EPiC Series in Built Environment
Volume 4, 2023, Pages 453–461
Proceedings of 59th Annual Associated Schools of Construction International Conference

Effect of Competency Grading in Statics and Mechanics of Materials Course on Student Grades in Follow-On Course

Kirsten A. Davis, Ph.D., PE, RA
Boise State University
Boise, Idaho

Competency grading is a non-traditional grading style that focuses on the proficiency of the learner. It has been proven in other studies to be an alternative grading system that works well in technical courses and has a lot of benefits for both the student and the instructor. The results of the data analysis for this study indicate that the mean grade in the follow-on course entitled "Introduction to Concrete and Steel Design" is higher when competency grading is used in the prerequisite course "Statics and Mechanics of Materials" than when traditional grading is used. The competency grading style helped students be more successful in the follow-on course than students taught with a traditional grading style because of changes to both student and instructor behaviors. Lessons learned are also included for faculty interested in considering adopting competency grading in their courses.

Key Words: Statics, Mechanics of Materials, Competency Grading, Alternative Grading, Construction Management

Introduction

Students are commonly assessed and graded using traditional means – they are given assignments and tests, each is scored in some way, and those scores make up a course grade. Depending on the quantity and weighting of the assignments and tests, it is often possible for a student to do very poorly on one or more assessments and still pass the course. For example, if there were four exams, they could score 85%, 75%, 65%, and 55% and earn a C average, yet they did not pass half of the exams. They may have completely failed major concepts, but still manage to pass the course. Because of issues like this, students may be allowed to progress into follow-on courses, but there may be gaps in requisite knowledge needed for those later courses.

At Boise State University, many students passing the junior level construction management Statics and Mechanics of Materials course struggled to successfully use that content in one or more of the four follow-on courses. In response to this mismatch, traditional grading was replaced with one based on competency. Competency grading requires that students prove their ability to successfully complete well-defined skills in order to pass the course.

This paper provides details of competency grading from the literature, as well as how it is used in a Statics and Mechanics of Materials course, provides an examination as to whether students that experienced competency grading were more successful in one follow-on course entitled "Introduction to Concrete and Steel Design" than students with traditional grading, and provides lessons learned for other faculty interested in trying this alternative grading method.

Competency Grading in the Literature

This paper will use the term Competency Grading, but it is relevant to note that there are many different names for non-traditional grading methods that focus on the proficiency of the learner, such as Standards Based Grading, Specifications Grading, Criteria Grading, Competency Grading, and Mastery Grading. There are small differences in what each of these names actually means (Nilson, 2015; Sadler, 2005; Townsley & Schmid, 2020), but the intent of all is similar – to ensure that students are evaluated on specific, clearly identified objectives, and that they master those objectives in order to successfully complete a course. Unlike in typical traditional grading schemes, here, course grades are clearly connected to level of mastery of the course objectives; students are required to show a well-defined level of mastery in order to pass a course. These alternative grading methods also generally allow students to show improvement over the duration of the course by providing multiple opportunities to demonstrate mastery of a topic.

Evidence in the literature suggests that these methods improve student engagement, help students have a more thorough comprehension of course materials, and help establish and maintain a high level of academic quality (Buckmiller et al., 2017; Iamarino, 2014; Kulik, et al., 1990; Nilson, 2015; Toledo & Dubas, 2017). Students cannot learn something halfway, but instead must review feedback from the instructor and incorporate it into future work in order to be successful in the course.

The use of competency grading is not well-documented in Construction Management disciplines, but is used in some engineering disciplines, including the teaching of statics courses. For example, Crough (2017) found that students in a statics course with weaker academic preparation were found to perform better when a partial use of this style of grading was used, with no harm done to students with stronger academic preparation. Ritz et al (2020) found that students exposed to a partial use of mastery learning received higher final exam scores than other students. Both of these studies used grades on traditionally graded final exams completed by both the mastery- and traditionally-graded students as their point of comparison between the groups.

Structure of Competency Grading in Course

Competency grading in the Statics and Mechanics of Materials course described in this paper began with a list of course objectives, which look fairly traditional for a course such as this.

Course Learning Objectives:

1. Recall and apply equilibrium equations to force systems.
2. Graphically illustrate problems of statics and mechanics using free body diagrams.

3. Calculate loads and the effects of forces on beams, trusses, and other simple structures.
4. Calculate engineering material properties and use with published strength information to solve problems.
5. Solve problems involving stress and strain.
6. Calculate and draw shear and moment diagrams for simply loaded beams.
7. Calculate bending stress, shear stress, and deflection in simply loaded beams.

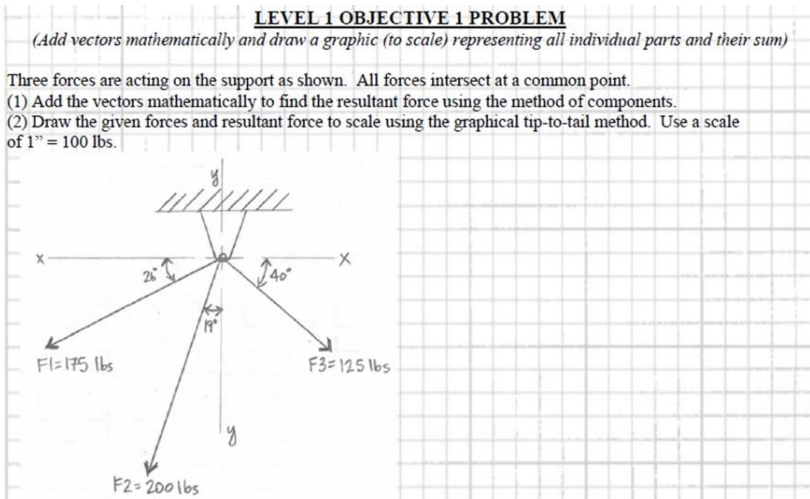
These objectives were then modified and clarified, in coordination with the instructors of the four follow-on courses, to create two lists of objectives for evaluation in the course. These lists specify individual tasks to demonstrate mastery of various items in the course. Level 1 objectives are those where mastery is considered necessary to pass this course. These objectives were formed based on input from the instructors of the follow-on courses as prerequisite knowledge needed for a student to be successful in their course. Students must successfully complete all twelve Level 1 objectives by the end of the semester to be eligible for a passing course grade. Level 2 objectives are a combination of more complex and, therefore, more difficult versions of Level 1 objectives, and also objectives that are not considered absolutely essential to master for a passing course grade, but are commonly found in statics and mechanics of materials courses. Level 2 objectives allow students to raise their grade beyond the minimum passing grade of C-.

Level 1 Objectives (mandatory to pass course):
1. Add vectors mathematically and draw a graphic representing all individual parts and their sum
2. Correctly draw a free-body diagram
3. Given a beam or truss with loadings, calculate reactions
4. Calculate tributary area loading
5. Calculate the centroid of a composite shape
6. Calculate the moment of inertia of a composite shape
7. Calculate and draw the shear diagram for a simply loaded beam
8. Calculate and draw the moment diagram for a simply loaded beam
9. Solve a simple stress/strain problem
10. Calculate bending stress for a simply loaded beam
11. Calculate shear stress for a simply loaded beam
12. Calculate the deflection in a simply loaded beam

Level 2 Objectives (not required to pass course but can raise a student's grade):
1. Calculate the resultant of a coplanar force system (may be concurrent, nonconcurrent, and/or parallel)
2. Calculate and draw the shear diagram for a more complicated simply loaded beam
3. Calculate and draw the moment diagram for a more complicated simply loaded beam
4. Solve a more complex stress/strain problem
5. Solve a friction-related statics problem
6. Given a truss, find the reactions and determine the forces in the members by method of joints
7. Given a truss, find the reactions and determine the forces in the members by method of sections

Student mastery of each individual objective is assessed through problems (a separate problem for each Level 1 and Level 2 objective) done during test days in class. See Figure 1 and Figure 2 for example test problems. Work on each problem is marked Pass or No Pass. A Pass for an individual objective would meet the following requirements:
- Proper set-up

- Correct use of diagrams, equations, and units
- Clear conceptual understanding
- Correct, complete, clear solution using correct method, though minor math errors are sometimes overlooked

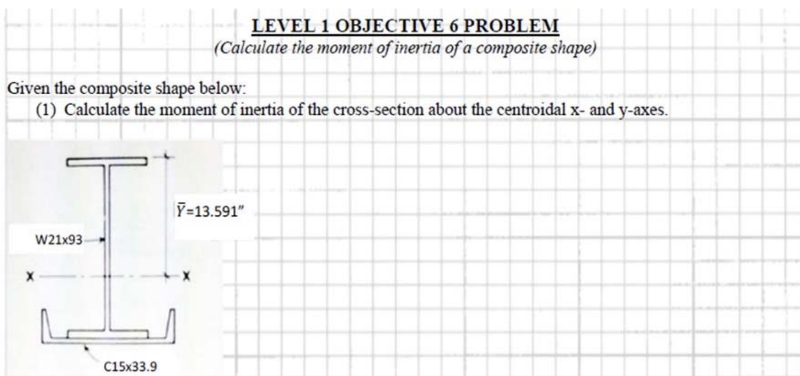


LEVEL 1 OBJECTIVE 1 PROBLEM

(Add vectors mathematically and draw a graphic (to scale) representing all individual parts and their sum)

Three forces are acting on the support as shown. All forces intersect at a common point.
(1) Add the vectors mathematically to find the resultant force using the method of components.
(2) Draw the given forces and resultant force to scale using the graphical tip-to-tail method. Use a scale of 1" = 100 lbs.

Figure 1. Example test problem



LEVEL 1 OBJECTIVE 6 PROBLEM

(Calculate the moment of inertia of a composite shape)

Given the composite shape below:
(1) Calculate the moment of inertia of the cross-section about the centroidal x- and y-axes.

Figure 2. Example test problem

In this course there are five (5) class periods during the semester set aside as test days where students can attempt (or re-attempt) any of the Level 1 or Level 2 objective problems available at that point (they are made available after the topic/objective has been covered in class). Any objectives that are not passed on a given test day can be re-attempted with a similar problem on a later test day with no penalty, providing students multiple opportunities to demonstrate mastery on each objective throughout the semester. The final exam period is used only for re-attempting any objectives that students have not yet passed. Students are expected to master the concepts in each objective and not just get things partially correct. The grade earned in the course is based on how many objectives they demonstrate mastery of by the end of the course. A passing grade requires showing mastery of all Level 1 objectives and a student can receive higher grades by demonstrating mastery of Level 2 objectives. For example, a B grade in the course would require the student to pass all Level 1 objectives and four (4) Level 2 objectives. Practice problem and homework completion are also requirements for the course, but generally do not have a significant effect on the course grade unless the student chooses not to complete several of the practice problem sets or homework assignments.

Method

The research described in this paper was carried out with undergraduate students that were enrolled in a junior level construction management (CM) course entitled "Statics and Mechanics of Materials for Building Construction" course at Boise State University between Fall 2015 and Fall 2021 semesters (13 semesters total). A complete list of objectives covered in the course was included in the previous section. Those enrolled in the course are all CM majors and they have a minimum of one more year to complete their degree. The different semesters of the course were similar with respect to age, gender, and other demographics.

Three instructors of the Statics and Mechanics course are included in this research:

- Instructor 1 taught the course using traditional grading (2 semesters of student data)
- Instructor 2 (author) taught the course using competency grading (9 semesters of student data)
- Instructor 3 taught the course using competency grading (as established by the author) while the author was on sabbatical (2 semesters of student data)

The follow-on course that was evaluated is a senior level CM course entitled "Introduction to Concrete and Steel Design" using Spring 2016, 2018-2022 and Fall 2021 semesters (seven semesters total). It is also entirely CM majors and different semesters of the course were similar with respect to age, gender, and other demographics. This course is an introduction to the design of reinforced concrete and structural steel including sizing and design of beams, columns, and simple footings. It was taught by the same faculty member for all offerings evaluated here. Spring 2017 data for this course is omitted from this analysis because it was taught by a different instructor.

Grade data from students who completed both courses was analyzed to determine whether students that experienced competency grading in Statics and Mechanics had a higher mean course grade in the follow-on course than students with traditional grading. Because students do not necessarily follow from one course to a subsequent one as a cohort, this evaluation of success in the follow-on course is done only by instructor and method, and does not look specifically at semester that the course was taken. The hypothesis analyzed is as follows:

- *Null*: There is no difference in the mean course grade of students in the follow-on course due to the grading method used in the Statics and Mechanics of Materials course.
- *Alternate*: The mean grade of students in the follow-on course is higher for students that experienced the competency grading method in their Statics and Mechanics of Materials course than for those that experienced the traditional grading method.

Results and Discussion

As illustrated in Table 1, the overall pass rate (C- grade or higher) in Statics and Mechanics for the competency grading method is higher than for the traditional grading method. The competency grading method has also resulted in many fewer withdrawals of students mid-semester (6 withdrawals in 2 semesters of traditional grading vs 2 withdrawals in 11 semesters of competency grading). This is likely because they have the opportunity to continue to reattempt concepts and ultimately be successful in the course with this method even if they start the semester poorly. They also have the ability to clearly see what they need to achieve to pass the course, allowing them to make better decisions about their own success in the course.

Table 1

Grades from Statics and Mechanics course over 13 semesters

Instructor	Grading Method	# of Semesters in Study	Passed Course	D/F/W grade	Total # Enrolled	Total # Completed Course	% Passing (overall)
Instructor 1	Traditional	2	46	10	56	50	82.1%
Instructor 2 (Author)	Competency	9	237	29	266	264	89.1%
Instructor 3	Competency	2	46	1	47	47	97.9%

In Table 2, the follow-on course grades are shown by grading method from the Statics and Mechanics course. Students who took Statics and Mechanics using competency grading had a lower D/F rate than traditional graded students in the follow-on course (6.8% for competency vs 12.5% for traditional) and the percentage of A and B grades in the follow-on course was notably higher (54.3% vs 18.8%).

Table 2

Follow-on Course Grades based on Grading Method of Statics and Mechanics course

Grading Method in Statics Course	% Passing Follow-on Course	% A Grades	% B Grades	% C Grades	% D/F Grades	Mean Grade
Traditional	87.5%	6.3%	12.5%	68.8%	12.5%	2.063
Competency	93.2%	15.4%	38.9%	38.9%	6.8%	2.611

Grade data shown in Table 2 was transformed from letter grades to numerical ones where A = 4, B = 3, C = 2, D = 1, and F = 0. Any pluses or minuses included in student grades were ignored (for example, an A- grade was counted as an A grade for data analysis). A one-tailed t-test of the data comparing the mean grades of students from the two grading methods found that students completing the competency graded prerequisite course had a higher mean grade than the students completing the traditionally graded course (mean of 2.611 vs. 2.063) with a statistical significance of $p=0.012$. In other words, the mean grade for students who had Statics and Mechanics using the competency grading method was about one-half letter grade higher in the follow-on course than the students who had the traditional grading method.

Students Are Better Prepared

Students that pass the follow-on course are receiving higher course grades overall when competency grading is used in the prerequisite course than when traditional grading is used and the statistical analysis discussed previously supports this. There are two primary reasons why students are better prepared to be successful in the follow-on course: (1) student behavior and (2) instructor behavior in the Statics and Mechanics course.

Student behavior is different in a competency-graded course when compared with a traditional-graded course. In general, the author has seen increased engagement from students regarding the course content. Students discover that they must actually review feedback received on homework and exams, as they have to keep attempting an objective until they pass it. They cannot just skip over a topic if it is a Level 1 objective. Students interested in higher grades work even harder because they must master topics that are more difficult.

Because they do not receive scores for each objective, only a Pass or No Pass, students also become much less focused on their grades and more focused on learning and understanding each topic, including all of its subtleties, in order to pass each objective. Competency grading is ideal to help students develop a growth mindset, where a student believes their intelligence is not fixed, but can be developed, and also helps students focus more on the actual learning process which includes hard work, trying new strategies, learning from setbacks, and getting input from others (Dweck, 2016). Having a growth mindset can help students be successful in many different realms, from difficult courses to handling difficult tasks or problems in their future careers.

There are a number of instructor behaviors that are also important to consider that make students better prepared due to competency grading. The instructor must be able to help students overcome their failures. Students are generally not used to alternative grading methods such as this and it does take them time to adapt. The instructor must help students understand concepts more fully and help them learn from their failures when they receive a No Pass on objectives. Sometimes the author feels more like a coach, building up students' confidence of that they CAN do this. The instructor may also need to adapt the schedule of the course (front-loading important concepts is best) to allow time for the learning process to occur and ensure that students have time to overcome any failures before the course is completed. Additionally, the instructor must be flexible and able to teach students in the moment, when they are actually ready to sort out their misconceptions on various topics, which is not always when the topic is initially taught during the course. In the Statics and Mechanics course described in this paper, a number of class sessions are reserved for questions on any topic up to that point in the course. This often turns into a series of mini-lectures with small groups of very engaged students, while other students work on practice problems focused on their own topics of weakness.

Limitations

As with any educational study of this sort, there are many limitations that should be identified. Three categories of limitations will be described here: continuous improvement of instruction, COVID, and the data collected.

Both the author teaching with the competency grading method and the instructor of the follow-on course made incremental changes over the time of this study to support continuous improvement in their teaching. These changes influence the success of students in both courses, hopefully in a positive way overall. Additionally, most instructors improve their teaching of a course simply by getting more comfortable with the material and the topics that students tend to struggle with. These small changes, over the large number of semesters of the study, may have influenced the results favorably.

Changes in teaching mode due to COVID also presents a weakness in the data analyzed in this study. Two and one-half semesters of the author's course (half of Spring 2020, Fall 2020, and Spring 2021) and one-half semester of the follow-on course (Spring 2020) were taught live, but remotely through

Zoom due to COVID. Testing was also done remotely and, due to the type of content being tested, it was necessary to rely on trusting that the student was not using unauthorized resources during each test. If this assumption was not true, a student's grade in the course may have been inflated beyond what they would have earned in a more traditional classroom setting. Additionally, faculty were encouraged to be more flexible with their students, particularly in terms of assessments, due to higher levels of stress from COVID and other outside circumstances (McMurtrie, 2020). All of these factors may have influenced the results, again, favoring the competency grading mode in the data analysis.

The data itself is also a limitation of this study. Data collected in an educational setting is tremendously complex and can be affected by many different variables (McKeachie, 1999), including aspects that are not intended to be part of a study, such as (in this work) student and instructor characteristics. Adding more data both from future competency-taught semesters and from past semesters of the traditionally-taught course would strengthen (or weaken) the conclusion that competency-based grading does better prepare students for a follow-on course. With more data, the analyses performed could also be more complex, reducing the effect of some of the potentially confounding variables such as the influence of COVID, and providing a clearer picture of the influence of competency grading on the follow-on course. Having more data may also indicate a way to predict students that are likely to be at risk of not passing the follow-on course so that additional support can be provided to them.

Lessons Learned

Faculty considering trying this method in their classroom should be aware of some advantages and challenges when using competency grading. The grading of exams is generally much quicker in competency grading because each problem is graded as Pass or No Pass, with no scores or partial credit. Also, students who are not interested in A or B grades in the course attempt only the Level 1 problems and leave the Level 2 problems blank, potentially reducing the amount of grading required. However, exam creation takes more work. Custom exams are prepared for each student, including only the objectives they have not yet passed. Additionally, because students can reattempt objectives, there is a need to prepare the same objective multiple times through semester. The additional preparation time can be reduced once a large bank of test questions has been created, but in the beginning, it can be more work.

Giving students multiple opportunities for demonstration of mastery helps students who are slow to catch on to concepts and/or have a bad test day. As long as they are able to master each concept by the end of the semester, they will be successful in the course. Some students see the requirement for proving mastery as a negative, however, and view this grading style as "horribly flawed" (actual quote from a course evaluation). They are used to getting things partially correct and earning enough credit to pass a course. The competency grading scheme does not accommodate that approach very well and it can be a significant adjustment for some students, particularly when they receive a No Pass on an objective for what they view as a very minor error, while the instructor grades it as a significant concept error. It is important that the instructor focus on feedback that helps a student to develop a growth mindset; they are capable of learning from their mistakes and improving over time.

In addition, changes to both student and instructor behavior that were discussed elsewhere in this paper are also important to acknowledge as adjustments that may need to be made if considering a transition from traditional to competency grading.

Conclusion

Competency grading has been proven in other studies to be an alternative grading system that works well in technical courses and has a lot of benefits for both the student and the instructor. The results of the data analysis for this study indicate that the mean grade in the follow-on course is higher when competency grading is used in the prerequisite course. Students taught using a competency grading style are more successful in a follow-on course than students taught with a traditional grading style.

References

Buckmiller, T., Peters, R., & Kruse, J. (2017). Questioning points and percentages: Standards-based grading (SBG) in higher education. *College Teaching*, *65*(4), 151-157.

Craugh, L. E. (2017, June). Adapted mastery grading for statics. In *2017 ASEE Annual Conference & Exposition*.

Dweck, C. (2016). What having a "growth mindset" actually means. *Harvard Business Review*, *13*(2), 2-5.

Iamarino, D. L. (2014). The benefits of standards-based grading: A critical evaluation of modern grading practices. *Current Issues in Education*, *17*(2).

Kulik, C. L. C., Kulik, J. A., & Bangert-Drowns, R. L. (1990). Effectiveness of mastery learning programs: A meta-analysis. *Review of educational research*, *60*(2), 265-299.

McKeachie, W. J. (1999). *Teaching tips: Strategies, research, and theory for college and university teachers* (10th ed.). Houghton, Mifflin Co.

McMurtrie, B. (2020, June 4). *What does trauma-informed teaching look like?* The Chronicle of Higher Education. https://www.chronicle.com/article/What-Does-Trauma-Informed/248917

Nilson, L. B. (2015). *Specifications grading: Restoring rigor, motivating students, and saving faculty time*. Stylus Publishing, LLC.

Ritz, H., Dimiduk, K., & van Paridon, A. (2020, June). Effect of mastery-graded exams on student outcomes in statics and mechanics of solids course. In *2020 ASEE Virtual Annual Conference Content Access*.

Sadler, D. R. (2005). Interpretations of criteria-based assessment and grading in higher education. *Assessment & Evaluation in Higher Education*, *30*(2), 175-194.

Toledo, S. & Dubas, J. M. (2017). A learner-centered grading method focused on reaching proficiency with course learning outcomes. *Journal of Chemical Education*, *94*(8), 1043-1050.

Townsley, M., & Schmid, D. (2020). Alternative grading practices: An entry point for faculty in competency-based education. *The Journal of Competency-Based Education*, *5*(3). https://doi.org/10.1002/cbe2.1219