. Multiple sections of several types of classes used the web-based grading. When surveyed, students had similar opinions of web-based and email-based grading, which students previously used. With the new system, faculty have greater access to the students' submissions, which assists them in discovering their mistakes. Other faculty at the university appreciated the help in grading that the system provided.

Since the program runs on virtual machines, it can be expanded to handle as many users as necessary. Because of this, future work could involve collaboration with other universities for a more extensive study of the effects on student learning when using the different types of programs with automated grading.

Also, more refined grading capabilities are being added to the SOLIDWORKS grading program, allowing evaluation of operations, sketches, and drawings in addition to basic geometry properties. The expanded grading can provide feedback to the students on which step of a tutorial they made a mistake, rather than just telling them that their end geometry is incorrect.

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