

Self-Graded Problems in Engineering Mechanics

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Work in Progress: Self-Graded Problems in Engineering Mechanics

Abstract

Engineering mechanics is known to be a “bottleneck” course required in various engineering disciplines. Previous work by faculty at Florida Gulf Coast University (FGCU) teaching “engineering mechanics: statics and dynamics,” investigated factors impacting student performance. These factors included traditional paper-pencil homework problems, Pearson Mastering Engineering software, “adaptive follow-up” modules, McGraw-Hill Connect online homework, ungraded homework with full access to the assignment solutions, frequent quizzes based on homework problems, daily class quizzes, metacognitive exam wrappers, survey questions targeting students’ attitude towards learning addressing study habits, preparation, participation, and engagement, among others. However, results of these distinct approaches suggested that these changes had a minimal impact on the students’ academic performance.

In previous work in Progress, self-graded homework was implemented, by assigning traditional paper-pencil carefully crafted problems. These selected problems were self-graded by the students during review sessions before the mid-semester and final exams. The results of that one semester study (fall 2023) suggested that this change did not significantly impact students’ exam scores. However, having students grading their own work fostered reflection. Some students found that the problems were too difficult, suggesting that they should be more manageable and preferred them as group assignments. Moreover, they expressed a desire for hints, including partial solutions or final answers to be provided, or the opportunity to go over problems in more detail in class. Overall, the feedback provided insights into the strengths and areas of improvement for the self-graded assignments.

Adjustments in homework difficulty and format, and support for students have been implemented in the fall 2024 semester. Preliminary results are presented, based on observation of students’ performance ($n=35$) on one exam problem, and a survey of students’ perceptions.

Introduction

Self-assessment is a valuable practice in engineering education, empowering students to evaluate their understanding, performance, and progress. By reflecting on their own work, students can identify areas of strength and weakness, take ownership of their learning, and develop skills that are critical for academic and professional success. It encourages students to analyze their problem-solving processes, assess the accuracy of their solutions, and understand the reasoning behind their choices. This promotes deeper learning and cultivates critical thinking, a fundamental skill for engineers.

Engineering professionals are often required to independently evaluate their designs, analyses, and decisions. Introducing self-assessment during academic training mirrors this responsibility, helping students build confidence and competence in their abilities. The engineering field evolves rapidly, requiring continuous learning and adaptation. Self-assessment fosters the ability to recognize knowledge gaps and proactively seek out learning opportunities, a crucial habit for lifelong success. By mirroring real-world practices, self-assessment helps students transition

smoothly into professional roles. It makes students active participants in their learning process, leading to greater engagement, and enhancing development of professional skills.

It is not the author's intention to present a comprehensive literature review of the self-grading practice but rather present a concise report about the status of the work in progress. Some of previous relevant published work are listed in the reference section [1-10].

Method

An experiment has been adopted in the fall semester 2023 in which sophomore students in bioengineering, civil engineering and environmental engineering were assigned the task to grade their own work [11] in an engineering mechanics (statics and dynamics) course. The self-graded assignments (SGAs) were assigned in addition to the McGraw-Hill Connect online homework.

The course is a four-credit course taught in a combined lecture/lab environment with three meetings a week for a total of five contact hours. It is typically taken by engineering students in their second year of study, either fall or spring. The course instruction closely follows the ExCEED Teaching Model. Since the course is taught in the combined lecture/lab format, there is ample time and opportunity for active, hands-on learning during the class period. Students spend considerable class time working in groups to solve problems under the instructor's supervision. The prerequisites for the course are Calculus 1 and Physics 1, and students are expected to be proficient in these areas. Students must earn a minimum grade of C (73.34%) in the course and at least a 70% exam average to move on to follow-up courses that require engineering mechanics as a prerequisite.

Students scanned and uploaded their assignment on CANVAS (learning management software) before class. At the start of class, the instructor showed the solution to the assigned problem on the projector screen. Students graded their own work based on a scoring rubric set by the instructor for each segment of the solution. Students were encouraged to ask for clarifications regarding the solution and the grading scheme.

During the fall 2023 study [11], some students found that the problems were too difficult, suggesting that they should be more manageable and preferred them as group assignments. Moreover, they expressed a desire for hints, including partial solutions, final answers to be provided, and the opportunity to go over problems in more detail in class. Overall, the feedback provided insights into the strengths and areas of improvement for the SGAs. As a result, adjustments in homework difficulty and format, and support for students have been implemented in the fall 2024 semester. Students were given final numerical answers to each problem and were encouraged to collaborate as a group with their classmates. The problems were assigned early, giving enough time to the students to brainstorm together. Also, for challenging problems, three different submissions were assigned to ensure intermediate answers were corrected as needed.

The following statement was added to the assignment on CANVAS “*Note: The purpose of this assignment is to build on what you learned in class and the online homework. The numerical answers are provided, with the goal for you to retry as needed, figure out any mistake, until you get the correct answer, while consulting with your classmates, the learning assistant, or your instructor. However, the final submission should be your own.*”

Figure A1 of Appendix A shows a 3D equilibrium problem, purposefully selected to cover various aspects of the analysis, including support reactions, forces in cables, and vector manipulation. The problem was assigned in mid-September and self-graded during the review session, two days before the first statics exam. Beginning October, hurricane Milton hit the region and consequently the university closed for a week-and-a-half, resulting in an adjustment of the course schedule, course delivery mode, assignments, and exam dates. Although self-graded problems in trusses and challenging dynamics topics were introduced, such as rigid body kinematics with no-slip rolling wheels, method of instantaneous center of zero velocity, work-energy method, and impulse momentum, the students' submission rate of these SGAs was low as some students were affected by the hurricane. Therefore, it was decided to only report here results from the 3D equilibrium exam problem.

Students' perception about SGAs throughout the fall 2024 semester was assessed by an anonymous survey, including two Likert scaled questions and three open-ended questions.

Findings

Figure 1 shows the average exam grade for the static 3D equilibrium problem in seven different semesters. The self-graded 3D equilibrium problem was assigned to the students only in the fall 2024. The same instructor taught the seven semesters. This result is promising, showing an increase in the fall 2024 semester average grade compared to all other semesters. A decision is made to extend the use of SGAs into the subsequent course of mechanics of materials currently taught in spring semester 2025. It is hoped that a similar trend will be observed.

Students' perception about the SGAs was assessed by an anonymous survey administered towards the end of the semester. Figure 2 shows the students' response to the multiple-choice question *"How would you rate your experience with self-graded assignments?"* About 76% (fall 2024) and 38% (fall 2023) of students believed it was very good or good. About 19% (fall 2024) and 33% (fall 2023) of students believed it was neutral. Only 5% of students (fall 2024) believed it was fair. Figure 3 shows the students' response to the statement *"Self-graded assignments are beneficial for your learning"* About 85% (fall 2024) and 54% (fall 2023) of students strongly agreed or agreed. No students (fall 2024) and 21% (fall 2023) of students strongly disagreed or disagreed. These results indicate that the implemented adjustments in the difficulty and format of the SGAs lead to a considerable improvement in students' perception of the SGAs.

Appendix B lists students' responses to three open-ended questions: (1) *"what did you like best about grading your own homework?"* Most of the students listed positive comments regarding finding their own mistakes, knowing the answers beforehand, trying to correctly solve the problem with their classmates. One student's comment summarizes the benefit of the adjustment implemented in fall 2024 by stating "I really love these self-grading assignments because even if I am struggling with solving a problem it really highlights where my weaknesses are and then I can implement that when studying. I also love how they relate closely to actual problems we have previously worked on in class. I also like that the answers are published after the due date this gives me even more material to help me study," (2) *"what did you like least about the grading your own homework?"* Few students disliked that the problems varied in difficulty, that they had issues with understanding the grading scale, and that they were not worth more credit. However, other students had positive comments stating that there is not a real problem with the self-grading and wished for more SGAs, and (3) *"How can we improve the self-graded assignments to be more effective?"* Few students felt that the problems could be reduced in

difficulty, increased in credit, one student suggested the problems be assigned in pair, one to be solved individually and the other as a group assignment, another suggestion was to assign more SGAs.

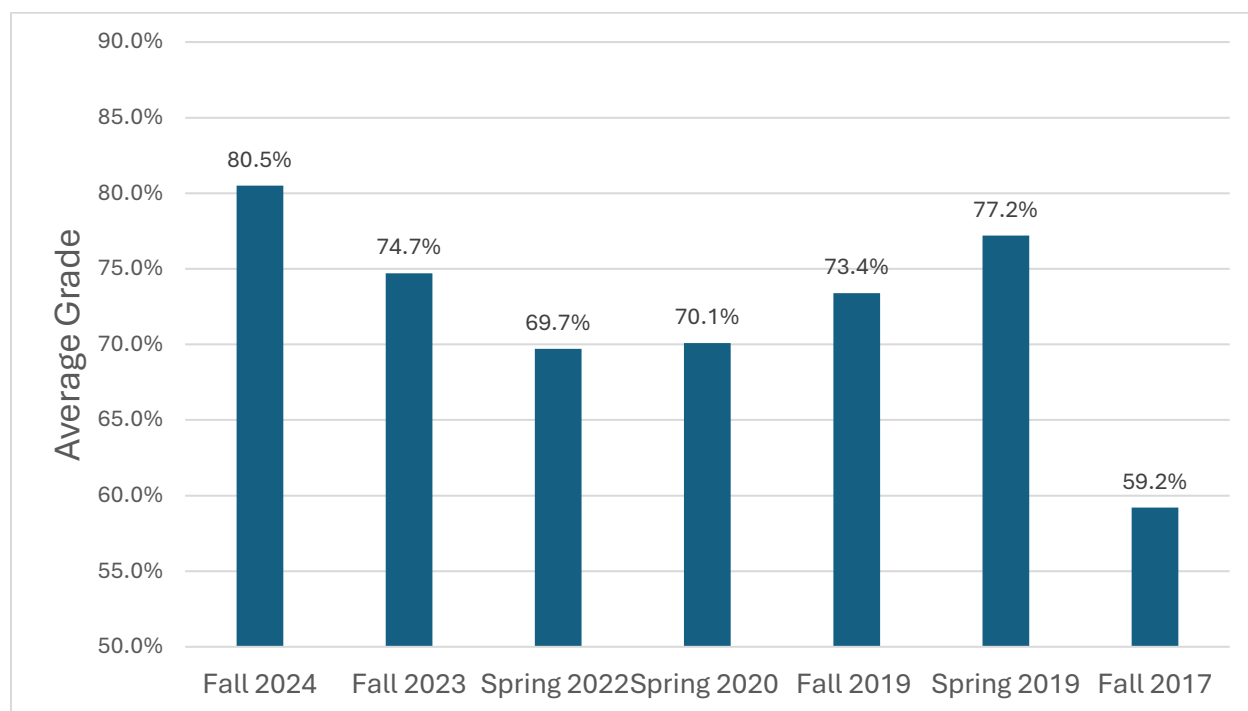


Figure 1 - Average Exam Grade – 3D Equilibrium Problem (Self-Graded 3D Problem introduced only in Fall 2024 semester)

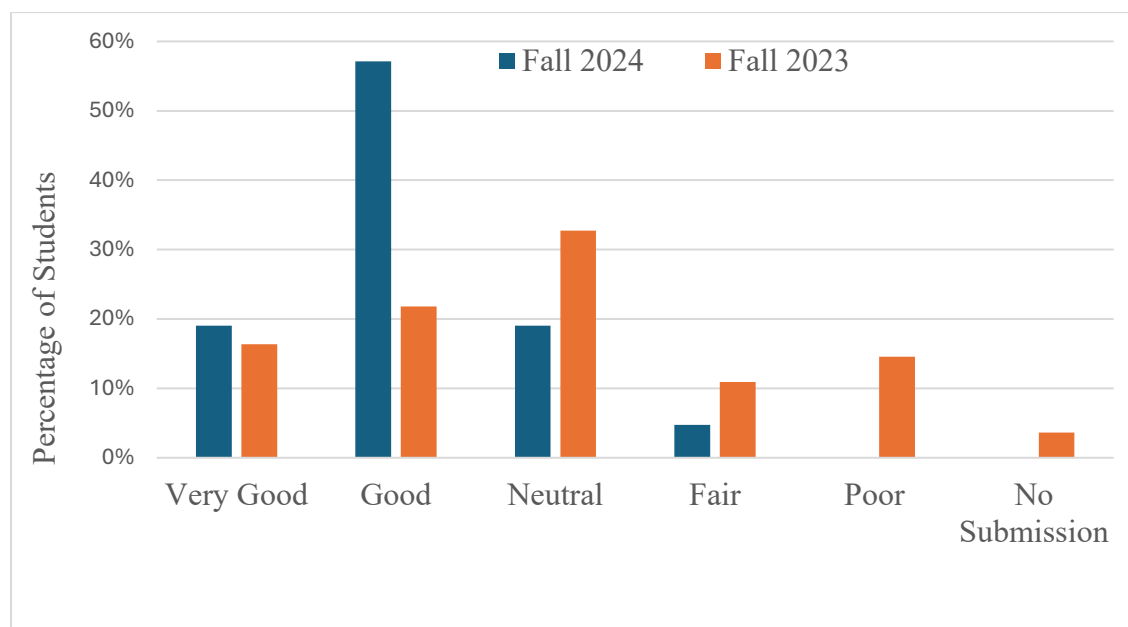


Figure 2 - How would you rate your experience with self-graded assignments?

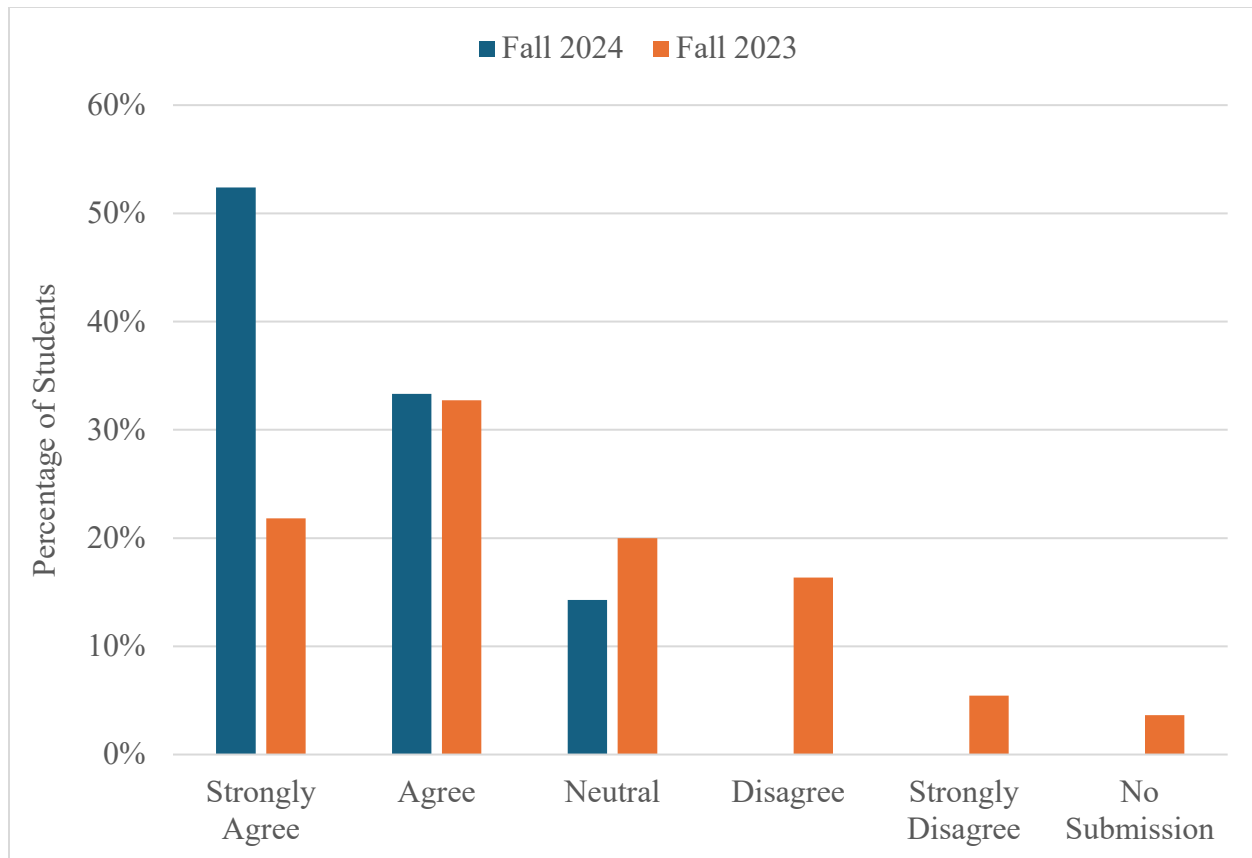


Figure 3 - Self-graded assignments are beneficial for your learning.

Summary and Conclusion

To improve the students' performance in an engineering mechanics (statics & dynamics) course, traditional paper-pencil problems were carefully crafted and assigned. These problems were self-graded by individual students during review sessions before the mid-semester and final exams. The efficacy of this experiment is currently based on observations from the instructor, a survey of students' perceptions, and a comparison of students' performance in one exam problem, showing an increase in the average class grade compared to six previous semesters taught by the same instructor.

Overall, the students' feedback provided insights into the strengths and further areas of improvement in the format of the SGAs. The implementation of SGAs is being extended to the subsequent course of mechanics of materials, currently taught in the spring semester 2025. Further study is warranted to collect enough data and verify whether there is a statistically significant difference in students' performance due to the introduction of SGAs.

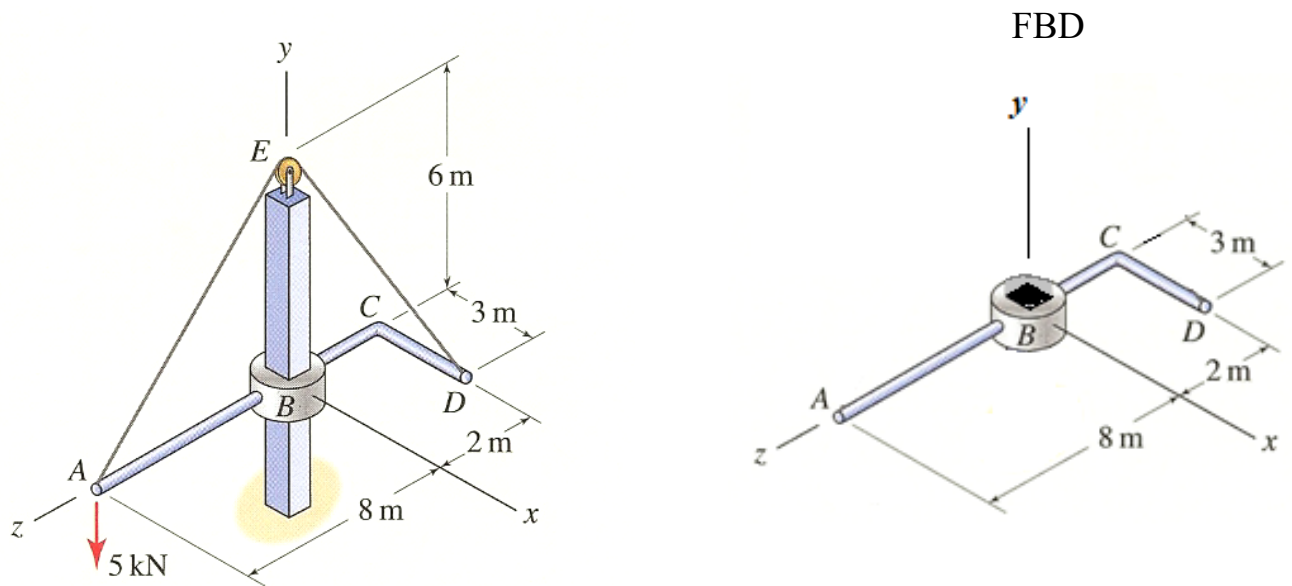
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Appendix A – Self-Graded Problem

Bar $ABCD$ is supported by a cable AED , which passes over a frictionless pulley at point E , and a collar B that slides without friction on a vertical shaft with a square cross section.

- a. Draw a complete Free Body Diagram of the body $ABCD$ below.



- b. Determine the tension in cable AED and all support reactions.

Answer: $\vec{B} = [1.47 \ 0 \ 1.76] \text{ kN}$, $\vec{M}_B = [-29.4 \ 0 \ -8.81] \text{ kN.m}$,
 $F_{AE} = F_{DE} = 3.43 \text{ kN (T)}$

Figure A1 – 3D Equilibrium Self-Graded Assignment

Appendix B – Survey Questions

What did you like best about grading your own homework?

It allowed me to see the mistakes I made while doing the assignment and fix them.
I was able to check my work and see my score immediately after the solution was posted.
Learning the path where I went wrong
I liked that the answer was given. It allowed me to work through the problem, and if I got a different answer I could go back and re-evaluate what I did wrong. As opposed to working through the problem and waiting to see if my answer was correct or not. It also gave me more time to sit in front of the questions and work on them at my own pace outside of the classroom, while continuing to build upon the topics during lectures.
I liked that I could look at and compare the step-by-step solutions and my work.
I liked the fact that we had the right answer available, and lots of time to be able to work through the problem.
I like the idea of seeing how each step is importantly considered for each problem. Once you grade an assignment you realize what you could have done better or what you missed as a whole.
It gave us extra problems to work through with the correct answer to work towards.
It forced me to sit with a difficult problem for a long time. I've found that looking at the solution (or rather, a submission accurate to how you've taught us to solve a problem) of something I worked on for a long time is incredibly beneficial to my learning in a long term.
It was great how it forced me to do the problem over and over again. It helped out my learning and I feel better with some buffer to my grade as well.
Since I know the answers beforehand, I get to focus on how to do the problem instead of stressing on what the correct answer is. It allows me to understand what I am doing and why.
That you could keep trying the problem until you got the right answer since the answer was given.
I liked how I could notice my own mistakes and correct them on the spot myself. It was also a very organized way to have these self-graded reference problems to look back on.
learning
N/A
We were given the answer to the problems so that we could see if we were setting up the problems correctly and getting the right answer
I liked being able to go back and check the answers provided to see if mine were close in any way. If not, then I can adjust accordingly. Grading my homework myself allows me to see what I am doing right and wrong, whilst practicing how to solve the problems in the correct way.
Being able to learn and getting good grades for it
I really love these self-grading assignments because even if I am struggling with solving a problem it really highlights where my weaknesses are and then I can implement that when studying. I also love how they relate really close to actual problems we have previously worked on in class. I also like that the answers are published after the due date this gives me even more material to help me study
I don't really think it made a huge difference to be honest, but I do like that we had written homework
That I was able to work on it with other people.

What did you like the least about grading your own homework?

n/a
The homework was a lot more difficult than the rest. And sometimes I couldn't tell where I made the error.
When I got stuck, I didn't know what to do
I don't have anything negative to say about the self-graded homework.
If I got something wrong, it would feel way worse to me.
I did not like that the self-graded problems were so few; I think I'd prefer more of them over more online quizzes.
The thing I liked least about the self-grading homework is that it sometimes varied on difficulty. Some of them were ok and liked the class content while others were more challenging. Maybe if it was more uniform in terms of difficulty it could be better.
Understanding the grading scale.
I'm not sure it has many downsides I think, at least for just an assignment.
Sometimes the day to submit the cover sheet wasn't that clear but the recent ones have a date to submit the cover sheet by so it's not really an issue.
The only thing I don't like is that sometimes I don't know if my answer is correct because it is slightly off from the given answer due to rounding errors and calculator errors. This causes confusion as I did the correct steps but got a different answer.
Sometimes I would get stuck and there is no guidance.
That they were not worth a lot of points. Sometimes, I felt like I took quite a bit of time solving them, but they were never worth many points toward the grade.
nothing
N/A
How most were due at 9:30 am instead of the day before
There is not a real problem I have had with self-graded problems.
Some problems of the static were a bit more complicated
didn't see the benefit really.
N/A

How can we improve the self-graded assignments to be more effective?

None, they were beneficial
The problems are a bit too hard, maybe give a bit easier ones
Putting a reminder to resubmit
Maybe running through the solutions quickly in class after submission just to get the instructors' view of the worked-out solutions. Even if the instructor doesn't work out the problem just going over the steps of the solution verbally with each assignment could help
Make the grade based more off of completion because then people would not be afraid to completely mess it up but if they just scribbled random things down to do it they would not get a good grade

There could be more problems that are slightly simplified. I think the more problems done, the better
The self-graded homework, I think there could be two of the same topic, one as a group while the other by ourselves. Even though we work in groups on the board to do the assignment if it integrated the self-grading as a group in which we choose our groups it could be better for getting the concept in a less time crunch way. Then we could do one by ourselves to see if we got the concepts.
Better grading scale.
Maybe they could be slightly less difficult? I don't even fully believe this since they never strayed too far from what was fair. I think it's fine as is.
I think they're pretty good as they are now
I'm not sure.
I'm not sure maybe give some hints or something
Make them worth more points to give students incentive to try harder on them. Overall, I think they were an effective way to make students revisit lesson topics!
N/A
Use the same question on the test lol.
Assign more of them, and maybe make some of them a little easier so you can fit more into one assignment. That way students can practice a few different scenarios.
Be easy to do since the idea is to practice
I would have liked more of these assignments throughout the course because I use these for review, and I learn best through the constant repetition of working through problems. I looked more forward to these problems rather than online hw. Again for the reason that you could see what you did wrong and then study as a result, knowing your weaknesses.
Nothing.
I would have liked to see the answers after I submitted to check my answers instead of waiting till the next class to check them