Targeted Self-Graded Problems in Engineering Mechanics

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Work in Progress: Targeted 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, 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 minimal impact on the overall students' academic performance.

In this current work in progress, the authors continue their effort in engineering mechanics by assigning traditional paper-pencil carefully crafted problems. These selected problems are self-graded by the students during review sessions before the mid-semester and final exams.

The efficacy of this experiment is currently based on observation from instructors, a survey of students' perceptions (n= 55), and limited comparison of students' performance on exams. If proven promising, the targeted self-graded problems will be extended to upcoming semesters and the subsequent course of mechanics of materials, providing further data on students' performance in exams, to be reported in a follow-on paper in 2025.

Introduction

For the last decade, different authors at FGCU have been investigating ways to improve student performance in engineering mechanics (statics and dynamics), a required course for students majoring in bioengineering, civil engineering, and environmental engineering. Success in this course is critical to excel in follow-up mechanics courses and upper-level engineering courses. Data has been collected on students' performance on homework, quizzes and exams, and on the students' thoughts on learning and course delivery. Thus far, it has been concluded that the use of traditional hand-written homework, frequent assessment via quizzes [1] or the Pearson Mastering Engineering [2] software for formative assessment did not have a significant impact on students' performance on exams. It was also observed that neither traditional nor online homework scores correlated well with exam scores; however, in-class quizzes did correlate with final exam scores. Moreover, using the Mastering Engineering online system, specifically the inclusion of the Adaptive Follow-Up modules [3] did not impact the overall student performance. In fact, Adaptive Follow-Up in the Mastering Engineering system was perceived as punitive by some of the students, rather than as a resource to encourage mastery of the material [4]. Additionally, although Exam Wrappers did not seem to increase exam scores and performance; overall, having students fill out wrappers after quizzes and exams did seem to foster reflection and adjustment in most participants [5]. Most recently, Exam Wrappers appeared to be useful, encouraging students to think about study habits, source of error, and different ways in which they engage with the course [6].

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. Although the course has been taught by nine different instructors over the past several years, it is essentially a team-taught course. The instructors use the same textbook and syllabus, assign the same homework, collaborate on writing quizzes and exams, and use common grading rubrics. The course instruction closely follows the ExCEEd Teaching Model with the use of common board notes among the instructors. 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 a lot of class time working in groups to solve problems under the instructor's supervision. All instructors require attendance, take roll, and for students who have an excessive number of unexcused absences, there is a grade reduction outlined in the syllabus. 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 in the course and at least a 70% exam average to move on to follow-up courses that require engineering mechanics as a prerequisite.

It is well documented that students who work on problems outside the class period are better prepared to perform at a higher level, but does requiring that work be submitted for a grade and feedback make a difference? In 2003, a study was performed with students in a sophomore level electrical and computer engineering course. Two semesters were studied with one section having required homework and the other with problems provided but not required homework. In the first semester the section with graded homework scored significantly higher but in the second semester the two sections did not differ significantly in their test scores [7]. A similar study was performed over a 3-year period in a numerical methods course for mechanical engineers. Results indicated that requiring homework for a grade did not affect student performance [8].

Recently, the performance of students in two sections of the engineering mechanics course was examined, where one section was required to submit homework to be graded (control section) and the other section was provided the same problems to use for study purposes but not required to complete or submit for a grade (test section). The scores for all three exams showed no statistically significant difference between the two sections, leading the authors to conclude that requiring students to submit homework for a grade and providing feedback does not improve their performance on exams [9]. It seems apparent that students can prepare themselves for exams without the requirement of graded homework. Considering the instant availability of solutions to any statics problem created, students today think nothing of finding solutions, copying them and turning them in for a grade with little or no learning occurring during the process [10]. The results of this experiment should not come as a surprise. This experiment was conducted in the fall of 2019 and continued in the spring of 2020, thus giving the authors another semester of data to consider the question. If requiring graded homework does not improve exam performance, it may be more effective to reallocate teaching assistants to interacting with students in small group settings rather than grading homework.

Students rarely use graded feedback to study and many just quickly review the graded assignments without giving the necessary attention to identifying errors, let alone discovering alternative solution methods to the same problems. The reality is that many students seldom use the opportunity to learn from homework/exam mistakes. The loss of this learning opportunity from TA – or instructor - graded homework prompted the idea of letting the students discover their own mistakes through self-grading of assignments.

To take a different approach towards improving student mastery of the course material, the instructors in the course have turned to paper-pencil self-graded assignments (SGA) in the fall 2023 semester. No peer grading was used in this study to avoid potential conflict or violation of the Family Educational Rights and Privacy Act (FERPA) rules and regulations.

Method

An experiment has been adopted in which sophomore students in bioengineering, civil engineering and environmental engineering were assigned the task to grade their own work. Students scanned and uploaded their assignment on CANVAS (learning management software) before class. At the start of class, the instructor showed the solution of 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.

The SGAs were assigned in addition to the McGraw-Hill Connect online assignments, which were already set-up for the course, as the decision to add SGAs was made after the start of the semester. Since many students at FGCU work while enrolled in the engineering mechanics course, only five carefully crafted problems were assigned to not overburden the students with extra work.

Figure A1 of Appendix A shows a single truss problem, purposefully designed to incorporate different truss configurations. It was assigned and self-graded to empower the students in truss analysis. The idea was to assign only one problem, while covering as many configurations and methods as possible, to maximize the benefit for the students. Similarly, self-graded problems in dynamics were introduced in known challenging subjects, such as rigid body kinematics with no-slip rolling wheels, method of instantaneous center of zero velocity, work-energy method, and impulse momentum. One sample work-energy problem is shown in Figure A2 of Appendix A. Again, the problem incorporates many components of the method, including wheels and springs.

Students' perception about self-grading five homework problems throughout the fall 2023 semester was assessed by an anonymous survey, including two Likert scaled questions and one open-ended question. Figures 1 and 2 depict the perspectives of students in two sections (9:30 am and 11:30 am sections), together with an aggregate view of responses from all 55 students.

Findings

Figure 1 shows the students' response to the multiple-choice question *"How would you rate your experience with self-graded assignments?"* About 54% (9:30 am section) and 24% (11:30 am section) of students believed it was very good or good, with an overall of 38% for both sections. About 27% (9:30 am section) and 24% (11:30 am section) of students believed it was fair or poor, with an overall of 25% for both sections.

Figure 2 shows the students' response to the statement *"Self-graded assignments are beneficial for your learning"* About 62% (9:30 am section) and 48% (11:30 am section) of students strongly agreed or agreed, with an overall of 54% for both sections. About 18% (9:30 am section) and 24% (11:30 am section) of students strongly disagreed or disagreed, with an overall of 22% for both sections.

An anonymous open-ended question *"How can we improve the self-graded assignments to be more effective?"* was used to collect students' feedback towards potential future enhancement of the implementation of SGAs. Detailed student responses are listed in Appendix B. Some students reported that SGAs are more beneficial than other types of homework, that the instructions for the SGAs were clear, and a few students liked the self-grading aspect and found it helpful for learning. However, 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 given, or the opportunity to go over problems in more detail in class.

Overall, the feedback provides insights into the strengths and areas of improvement for the self-graded assignments. Adjustments in difficulty, format, and support for students may enhance their effectiveness in the course.

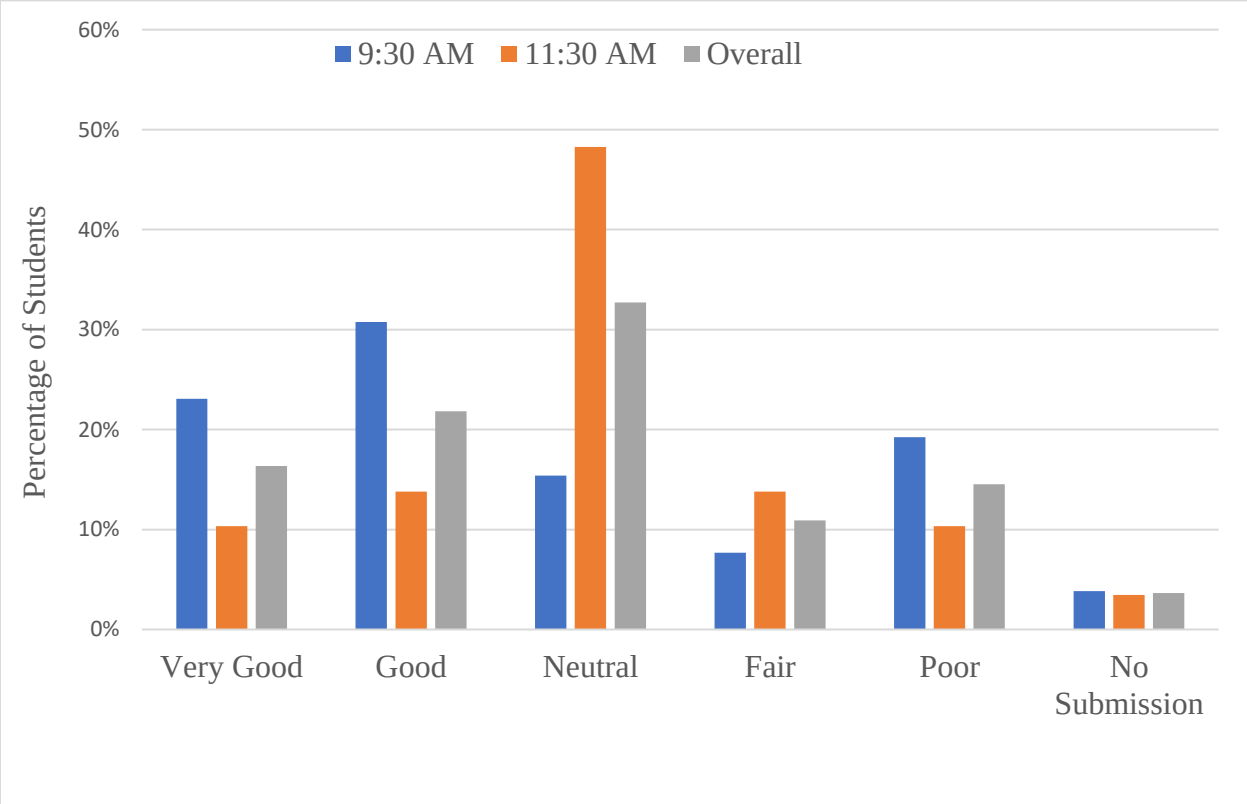

Figure 1 - How would you rate your experience with self-graded assignments?

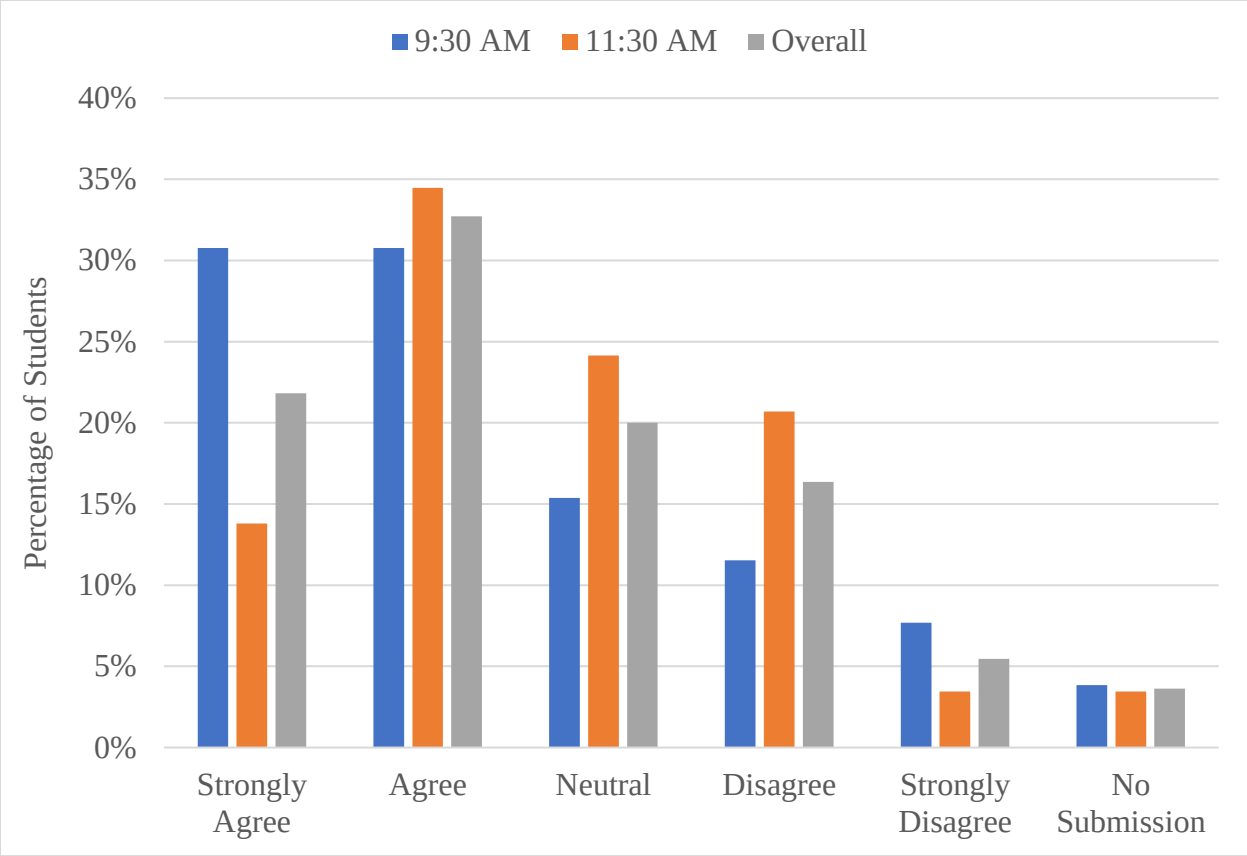

Figure 2 - Self-graded assignments are beneficial for your learning.

The current study examined the effect of SGAs on the performance of students solving the same exam problem of truss analysis in two semesters of the course. In one semester SGAs were not introduced (Fall 2017, control semester, n = 37), while in the other semester students completed SGAs (Fall 2023, test semester, n = 52). A two-sample t-Test with unequal variances resulted in a p-value of 0.150, greater than the α-value set of 0.05, indicating no statistical difference between the means of students' exam scores, i.e., SGAs did not significantly affect students' exam performance. Similarly, a comparison of the overall grades in the final dynamics exam (same exam assigned) resulted in a p-value of 0.088, again showing no significant difference between the performance of the two groups.

Summary and Conclusion

To improve the students' performance in engineering mechanics (statics & dynamics), 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 instructors, a survey of students' perceptions, and comparison of students' exam performance.

Results from the first semester of this study showed that self-graded homework problems did not significantly impact students' exam scores. Although self-graded homework did not increase exam scores and performance, having students grading their own work did foster reflection.

Overall, the feedback provided insights into the strengths and areas of improvement for the self-graded assignments. Adjustments in difficulty and format will be implemented in upcoming semesters and the subsequent course of mechanics of materials, providing further data on students' performance in exams to be reported in a follow-on paper in 2025.

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Appendix A – Self-Graded Problems

A truss structure is given below. It is pin supported at point A and supported by rollers at points C and N.

1. List the zero force members in the truss structure.
2. Determine the support reactions and the force in member OA. You need to calculate the forces on your own (**Answers: Cy** = 91.1 KN Up, **Rn** = 162.7 KN Up perpendicular to the roller plane, **OA** = 105.0 KN (C))
3. Determine the forces in the following members: *BO, BC, QR, RW, WF, EF, RS, SZ, ZF, UV, UL, KL* and *MN*.

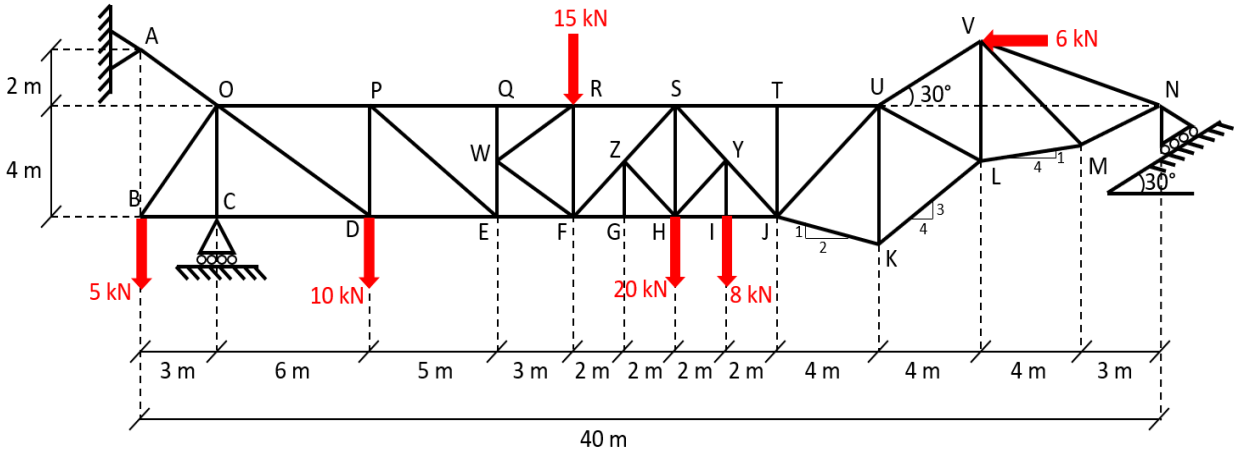

Figure A1 – Truss Self-Graded Assignment

If the system is released from rest in the position shown below, determine the angular velocity of the wheel once the block has fallen 1 foot. The 20-lb no slip wheel, B_1, has a radius of gyration of 4 inches about its center. A cable wrapped around the inner radius passes under and over two small frictionless pulleys and is attached to the 50-lb block B_2. The spring (k = 90 lb/ft) is initially unstretched at a length of 13 in. (from the wall to the contact point on the disk), and there is enough friction to prevent slipping. Note that $I_G = mk^2$.

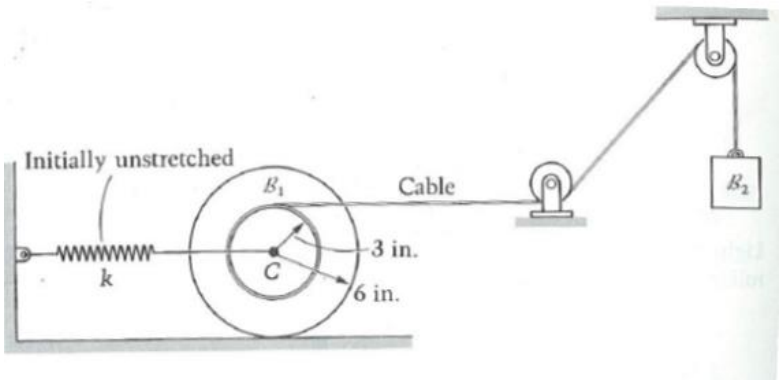

Figure A2 – Work-Energy Self-Graded Assignment

Appendix B – Survey Question

How can we improve the self-graded assignments to be more effective? (section 9:30 am)

Implementing these more than the McGraw Hill homework's because they were more beneficial
The self-graded assignments are good (instructions are clear), I just feel like I do not benefit from them.
Nothing they are pretty good
The one self-graded assignment I attempted was really difficult
Try not to time them so that they are due close to another homework
Have a partial solution posted to ensure students are going in the correct direction in regard to solving the problem.
Assigning self-graded problems to then fully go over during class is a way I feel would make them more beneficial
I wish that a hint was given on each homework problem in case any of the students didn't know how to approach the problem. I am not saying that they shouldn't know what to do because it aligns pretty well to what we do in class; however, it is good to have a hint sometimes. I believe that giving a hint will provide the instructor with more students that can understand the problem instead of not doing it, getting a 0, and misunderstanding.
Make it more clear what answers you want
Give some more time to complete them
It all went well. I really liked the self-grading points
I believe it's a good way for students to improve their knowledge.
Get rid of them. Many of us must support ourselves during our time in school. The homework just adds additional pressure to an already demanding subject material. I feel my time would be better spent meeting with a group and working through problems in a similar way we do in class. If this was the format of the self-graded assignments, they would be far more effective.
I think the self-graded assignments are more beneficial than the homework. So, instead of having both assignments due during the same week, it should alternate between weeks
I can't really think of any suggestions
I am not sure since the way it is set up helps with grading by sections, which is nice
Do not make the truss problem overly complicated and long. Self-graded assignment 2 was better because it was individual problems and did not require as much time.
Sometimes the problems were very difficult to solve on your own and they were hard to get right. Having them worth a lot of points can really hurt grades since if you mess up the beginning you get the rest of the problem wrong so maybe have more of a guidance throw the problems and either take them as participation grades or have them worth less points.
Replace the normal homework assignments with them. I felt like I learned the concepts by practicing them rather than the online homework. The self-graded assignments were closer to what we were learning in class. The normal homework felt very disconnected.
Give more hints before trying the problem and maybe go over some steps you can take to attack the problem before assigning it. Give us more chances to work in a group on a self-graded assignment

They should not be graded so harshly. Since they are very challenging and complicated questions, they are very difficult to understand. Overall, I feel as though they do not help the understanding of how to solve a problem for a quiz or an exam. The problems also take hours to solve.
Assign them more frequently.
Provide the solutions to the problems. Like just the answer to the question without the work so we know what we are looking for when solving. This would help so much to practice the steps so that we know if our work was correct to lead to the correct final answer

How can we improve the self-graded assignments to be more effective? (section 11:30am)

These assignments would be better if they were optional or as extra credit. They add stress to students who are studying for their exams and want to do well.
I think they would be the most effective if we went over all the solutions step by step in class with the professor. I think this will allow us to see where we went wrong and be able to ask questions in the moment.
I don't believe it can be improved for this course. The instructions were clear and self-grading forces the student to look over what they did incorrectly.
Maybe make them worth extra credit to promote students to try harder
I think it is beneficial that we are sent home to practice in our own time and then go over it in class, because then we already know what we struggle with. I also think it might help during class time if we were given a problem to try on out on our own for a few minutes before going over it in class, that might help engage students to start thinking about the problems rather than just blindly copying your work
I think the self-graded assignments were helpful, but it would be better if we could receive partial credit for questions.
Please leave our time to work on the actual homework. Adding complexity to a class like this is not always beneficial, and it would be better to spend time working out the homework problems and building a conceptual understanding of it. In other words, less problems means I can spend more detail on each problem instead of worrying about completion.
It is good.
N/A
I would rather them just be graded but not counted.
We can make it so there's one big problem instead of four/two and separate a small portion of class to go over it and do this maybe twice a week instead of one big day dedicated for it so it becomes a learning experience instead of just something we need to get done.
N/A
Maybe make them group assignments instead of individual so we can see other attempts of solving problems Having assignments that are a combination of simple and complex problems can be very beneficial.
It was a lot harder than anything we have done in class so far. Not a good representation of what we are learning in this class.
The biggest problem with both of the self-grading assignments is that they were used as one of the few review tools, where the problems (more specifically with the truss problem), were

nowhere close to the difficulty of the problems that would be seen on the test. The self-graded assignments are a good tool to see where one is at, but when the problems are so difficult it cannot be figured out by anyone, loses its purpose.
maybe by allowing a 2nd attempt to fix what was wrong or having some self-graded assignments be group work
Do not assign them
They are good enough. No changes are needed.
I think adding the solutions beforehand would be very beneficial to a lot of students.
Personally, I don't think they are very beneficial
Maybe spend class time going over the grading for the assignments as a class. And answer questions
I would just say that it’s not necessarily the self-graded portion per say, it's more OTP homework that I don't like in general. During homework I like to know if I'm doing something right or wrong before learning & getting points off for it.
I feel like they’re extremely difficult instead of being a regular difficulty.
Have a better guide as too how much each part of a question is worth.
make them less difficult than they must be
I'm not sure