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Efficient and Effective Grading of Student Work

Abstract

As new engineering educators, we are faced with countless responsibilities that compete for our valuable time. Grading student work is one of these new tasks that we all have to undertake. While grading is often a tedious and time consuming task, it is important for students to receive a fair assessment of their work accompanied by constructive feedback. Like many aspects of engineering, grading can be thought of as an optimization problem: maximize student learning while minimizing the grading time. In this paper, we provide advice for new faculty on how to improve grading efficiency without sacrificing its effectiveness; in other words "how to save time while grading".

Tips are presented for different types of student work found in engineering courses. For each type of graded activity, we encourage the faculty member to think about grading before handing it out to students. Poorly designed questions or assignments can lead to unnecessarily long and difficult grading. We also suggest methods that reduce the time spent on grading student work but still accurately assess the students' progress. Overall, the techniques presented in this paper are designed to help to make the grading process more efficient while remaining constructive and fair to the students.

1. Introduction

Grading is an important responsibility for all educators. Assessing the work of a student is a key component of the learning process. If done effectively, students can gauge how well they comprehend the course material, learn from past mistakes, and be motivated to learn even more.

The main purpose of grading is to assess the student with respect to the course objectives and outcomes. This process can be divided into two tasks. The first task is to design course activities in a manner such that students can meet the course objectives and the instructor is able to assess the students' progress. The second task is to accurately measure the students' achievement of the objectives (either for a particular question, an assignment, or for the whole course). There are a variety of different ways of measuring student progress. For instance, assessment can be done with respect to a standard developed by the instructor or it could be done with respect to other students in the course by curving the grades. In either case, great care must be done to make sure the assigned grades reflect the level of understanding of each student.

To accurately assess students, it is important to remain fair to all students. Being unfair or inconsistent will often lead to inaccurate evaluations. While almost all educators strive to be unbiased during grading, it is possible to be inconsistent during grading without necessarily being aware of the issue. If two students submit the same solution to a problem, they should receive the same grade. In order to achieve consistency, it is necessary to give the same scrutiny for all students to a particular question. For instance, a professor wants to finish grading an exam before class but needs to rush through the last exams quickly in order to meet the deadline. Exams at the bottom of the stack will get less attention and more inaccurate grades than exams

on the top. Many of the techniques presented in this paper improve consistency during grading without consuming significant portions of time.

Another primary goal of the professor is to motivate the students to learn. The grading and feedback process can significantly affect the learning process of the student. For some students, the feedback they receive on exams and assignments may be the only individualized communication they obtain from the professor. At a minimum, the instructor needs to communicate why the students deserve the grade they received. The amount of feedback can vary. For problems done incorrectly, some instructors may point out where the error was so the student can avoid the same mistake in the future. Others may allow the student another chance at the problem with the hope that the student is able to detect her/his own mistake, improving their learning. Writing detailed feedback can be time consuming but if done effectively, can motivate and aid the student in the learning process.

Grading is one of those activities (like writing) that can always be improved if more time is spent on the task. Since grading is one of many tasks competing for time, it is desirable to employ efficient assessment techniques. This is especially true for new faculty who are preparing and teaching courses for the first time. This paper concentrates on grading tips and techniques that are efficient but still evaluate student performance fairly and accurately. Spending less time on grading allows instructors to spend time on other course activities such as preparing lectures or designing assignments. Another benefit is that it decreases the time needed to return graded work back to the students. The feedback given to students is much more meaningful if the assignment or exam is still fresh in their minds.

In this paper, we present and discuss grading for several different types of student work that are common in engineering: problems, computer programming, writing assignments, and projects. Problems ask the student to solve a particular question and typically require a numerical answer. In computer programming assignments, students write programs in languages such as MATLAB, C++, or Java and are evaluated based on functionality, design, and style. Writing assignments in engineering classes can range from a small paper on a contemporary issue, a lab report, or a large proposal evaluating different design options. Projects, commonly used in upper-level electives and senior design courses, permit students to explore a particular topic in great depth. Grading a project may involve reviewing deliverables such as proposals, design documents, posters, presentations, and final reports. Since team work is an important part of projects, assessment may also include factors such as individual effort, team communication, and project management.

In compiling the list of tips presented in this paper, we not only relied on our experience as new faculty members but also received advice from more experienced faculty. We interviewed several faculty members from different disciplines of engineering and computer science on how they graded various course activities. Our first tip for new faculty is to talk to other faculty members in your department and school about grading strategies. Conducting our interviews was a tremendous learning experience for us.

The remainder of the paper is organized as follows. We start by reviewing related work. Then, we address the design and grading of exam problems. Next, we talk about grading homework

questions, followed by technical writing assignments. Tips for grading projects and computer programming assignments are presented next, followed by a discussion on student feedback. We conclude the paper with some general grading tips.

2. Related Work

Educators constantly experiment with different types of assignments and grading techniques. However, we were only able to find a few publications describing methods designed to reduce the time spent on grading. In general, the authors are more concerned with designing effective assessment methods than with the efficiency of the grading process.

Devine[1] discusses the need for writing assignments in engineering, how to structure the assignments, and finally how to assess the work. He advocates using an assignment sheet that delineates why the assignment is important, what the student needs to do, and how it will be graded. Martinazzi[9] describes grading a team project that takes both team success and individual performance into account. For computer programs, Lane and VanLehn[8] implemented a technique that monitors the computer programming process rather than merely the final product. This allows instructors to determine what the students intended to do, especially their initial attempts. Grading the entire process forces students to take each phase seriously. This includes the planning and design phases, steps often skipped by students.

Many instructors have explored the use of self-evaluation in assessing the students. Greene and Jalkio[5] discuss asking students to create portfolios where they assess their progress toward the course objectives. In 82% of the cases, the student assessment was within a half-letter grade of the instructor's assessment. Ellis and Mitchell[3] use self-grading for a software engineering course. A related technique is the use of student-led demonstrations of projects and computer programs. East and Schafer[2] describe their experiences for a programming class. The most significant benefit was the individualized interaction each student received with the instructor leading to a more conducive learning environment in the classroom.

Test anxiety has been an issue in evaluating students accurately. Schneiter[11] uses challenging open-ended problems that students work on in teams in lieu of tests. Students feel it is more accurate reflection of their abilities than exams. Gharibyan[4] analyzes the use of oral exams instead of written tests. If done effectively, students have the ability to demonstrate their mastery of the course material in an interactive environment with no time pressure. However, in this setting it may be difficult to be consistent to all students.

Grading is also a topic of several books. Walvoord and Anderson[13] include a chapter that lists several strategies to make the grading process more time efficient. One strategy is to separate commenting from grading. The authors reflect on which combination of commenting and grading will be the most efficient and effective for student learning. They also suggest that not all assignments have to be graded; sometimes giving comments is all the feedback that the students need. Other suggestions include using only as many grade levels as necessary, only spending time on comments that will actually reach students in a teachable moment, not wasting time on careless student work, and asking the students to organize their work so the instructor

can grade efficiently. They also suggest delegating the work to others by implementing student peer evaluations.

Haladyna[6] describes the development of a grading system that is a fair and accurate assessment of student learning and has a positive effect on student learning. The book explains the nature of student learning and the role that grading plays in this process. Traditional and nontraditional methods of learning are also evaluated. Ory and Ryan[10] write about effective assessment strategies. They provide practical advice on how to design classroom examinations from developing the course test plan, writing objective test items, administering the exam, to assigning the grades. Stevens and Levi[12] discuss rubrics, stressing the time savings resulting from the use of rubrics. The book provides detailed explanation about the purpose of rubrics and guidance on how to construct them. It also gives suggestions on how to effectively use rubrics for grading.

3. Grading Exam Problems

Problems with numerical answers are one of the most common types of exam questions encountered in engineering courses. In this section, we provide an insight on how to optimize the time spent on grading such problems while still getting an accurate assessment of how students are learning.

Tip 1: Design exams with grading in mind.

The time spent designing an exam can save a lot time while grading the exam. The exam should be easy to read with clear and concise directions. Students should be informed how many points they can receive for each correctly solved problem.

Make sure that exam problems are reasonable and straightforward to solve. There should be only limited options how to solve the problem. If the wording of a question is confusing or ambiguous, the instructor may have to deem several answers correct during grading. An example from a computer science class is the term kB (kilobyte) which can have a value of 2^{10} (1024) or 10^3 (1000). In order to reduce the number of legal solutions, it is wise to direct the students to use one definition. Of course, in some cases, it may be desirable to have an open-ended problem or a problem with not enough information such that multiple solutions are possible. We like to use such problems on homework assignments to give students ample time to think about the question.

A trial run can help eliminate any unnecessary confusion ahead of time. It can also make sure the exam is of appropriate difficulty and length. Having an exam that is too long will result in many exams with incomplete solutions which are difficult to grade. In order to judge the length of the exam, each instructor should learn her/his speed of solving problems and how it compares to the time students spend on the same problems. It is also important to have a variety of questions in terms of difficulty. Having some easy questions will show if students have a basic understanding of the material and are typically fast to grade since most students will get them right. Easy questions also improve student confidence. However, it also important to include a number of more difficult questions to differentiate students who have a superior knowledge of the course material over those who do not.

In addition, it is wise to use the course objectives to decide what topics should be covered in exams. While not directly related to grading, this may save time later on when the instructor is asked to prove student achievement of each course objective for program accreditation purposes. It is advised to compose exam questions throughout the quarter. Spreading the test design workload not only eliminates last minute rushes when designing the exam, but also ensures that the test questions are closer to the way that the material was presented in class, making the exam more fair to the students.

Tip 2: Develop a grading strategy.

Most instructors we talked to graded one question for all of the students in the class before moving onto the next one. This allows grading to be consistent for that problem and eliminates time spent on defending the scores afterwards. In addition, time is saved since the instructor's attention does not have to be constantly refocused between different problems.

Some instructors use two passes when grading exam problems. In the first pass, they only correct the problem, write comments, and keep notes to themselves generating a sheet of common errors. This first pass is relatively quick since no time has to be spent on assigning scores, instead, the instructor can concentrate on finding mistakes in the solutions. This allows the instructor to see what the common mistakes are and get a sense of how the class did on the question before assigning points. The second pass is used to assign points based on the errors found in the first pass and can be done very quickly. This two pass approach makes the grading consistent across all exams.

There are other ways of using multiple passes when grading. If the problem involves a numerical answer, the answers can be first sorted and then graded. Students with the same numerical answer will likely have made the same mistake. Another way is to judge basic understanding during the first pass and then concentrate on more in-depth understanding during the second pass (perhaps ignoring papers that did not demonstrate basic understanding).

If only one pass is used to grade the exam, to maintain consistency, it is advised to double check the first few exams to make sure that they were graded the same way as the last exams.

Tip 3: Create a consistent partial credit policy.

It is common to give partial credit for using the right method or approach but wrong numerical answer. Defining how many points are allocated to the process of solving the question (for example, 80%) and how many points are allocated to the correct numerical answer (for example, 20%) can be used as a starting point to generate a grading scheme. The partial credit rule should be consistent throughout the whole course. However, it could be different for exams and homework assignments. Students have significantly more time to spend on homework than on the exam and typically have more resources (books, notes, other students, etc.) to use, so correct solutions are more common. The partial credit policy should be communicated to the students ahead of time so they know where to concentrate their efforts during the test.

We advocate the use of a grading sheet for point deductions/additions. Before grading a problem, design a scoring scheme that indicates how many points a particular error is worth. Using this approach guarantees consistency and makes the problem straightforward to grade. When teaching a course for the first time, it may be difficult to predict the errors ahead of time. In this case, consider using two passes to grade the exams (as described in the previous tip). The first pass can be used to gather information to generate a grading scheme.

It is advised to use the lowest number of grading levels that allows you to achieve an accurate assessment of student learning[13]. For example, the traditional grading system (A through F with plusses and minuses) is a thirteen-level system. A six-level system would be A through F without plusses or minuses. Grading levels may be easier to design using a numerical scale, for example, four-level grading system is 1-4 and a ten-level grading system is 1-10. For simple questions, having two levels (all right/all wrong or pass/fail) is sufficient. For more complex questions, there are more opportunities for students to make errors and more levels are needed to accurately gauge assessment. In general, the grading process is faster with fewer grading levels.

In large classes, dealing with grading complaints after the exam can be time-consuming and frustrating. Giving a small amount of points for trying to solve a larger problem, instead of zero, can reduce the complaints. It has little, if any, effect on the overall grade since it is small and can be accounted for in a curve if necessary.

Tip 4: Use multiple step questions effectively.

Problems with many steps that depend on each other are potentially very difficult to grade. If a student makes a single mistake on an earlier part, the instructor may have to compute the answers for the subsequent parts using the incorrect answer in order to accurately award partial credit. It is often much wiser to just split dependent questions into two separate problems.

Some instructors may still want to use multiple step questions because such problems have the potential to test students' understanding of broad concepts taught in the course. In this case, it is advised to design such questions so their difficulty increases incrementally. This way, majority of the students will be able to solve the first part of the problem, fewer students will solve the second step, and only those who have a true understanding of the topic will solve the last step. When used in such framework, multiple step problems can become excellent tools to build students' confidence and to differentiate students who have only superficial knowledge from those who have a deep understanding of the course material. Again, the instructor should decide if the extra time spent grading such problems is worth the potential improvement in student learning and assessment.

Tip 5: Use multiple choice questions effectively.

Some instructors are not fond of true/false or other multiple-choice type questions because academically weak students can get lucky by picking the right answer and academically strong students can get the question wrong by being tripped up by the wording. Allowing students to write a couple of sentences to defend their answer can mitigate both of these concerns. By keeping the responses short, such questions are not very difficult to grade and the extra time

spent reading pays off in a more accurate assessment of the student. Questions of this sort are good practice for engineers who, during their careers, are often faced with selecting the best option to address a problem.

Multiple choice problems are also useful in regulating the length of the exam, especially in large classes. Since they typically take less time to complete than numerical problems, they allow the instructor to make sure that all key course topics are covered. In lieu of giving multiple choice questions for simple numerical problems, you could use a short answer format and grade on an all right or all wrong basis.

Tip 6: Improve the clarity of student work.

When a student solution to the exam problem is poorly written and organized, it takes a considerable effort from the instructor to correct and grade. We suggest communicating proper problem solving methods and enforcing a standard for the clarity of presentation early on in the course.

When preparing the exam, make sure there is sufficient space for the student to write a solution, possibly including blank pages for longer questions. This makes exams more organized during grading. Putting a box where the final answer should go eliminates searching throughout the paper for the final answer and reduces ambiguities in situations where students write more than one solution.

Tip 7: Make the final exam optional.

To reduce the amount of grading at the end of the term, the instructor may consider making the final exam optional. This means that the final exam can only help the grade, not hurt it. This approach also has some benefits for the students. First of all, it allows students with test anxieties to take the exam with less pressure on them. Another benefit of this method is that students will be motivated to perform well earlier in the course in order to avoid taking the final exam. Of course, care has to be taken that topics presented at the end of the course are evaluated appropriately.

4. Grading Homework Problems

In this section we consider homework questions that have a similar format to the exam problems discussed above but are assigned on a regular basis throughout the quarter/semester. Homework assignments are important because they force the students to practice the material learned in the lecture and they provide a more frequent assessment of student learning to the instructor. Homework is also a platform for giving feedback to the students about the quality of their work.

Tip 1: Give quizzes instead of homework assignments.

Making homework optional cuts down on grading. It also allows students to work on problems in groups without issues of cheating or unfair assessment. Unfortunately, some students may not do the assigned problems and not learn or practice the material. One way to combat this is to have

small quizzes, possibly containing problems verbatim from the assigned homework problems. These quizzes take much less time to grade than a copious amount of homework problems.

Tip 2: Grade only a subset of the homework problems.

This tip reduces the time spent on grading but still ensures student feedback. However, the students may feel cheated that only part of the work they handed in is graded (especially if the questions selected for grading were questions they did not solve correctly). One compromise is to have smaller graded homework that the students hand in and additional ungraded problems students can work on their own. We have attempted this with mixed results – students seem to try to get by doing only the required homework until the first exam. But once they do poorly on the test, they increase their effort for the duration of the quarter. Having an exam or quiz early in the quarter may mitigate this effect by giving feedback earlier rather than later.

Tip 3: Decide how strictly the homework assignments are graded.

Some instructors give the same level of scrutiny to homework problems as exam questions. This approach communicates to the students the quality of work that is expected from them during the exam. Other instructors grade homework in a much stricter way than they would grade an exam. This methodology is based on the fact that students have more time to spend solving the homework than the time allocated to the exam. Finally, there are some instructors who grade homework in a less strict way than the exams because the homework assignments often contribute much less to the final course grade than exams do. We encourage each instructor to select the option that fits her/his teaching philosophy best and use it consistently.

Tip 4: Find a good textbook.

The textbook used for the course should provide a broad selection of end-of-chapter problems that can be selected as homework assignments or used by students to practice the material learned during the lecture. It is also a good idea to look for a textbook that provides numerical answers to some of the end of the chapter questions. This way, students who practice problem solving on their own have an immediate confirmation if their solution is correct. We have found that students like textbooks that include numerous examples of fully solved problems in each chapter. Such examples are often used by students as a starting point to solve the assigned homework. A solutions manual with correct and detailed solutions to all problems is a big aid for the instructor. Having homework solutions ready to distribute to the students eliminates the copious amounts of time spent on writing customized solutions.

When assigning homework for students to hand in, the instructor may want to list the numerical answers to all or some of the homework problems. This is a very controversial issue as some instructors feel that such a practice builds poor habits in students: they learn that only the final answer matters and often try to adjust their solution to fit the answer. On the other hand, many instructors feel that this gives the students immediate feedback and forces them to go over their solution again in order to find the mistake. It may also encourage them to attempt to solve the problem using a different method.

It is obvious that instructors should stress the importance of the problem solving process instead of the final numerical answer. In addition, instructors should also teach students how to verify their answer on their own, possibly using an alternative method to solve the problem or via computer simulation tools. However, when time is an issue, giving out numerical answers to some of the homework questions will cut down the hours spent looking over students' solutions and trying to help them find out where the mistake is.

Tip 5: Encourage neatly written homework.

Instructors should not waste time grading poorly written homework. Grading a neatly prepared homework with the final answers clearly marked is much faster than having to search for the solution or even for the sequence of steps taken to achieve the solution. Early in the course, the instructor should communicate her/his expectations on how the homework assignments should be written. We tell the students to turn in a final draft of their solutions in a presentable manner and not to include incorrect attempts or other work not relevant to the solution. If a poorly written homework is encountered, the instructor may give the student an opportunity to rewrite the assignment (perhaps with a reduction in score) or require the student to type the solutions using a word processor in future assignments.

5. Grading Writing Assignments

Engineering writing assignments are considered to be the most time consuming and difficult to grade. In this section we present some tips on how to make this process more time efficient and effective.

Tip 1: Use rubrics.

One advantage to using rubrics[12] is that they clearly communicate to students what is expected from their writing assignments and provide the appearance that assignment will be graded more objectively than subjectively. Rubrics can be used to gauge content, proper observations, citing of sources, organization, style, grammar and spelling. Some rubrics may be specific to the assignment making sure that students answered particular questions somewhere in their paper. Another advantage of rubrics is that they make grading easier and more consistent by enforcing the instructor to adhere to the rubrics when grading. This can be problematic if the instructor encounters a situation that is not covered by a rubric. Therefore, some thought is required ahead of time when designing the rubric. For new faculty, revisions to the rubrics will likely be necessary once you have gained experience grading writing assignments. An example of a rubric that was used to grade final project report in a senior elective digital image processing course is shown in Table 1. The project involved research and MATLAB implementation of a solution to an image processing problem.

Table 1. Example of a rubric used to grade a final project report.

Evaluation Criteria	Points	Score	Comments
Format	15		Is the report format correct and professional? Are there any mistakes in the tables or figures? Are the tables and figures labeled correctly and referred to by name in the text?
Introduction	15		Is the most important report information highlighted in the executive summary? Does the introduction describe a clear report purpose?
Content	35		Is any information missing? Are the findings and statements accurate? Are the ideas fully developed? Are pictures placed effectively to explain text?
Conclusion	5		Does the conclusion address the main points?
Writing Style	15		Is the report carefully proofread (no errors in spelling, minimal errors in grammar, punctuation, etc.)? Is the writing concise and tone formal? Are clear transitions used between sections and ideas?
Appendix (source code)	15		Is the program easy to read? Are there enough comments?
TOTAL	100		

Tip 2: Require standardized style for design documents.

Having a standardized style will force all assignments to have a very similar structure. This allows the instructor to know where to find something in a document instead of having to search the entire document. It also makes grading more consistent across assignments. In addition, companies often have standards for documents they develop and therefore, getting students used to following a format prepares them for writing in their professional life. One example of a standardized style is the IEEE Standard 1063[7] which describes style and organization guidelines for software user documentation.

Tip 3: Require only one formal report that is graded thoroughly.

Grading a formal lab report can be very time consuming. It may be wise to consider only assigning one formal lab report during a course and using informal lab reports and/or lab notebooks to assess the other labs. A counter-argument is that writing a formal lab report is too important to do only once. However, if the curriculum is designed in such a way that students have to write at least one formal report for each lab course, they should receive plenty of experience. Another way of reducing the writing load is to require a different section of a formal lab report to be written for each lab.

Tip 4: Use frequent smaller writing assignments.

Small writing assignments (one page) can be very effective - even in classes that do not seem to lend well to writing, such as Circuits I and II. The best topics for these assignments are those that require the students to think about a problem or issue themselves. Given the small page limit, students have to be concise when writing, making the assignments easier to grade. Structure and organization are less important when grading smaller assignments. With the popularity of email in today's world, being able to write short informational messages or memos is increasingly important. While writing is an important skill for engineers, we recommend assigning writing as homework instead of the time-constrained environment of an exam.

6. Grading Projects

Projects are considered to be difficult to grade because the process is often as important as the final result. In addition, projects often involve teams making it difficult to assess individual students. The tips listed in this section are designed to make the project grading process more objective and faster.

Tip 1: Break down projects into parts and give feedback on each part.

Students often need assistance breaking down a project into steps. Early on in their academic career or in a course, it is a valuable learning aid to give feedback on each step or phase of the project. In particular, positive feedback gives the student confidence and encourages her/him to complete later steps and future projects. While initially the time investment is high, later assignments can be easier to grade because the students are already familiar with the process of dividing their projects into tasks.

Tip 2: Make each individual accountable in team projects.

One of the main difficulties of assessing group work is determining how much effort each individual put into the project[3,5]. We advocate making each student accountable for at least some portion of the project. One way to accomplish it is to require a status update. There are several ways of doing this: status reports, weekly time sheets, meetings, or a project notebook. For groups of up to six students, we have found that weekly meetings are a time effective way of monitoring group and individual progress. The instructor starts such meeting by asking each member what they have worked on in the previous week. Then time is permitted for the students to ask questions about the project which aids in their learning process. Since the meeting lasts an hour at most, it is quicker than managing and grading status reports or time sheets.

However, this may not be the most practical approach if you have to manage several teams or if the teams are large. Using required but ungraded weekly status reports can be a way to track individual performance. Instructors can read them quickly to make sure that everybody is on track. Status reports also give students experience with a task they likely will encounter in industry.

Unfortunately, students may not necessarily be completely honest when presenting their status updates. The use of peer evaluations can help indicate whether or not all members are contributing. Table 2 shows an example of a peer evaluation form used each quarter in a year-long senior design sequence. However, peer evaluations do not always work, as friends may cover for each other. To use peer evaluations effectively, try to convince the students that this is a very important tool in evaluating teamwork. One instructor we talked to makes everyone accountable for all aspects of the project, allowing him to ask questions of anyone in the group. This way, it is obvious if someone in the group is not contributing. However, this organization may not be the most effective use of team time.

Tip 3: Get input from other sources.

When working with a project team for a long period of time, it is natural to develop some level of bias towards individual team members or towards the entire team. To promote fair assessment of the final product, consider having other instructors sit on a project presentation or read the final report to gather opinions from a more unbiased source. Panel grading can be a very effective tool that ensures consistency among different teams.

7. Grading Computer Programs

Usually, grading computer assignments takes much more time than grading numerical problems. Typically, programs are graded on both functionality (does the program work?) and style (is the source code easy to read and maintain?). In this section we share tips on how to do it efficiently.

Tip 1: Use automated grading.

We suggest using a series of tests to grade program functionality. We typically use an all-or-nothing points policy on individual tests as it is too difficult to determine appropriate partial credit without analyzing the source code. From the students' perspective, severe deductions are possible if students hand in a program that does not work for most test cases. When this policy is communicated to students ahead of time, it encourages them to thoroughly test their programs before submitting them for grading.

Tip 2: Grade style by looking at a portion of the source code.

Grading style in computer programs is important but also very time-consuming. One technique for larger programs is to look at one section of code to grade style rather than the entire program. Most students are consistent with their style across the program so it is unlikely that sampling one section over another will have any significant impact on their grade. When using this technique, it is important to look at each assignment in the same manner. If you detect an error in one assignment, it is recommended to quickly scan other assignments to make sure that the student did not make the same error.

Table 2. Example of a form used for peer evaluation of teamwork.

TEAM NUMBER: _____ **YOUR NAME:** _____

PLEASE RATE **YOURSELF AND YOUR TEAM MEMBERS** USING THE PROVIDED TABLE. THIS PEER EVALUATION WILL BE USED IN ASSIGNING THE FINAL COURSE GRADE. THEREFORE, PLEASE FILL THE TABLE BELOW HONESTLY, AND AS ACCURATELY AS YOU CAN. USE THE FOLLOWING RATING SCALE:

0-NEVER; 1-SELDOM; 2-SOMETIMES; 3-USUALLY; 4-ALWAYS

FOR ADDITIONAL COMMENTS, PLEASE USE THE BACK OF THIS PAGE.

Names of each team member				
Regularly attends group meetings	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Comes to meetings prepared	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Constructively participates in group discussions	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Accepts responsibility for major tasks when needed	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Arranges personal schedule to fulfill commitments to the team	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Completes work in a timely and acceptable manner	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Identifies sources and other resources to aid team progress	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Accepts criticism gracefully	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Is considerate of needs of others	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Helps others identify their strengths and weaknesses	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Contributes to everyday hands-on design work and drawings	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Contributes to writing of the project proposal	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4
Contributes to management of the design project	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4	0 1 2 3 4

Tip 3: Use rubrics to grade style.

Writing computer programs, in some sense, is like writing a paper. Rubrics[12] can be used as guide for students and instructors when assessing style. Rubrics work best if they are given to the student ahead of time. This makes it clear to the students how their programming style is graded. Students tend to do the minimum work that satisfies the style requirements. Using rubrics can raise the expectations for style. Different scores can be given to students who put some thought

in organizing and writing their code versus students who merely go through the motions. Without some sort of a rubric, students may complain about points being deducted very subjectively. Providing example programs helps students understand the level of style necessary in order to get a high grade.

Tip 4: Let students find their own errors.

When a functionality error occurs in a program, the burden of finding the error should reside on the student. Trying to debug students' programs to point out the error can be extremely time-consuming. Instead, the instructor should provide the failing test and expected output. It is a valuable learning experience for the students to find the errors in their code. To motivate students to actually correct the errors, the instructor may want to allow students to hand in corrected versions where they can earn some points back on the assignment.

Alternatively, the instructor could group students into pairs and ask them to test and debug someone's code. In addition to removing the burden of finding an error from the instructor, this exercise has the potential to teach students how to write programs that are easy to test and debug. To ensure fairness, this activity is best done as an ungraded in-class exercise.

In order for these techniques to be effective, it is necessary to teach the students how to test and debug programs. Time should be spent early in the course (or curriculum) on how to use a debugger and how to think about different tests, especially corner cases. We have found that discussing types of tests in the first programming assignment pays dividends for later assignments.

Tip 5: Require other submission material such as a test suite or a design document.

One way to improve the quality of programs and make grading easier is to require other deliverables. One possibility is to ask students to submit a set of test cases with their programs. This also forces students to think about testing before submitting their programs. For more open-ended assignments, it can help your grading to require the students to write a brief description of what they did and any shortcomings or restrictions. East and Schafer[2] share their experiences when they ask students to explain their code via a presentation either to the instructor and/or other students in the class.

One challenge with this approach is that it can be difficult for students to take the extra deliverables seriously as they are aware the program itself is the primary focus of the grading. Consider making the extra piece a moderately sized portion of the grade (15-20%) and be clear about the expectations before the assignment.

8. Student Feedback

Giving feedback on homework assignments, computer programs, exams, and project documents is one of the most important ways to motivate students, build their confidence, and encourage further learning. In addition, feedback informs students that they lack knowledge or skills in a particular topic and notifies them what improvement is expected from them by the end of the

course. However, giving detailed feedback on every assignment is extremely time-consuming. This section addresses this issue and gives hints on how to provide quick but meaningful feedback to students.

Tip 1: Go over answers in class or provide a handout with solutions.

If a class struggles on a question, the best way to give feedback is to go over the problem in class. Since time is often a constraint in lecture, only give feedback for problems that most of the class got wrong. Also, give a solution handout so students know the correct answer. Students with mostly incomplete answers can be directed to the solution. Having a solution handout also reduces the number of complaints from students that feel that they got a particular question right.

Tip 2: Ask students to see the instructor.

If a student exhibits a complete misunderstanding on a particular question or topic, a small written amount of feedback is likely not to help all that much. Instead, telling the student to see the instructor during the office hours may be a more effective solution. During office hours, the instructor can go over the trouble areas with the student. The instructor may also ask students who perform poorly overall to schedule an appointment to discuss ways of improving their performance in the class.

Tip 3: Skip feedback on the final exam.

If students usually do not pick up the final exam, it is not necessary to give detailed feedback for this exam. This clearly saves time. However, the instructor should be careful and remember to write down some comments to indicate why points are taken off so that the course grade can be defended if a grading dispute arises.

Tip 4: Hand back a feedback sheet.

Feedback given for computer programs, writing assignments and even problems with numerical assignments may be similar for large groups of students. Instead of writing comments on each paper, the instructor can prepare a handout that lists the most common mistakes and distribute it when the graded assignment is given back to the students. The instructor can personalize the feedback handout by circling the type of mistakes that this particular student made.

When using rubrics for grading, an individualized handout sheet can be prepared for each student. The rubric score is marked with a brief comment explaining why the grade was given for that particular rubric. Giving the sheet ahead of time makes it clear to the students how their work will be graded. This feedback sheet can be independent of any specific comments or corrections written on the paper.

Tip 5: Restrict options for grading disputes.

Resolving grading disputes can be time consuming for instructors, especially in large classes. While it is important to address legitimate concerns, developing course policies to restrict grading disputes may reduce requests that are likely to be frivolous. We do not hear grading disputes on the day the exam was handed back to students. This requires the students to consult the solutions handout before asking questions about their own answers. It also gives the students a chance to cool-off emotionally from any sticker shock they may have received when the exams were returned.

We also only allow a limited time for grading disputes – a week from the time the exam or assignment is handed back. This will eliminate regrade requests of students trying to beg for points at the end of the quarter using old assignments and exams. This time limit forces the students to review their assignments immediately and hopefully makes them realize on what areas of the course material they should concentrate more.

9. Other Grading Tips and Activities

Tip 1: Hire a teaching assistant or a grader.

In large universities, it is very common for faculty to hire a Teaching Assistant (TA) to help with grading student work. From our interviews, we have learned that most faculty members who use TAs ask them to grade homework and lab assignments, but not exams. Since exams usually count much more toward the final grade than homework assignments, the instructor can ensure that students are treated fairly and have a first hand experience with student work.

If the instructor has a TA to help with the grading load, it is wise to allocate time at the beginning of the quarter to talk about the instructor's expectations with regard to the quality of the TA's work and rules for grading. The instructor should monitor the TA's work and use the first couple of homework assignments to clarify her/his expectations. Also, it is always a good idea to review the graded homework assignments before they are given back to the students. The instructor should know if the students are learning and when they have troubles understanding the material. The students should be also informed of their progress throughout the quarter.

Asking the TA to solve the exam problems before the actual exam ensures that there will be no mistakes in the exam. In addition, the instructor can better judge the difficulty of the exam and its length.

Tip 2: Find a grading environment and schedule that works well.

Each instructor should find a grading environment that works well for her/him. Some faculty members grade at home since there are less distractions. Some instructors grade while riding a bus, while others go to the local coffee shop. It is also important to develop a consistent grading schedule and try to grade the assignments soon after they are turned in. If the instructor falls behind on grading, it is usually hard to catch up. In addition, if the assignments are promptly

graded and returned to the students, they receive feedback in a more timely manner and can take advantage of it for the next assignment.

Tip 3: Set clear expectations.

By setting clear expectations ahead of time, students are well aware of what they are being graded on. This causes the submitted work to be of better quality and closer to what you expect. This makes grading assignments much easier. It is important to enforce these clear expectations from the start. Grade the very first homework assignment or first exam strictly according to the expectations. Communicate expectations including the clarity of the solution, the process at arriving at the final answer, the neatness of the homework, and the use of proper units. You may also consider allowing students to resubmit their work to get half of their points back on the first assignment so students do not feel that they are being subjectively penalized. The extra time spent grading early in the quarter will pay dividends later in the quarter both in terms of grading time and student learning.

10. Conclusion

We provide advice for new faculty on how to improve grading efficiency without sacrificing its effectiveness or fairness. We discussed tips and techniques for grading several different types of student work that are common in engineering: problems, writing assignments, computer programs, and projects. A common theme that permeates many of the tips is to think about grading before handing out the assignment and to make sure that you clearly convey your expectations and grading criteria to the students. This was by far the most common tip from the faculty members interviewed for this paper. Such a strategy forces the instructor to be fair and improves the quality of student work, making grading straightforward and less time consuming.

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