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Experiences with Specifications Grading in Computer Engineering: Making Class About Learning Again

Christopher Cischke, Michigan Technological University

Christopher (Kit) Cischke is a Teaching Professor in the Electrical and Computer Engineering Department at Michigan Technological University and a Ph.D. student in the Psychology and Human Factors Department where he studies learning and memory in the engineering classroom.

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Background

Students and faculty agree that learning the material from a given course is valuable. Faculty members believe that the value of the material is inherent in the material itself. Mastery of the material is valuable simply because those concepts are interesting and edifying. Understanding a concept is its own reward. How could they not also select a career that transmits this valuable knowledge to future generations and possibly engage in research to foray into the knowledge frontier of this inherently valuable field? An instructor may go so far as to define "learning objectives" for their classes and explicitly advertise to the students the key skills and knowledge for the class.

Students are also concerned with learning the material, though their reasoning tends to be vastly different. Mastering the material is frequently a means to an end and not an end in itself. Demonstration of mastery leads to job opportunities and paychecks. The student can be forgiven for this; this focus has been part of the university's marketing plan since first contact with the student by advertising job placement rates, median mid-career salaries, and return on investment metrics. While the underlying motivation differs for precisely why learning the material is valuable, at least the agreement remains.

Then, it is incumbent on the instructor to assess the amount of learning that has occurred. Modern neuroscience tells us that learning is a change in the synaptic wiring of the brain. Connections are made or strengthened as a result of learning processes. Measuring these changes is difficult or impractical, so performance is used as a proxy measure. In theory, greater performance is indicative of greater learning. In the modern classroom, that almost always translates practically as various flavors of assessments (homework assignments, projects, quizzes, labs, exams) with point values. A final grade is assigned based on a weighted sum of points. More accumulated points represent a better performance, implying greater learning. Such is the intention of the grading scheme.

When instructors create proper rubrics for assignments that explicitly map learning objectives to point values, it may be clear how the points earned on the assignment represent material successfully learned by the student. However, that connection is often not explicit, and the point allocation is nearly random. Once the points are disconnected from the learning, the class turns into a points chase. Behavior becomes performative, with students more concerned with picking up points than learning the material. Students will frequently approach the faculty member seeking to recover points on an assignment they thought was unfairly graded.

Thus, GPA becomes an overall measuring stick we cannot avoid. A student's GPA invites or retains scholarship money. It defines their ability to participate in extracurricular activities. It becomes the gateway to interviews and eventual offers for the first job. The reality is that GPA has almost no relevance to a student's eventual success. Samson et al. [1] found that college GPA and test scores had almost no predictive ability for a student's future success. These academic metrics explained only 2.4% of the variance in occupational performance criteria, such as wages

and job satisfaction, with engineering being notably lower than the average. Students are overly concerned with collecting points to pad a GPA that doesn't really mean anything.

The logical conclusion is to change the way we assess students. When considering any grading system, including the currently dominant points-based system, we can and should demand certain characteristics of the system. It should always uphold rigorous academic standards and clearly connect with student learning objectives. A bonus is if the system itself could discourage cheating and reduce student stress. Ultimately, what if the grading scheme eliminated the chase for points by eliminating points? Could the focus be moved back to learning the material?

Specifications Grading

Specifications grading (or simply "specs grading") is one effort to refocus classes to learning. Originally described by Linda Nilson [2], Howitz et al. [3] provide a systematic review of various implementations of specs grading in a variety of STEM classes. Their findings are largely consistent with what is presented here. The heart of specs grading is reducing the grade of every assignment to a pass/fail decision. If the submission meets the posted specifications for the assignment, it passes. (Here, we also see the inspiration for the name.) Some have jokingly referred to it as "nearly pointless education" [4].

Three critical things make specs grading work:

- Rubrics to concretely yet concisely define the specifications for any assessment
- Bundles of assignments to calculate a final course grade
- Tokens for reworking failed assignments

Rubrics

The students cannot know the specifications for an assessment unless they are clearly specified. The rubric's form can be as varied as that of the assessment. For certain types of assignments, the instructor might set forth a collection of both outcome-based and process-based criteria that the student must meet. For example, a programming assignment might require the implementation of a simple client-server pair in Python, using TCP sockets (both *process* criteria), and performing a prescribed operation with specific formatting of the displayed output (both *outcome* criteria). Similarly, a simulation or design task might specify the number of types of various circuit elements used in the system (*process* criteria) and a maximum power delivery or frequency response envelope (*outcome* criteria). Drill problems, such as those involving the analysis techniques in an introductory circuits class, might require a more creative solution. A possibility here is to declare that a particular analysis method is required (e.g., nodal analysis) and that the series of equations must be correct, even if the final numeric answer is not. The idea of marking a particular exercise as "passing" when the final answer is incorrect may feel foreign, but is more likely tied to a published course objective (such as "Mastery of DC circuit analysis by node and mesh methods") than the prerequisite skill of solving a series of linear equations.

Bundles

Bundle	Lab Grade
11 complete labs	A
10 complete labs and 1-2 remaining tokens	AB
10 complete labs and 0 remaining tokens	B
9 complete labs (must include labs 5-7, and 9) and 1-2 remaining tokens	BC
9 complete labs (must include labs 5-7, and 9) and 0 remaining tokens	C
8 complete labs (must include labs 6, 7, and 9) and 1-2 remaining tokens	CD
8 complete labs (must include labs 6, 7, and 9) and 0 remaining tokens	D
Anything Less	F

Figure 1: A set of bundles translated to final letter grades.

Bundles

The course still needs to have a final letter grade assigned to each student. "Bundles" provide the mechanism by which the instructor can transform a collection of pass/fail assignments into such a grade. Consider Figure 1, which comes from the syllabus of a particular lab course. In order to achieve a particular letter grade, a student must pass a certain number of the labs. If the student cannot (or, more often, *chooses* not to) pass a particular assignment, their grade drops. The instructor may choose to promote certain assignments to a mandatory status, such as labs 6, 7, and 9 in the example. In this case, these represent the critical skills a student must demonstrate in order to prove satisfactory mastery of published learning objectives and pass the class.

Bundles also provide a method for grading traditional homework assignments composed of a collection of drill problems. The instructor might specify that the student must attempt 100% of the questions, but only 80% of them need to be correct in order to pass. Again, the definition of "correct" is dictated by the specifications rubric. Suppose the rubric defines "correct" as being roughly 80% of the way to a fully correct solution, and the mini-bundle requires 80% of the questions to be correct. In that case, this is mathematically equivalent to requiring 64% of the submission to be correct – a common threshold between a passing and failing grade under a traditional points-based grading system.

The construction of bundles for the entire course or mini-bundles for a particular assignment is entirely at the discretion of the faculty member.

Tokens

The pass/fail grading policy clearly eliminates the points chase aspect of a course but cannot, by itself, refocus the class on learning. A key ingredient of specs grading is allowing the student to rework a failed assignment. When failing an assignment is a permanent state of affairs, a message is implicitly sent to the student—the opportunity to learn that material has passed. Maybe there will be a follow-up opportunity on a summative assessment, but often, there is no such opportunity. Providing students with infinite opportunities to rework assignments only

ensures two outcomes. First, they will rarely take the first attempt seriously. Secondly, faculty members will spend enormous amounts of time grading endless resubmissions. Students are issued tokens to elicit a good-faith first effort and limit the number of resubmission opportunities. Redeeming a token allows the student to rework any assignment, even up to a Final Exam. Critically, the student must leverage the clearly established power of reflection in learning when resubmitting the assessment by explaining what went wrong in the initial attempt and providing corrected work. It is often valuable to reward students who navigate the class without the use of tokens, such as by providing an automatic "pass" on the Final Exam. Some students find this reward to be more of a stick than a carrot. The pressure to hold on to every token increases the perceived importance of every assignment.

The number of tokens and the schedule for when they are issued to the students are issues that have no easy answer. Some suggest counting the number of high-impact assignments, such as projects and exams, and issuing an equivalent number of tokens [3]. Some suggest taking that number plus one additional token. When multiple tokens are issued at the beginning of the semester, students tend to hoard them and are reticent to use them. Experience has shown that students rarely run out of tokens, but it may be worth considering how students may earn additional tokens – if the token system is used at all.

Practical Experience

This grading scheme has been implemented for five of the last six semesters in a moderately sized (~35 students) junior-level computer engineering course. This course has both a lab and a lecture component, both of which utilize specs grading.

The Good

Students are usually nervous the first time they encounter specs grading due to its considerable difference from what they have seen in every other class they have taken, and it can sometimes require multiple explanations. One student specifically said, “The assignments feel like life or death with the scheme and threshold.” However, once students understand the scheme, they react mostly positively. They enjoy not having to worry about particular point values on assignments and chasing after every available point. The bundles in the syllabus allow them to gauge their workload and standing in the course easily. There are no discussions at the end of a semester asking to round a grade up just a bit or for some extra credit assignments. There has been no sense of grade inflation. The grades from the last five semesters are shown in Figure 2. Semesters 1, 3, and 5 are smaller classes during the Fall semester and generally out of the normal sequence for students. Semesters 2 and 4 have somewhat larger populations. If there is any discernible pattern as an impact of specs grading, it would be that fewer students slip by without actually learning the material. The amount of extra grading needed for various resubmitted assignments is actually quite low – no more than 10% of the students resubmit any given assignment.

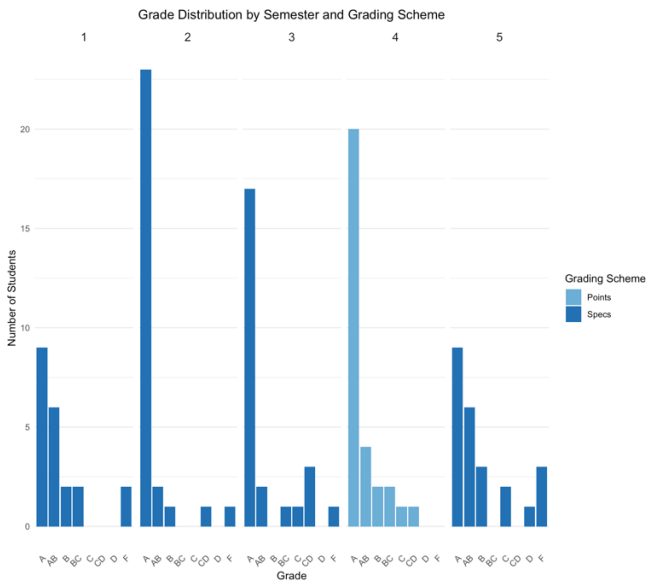

Figure 2: Grade distribution over five semesters of the same class. Specs grading has not led to grade inflation.

If the point of specs grading is to refocus the class on learning, is this happening? The same student who felt like specs grading made every assignment "life or death" said, "Your assignments are more interactive, you ask questions that make you think, and makes you put in effort to come up with a right answer and I can definitely say I have not had that experience with any other instructor/professor." Judging longer-term outcomes, students who went through the specs grading version of this course collectively scored 2-5% higher in the follow-up course than the historical average. It would seem they are carrying more knowledge into their future classes, though the sample size here is too small to draw overly strong conclusions.

A pair of faculty members team-teaching an engineering entrepreneurship course at another university have recently implemented specs grading in their project-based course. Their report is positive: "Definitely, takes less time to grade and seems to be sufficiently clear to students. We've got some room to improve both for next year and future assignments this semester. So far, so good!"

Administrative support from every level has been positive. Department chairs, deans, and provosts have voiced support for this rethinking of grading. These administrators do not necessarily see specs grading as the final shape of the grading scheme of the future, but certainly as a large step in the right direction.

The Bad

In the first semester, the students found a considerable loophole. The policy has always been that they could redeem all of their tokens to pass the final exam automatically. However, many of these students had multiple outstanding failed assignments throughout the rest of the course. The goal had been to reward students who had consistently demonstrated mastery of the material, but these students had not done that. The revised policy now states that the tokens can be redeemed, but all other requirements for the A-level bundle must be satisfied as well.

It is crucial to force students to use their tokens to resubmit work via the Learning Management System. The easiest way is to lock the assignment at the normal deadline. This obligates students to explicitly contact the instructor or course support personnel to use a token, and it is an easy way to ensure that this bookkeeping takes place.

If grading tasks ever get behind schedule, it can be highly problematic. Students may not have enough time to rework failed assignments, and the knowledge required to rework them may grow stale. While it is generally bad to let grading tasks build up, the consequences in specs grading seem to be somewhat more severe.

While grading homework assignments and certain other assessments can be significantly faster under specs grading, experience has shown that exams can be much slower. The grader must adapt to only pointing out that something is wrong and not explaining how or why it is wrong. Otherwise, the student cannot identify and correct their own errors, which has been shown to be of immense benefit to student learning outcomes [5]. Students are often unenthusiastic or unwilling to investigate why an answer was wrong and simply ask the instructor to explain it. A mathematics instructor attempted to use specs grading for a Calculus I class and found that unlimited rework opportunities resulted in students not taking the initial attempt at an assignment seriously. They submitted half-hearted efforts, knowing that they could revise assignments until they were satisfactory. This led to much increased grading time.

Most LMSs do not have a native method for tracking tokens, so devising a solution becomes necessary. Using a fake assignment has proven to be fairly effective. The learning management system probably does not natively support a pass/fail grading scheme either. Using a binary 1/0 scale was a natural solution for the target population of computer engineering students.

Refactoring assignments and course policies to support specs grading is a non-trivial task. The amount of effort combined with a suspicion that academic standards have been compromised (or are, at the very least, in danger) has led to some pushback from other faculty members. This stands in stark contrast to the enthusiasm shown by the university administration.

Conclusion

Specs grading may not be the final solution in this space. Overcoming challenges such as initial student skepticism and lack of support in LMS software may require more effort than many faculty members want to invest in an alternate grading scheme. However, when student satisfaction is higher and learning objectives are more demonstrably and consistently met, it represents a step in the direction of returning our classrooms to a place of learning. Perhaps it is points-based grading systems that are truly "pointless."

[1] G. E. Samson, M. E. Graue, T. Weinstein, and H. J. Walberg, “Academic and occupational performance: A quantitative synthesis,” *American Educational Research Journal*, vol. 21, no. 2, pp. 311–321, 1984.
[2] L. B. Nilson and C. J. Stanny, *Specifications grading: Restoring rigor, motivating students, and saving faculty time*. Routledge, 2015.

[3] W. J. Howitz, K. J. McKnelly, and R. D. Link, “Delving Into the Design and Implementation of Specifications Grading Systems in Higher Education: A Systematic Review,” Nov. 08, 2024, *Chemistry*. doi: 10.26434/chemrxiv-2024-d0tf6-v2.
[4] R. P. Rylaarsdam and C. Heinz, “Specifications based grading: Nearly pointless education that points students to key concepts,” *The FASEB Journal*, vol. 30, pp. 662–13, 2016.
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