# Defining and Assessing Competencies in an Undergraduate Reinforced Concrete Design Course

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**Abstract:**

Traditional grading can be a common source of frustration for engineering faculty. Allocating points consistently for partially correct work is a constant struggle and leaves something to be desired. The lines between different grades certainly become grayed, and it seems possible that a student can receive a passing grade in a course without ever answering a single problem correctly. Specification grading is a novel approach to grading that provides solutions to some of the common frustrations with traditional grading. Specification grading requires instructors to define assignment, project, test, or even course level specifications. These specifications are often linked to core course competencies or outcomes. Student work for the course is assessed pass/fail depending on if the relevant specification was met or not. With this approach, students are given a clear picture of what must be demonstrated for certain grades and given the freedom to select which grade they would like to pursue. Instructors are given confidence that a student receiving a passing grade has demonstrated at least some basic level of competency for the course.

This paper provides a review of the application of specification grading for two iterations of an undergraduate reinforced concrete design course. Student work is compared between the two enhanced versions of the course and that of a traditional approach. Students were also surveyed to determine their perception of the enhanced specification course versus that of other traditional courses they have taken in the past. Finally, this paper includes a reflection of the implementation of specification grading, a reflection on the appropriate competencies for reinforced concrete design, and the potential benefits for use in broader civil engineering education.

## Introduction and Background

A picture of traditional grading as providing constructive feedback and serving as an impactful learning device sounds both noble and desirable. However, traditional grading, at least in traditional engineering courses, often falls short. Rather than profound guidance, grading often manifests itself as a cutthroat point competition. Students become frustrated because traditional grading can seem arbitrary, rewards students that are "good" at taking tests, and (while they would not say it in these words) is [almost] an exclusively summative assessment of their learning. Faculty become frustrated because grading is time consuming, requires faculty to make black and white scoring decisions about very grey lines of performance, and does little to motivate students toward real learning. As the course ends, the faculty member will tally all the points earned for the course and assign a single grade; all the while asking of the student who earned 70 percent of the points, "Does this student have a mastery of 70 percent of the material, or do they have 70 percent proficiency on 100 percent of the material?"

Specification grading is a grading approach that placates some of these frustrations. Specification grading requires instructors to define assignment, project, test, or even course level specifications. These specifications are often linked to core course competencies or outcomes. Student work for the course is assessed pass/fail depending on if the relevant specification was met or not. With this approach, students are given a clear picture of what must be demonstrated to earn a specific grade and given the freedom to select which grade they would like to pursue. Instructors are given confidence that a student receiving a passing grade has demonstrated at least some basic level of competency for the course. Nilson (2015) identifies 15 components (*Listed Below for Reference*) of an effective grading scheme:

"*A grading system must…*

1. *Uphold high academic standards*
2. *Reflect student learning outcomes*
3. *Motivate students to learn*
4. *Motivate students to excel*
5. *Discourage cheating*
6. *Reduce student stress*
7. *Make students feel responsible for their grades*
8. *Minimize conflict between faculty and students*
9. *Save faculty time*
10. *Give students feedback they will use*
11. *Make expectations clear*
12. *Foster higher cognitive development and creativity*
13. *Assess authentically*
14. *Have higher interrater agreement*
15. *And be simple."*

And, it is her assertion that a well-designed specification grading course meets these requirements.

**Application of Specification Grading**

In the 2016-2017 and 2017-2018 academic years, a required undergraduate course, Structural Design in Reinforced Concrete, at Rose-Hulman Institute of Technology was modified to incorporate specification grading as the sole grading criteria for the course. The course is a 10 week, 3 credit lecture based course (30 scheduled meetings). The enrollments for the 2016-2017 and 2017-2018 iterations of the course were 35 and 29, respectively. Three performance criteria (Table 1) were defined for the course by following recommendations from Nilson (2015) for "Making the Transition" from a traditional grading scheme to a specification grading scheme. Specifically, the specification grading performance criteria were selected to help emphasize the need for greater rigor, the "pass/fail" reality in engineering practice, and a direct tie to student performance on course objectives. The grading scheme also emphasized that students are empowered to choose the grade they want to pursue. To receive a particular grade, students were required to satisfactorily complete all criteria identified for that grade level. Students who did not complete at least the C-Level requirements were assigned a failing grade for the course. Each of the elements of the grading scheme are explained in further detail below.

**Table 1:** Grading Criteria for Structural Design in Reinforced Concrete.

| |
|---|
| For a C in the course, students must:<br>• Have no more than three unexcused absences.<br>• Complete and submit 6/8 homework assignments on time.<br>• Receive a passing grade (>70%) on two exams.<br>• Pass 3/5 quizzes for the quarter.<br>• Complete individually or in a group of no more than 3 the “C-Level” requirements for the term project. |
| For a B in this course, students must:<br>• Have no more than two unexcused absences.<br>• Complete and submit 7/8 homework assignments on time.<br>• Receive a passing grade (>70%) on two exams.<br>• Pass 4/5 quizzes for the quarter.<br>• Complete individually or in a group of no more than 3 the “B-Level” requirements for the term project. |
| For an A in this course, students must:<br>• Have no more than two unexcused absences.<br>• Complete and submit 7/8 homework assignments on time.<br>• Receive a passing grade (>70%) on two exams.<br>• Pass 5/5 quizzes for the quarter.<br>• Complete individually or in a group of no more than 3 the “A-Level” requirements for the term project. |

*Homework Assignments*

Students were assigned “weekly” homework assignments (homework was not assigned during exam weeks). The types of homework problems were similar in content and number to previous iterations of the course (3-6 analysis or design problems per assignment). Additionally, homework assignments were reviewed and marked-up as one might in a standard grading scheme. However, rather than receiving a certain number of points for correct answers, students were given a pass or fail grade based on demonstrating a “good-faith effort” – completing all problems, satisfying defined homework format guidelines, and submitting by the due date.

*Term Exams*

Three exams were defined for the course: two term exams and a comprehensive final exam. The term exams were administered during the $5^{th}$ and $9^{th}$ weeks of class, respectively. Each term exam was 120 minutes in length, and the final exam was 180 minutes in length. Exams were comprised of concept and short answer questions, as well as two to three calculation questions. Exams were scored following a scoring rubric for each problem. As a part of the performance criteria, all three grade levels required students to achieve a passing score (>70%) on two exams. Therefore, if a student were to receive passing scores on both term exams, they were not required to take the final exam.

*Term Project*

Each student was required to complete a design project individually or in a team selected by the student of no more than three students. The project description defined three separate performance criteria. All performance criteria required groups to design a one-way floor slab, a three-span continuous beam, and one interior column for a two-story academic building. The higher performance criteria demanded higher levels of detailing, report writing, and feasibility. Student groups were allowed to submit one draft for review, and the final draft was evaluated by ensuring that all performance criteria were met for the identified performance level.

*Competency Quizzes*

The final course requirement, competency quizzes, was the most significant delineator between performance levels. On even weeks throughout the course, students were required to take a competency quiz during class. The quizzes were administered in succession (i.e. Week 2 – Quiz 1, Week 4 – Quiz 2, etc.). On odd weeks of the course, students were given the option to take a new version of **any** quiz that they had not yet passed (i.e. Week 3 – optional retake for Quiz 1, Week 5 – optional retake for Quiz 1 or Quiz 2). These quizzes were proctored outside of regularly scheduled class meetings. A total of five different competency quizzes (Table 2) were identified for the course centered on major course objectives. Quizzes consisted of multiple choice, true/false, and calculated answers. Because a student could not retake a quiz until after the initial attempt, the total number of possible attempts for each quiz is different.

The quizzes were administered through the institute supported learning management system (LMS), Moodle. Each quiz utilized random generated variables as a part of the problem, so each student received a different version. In order to receive passing credit for a quiz, students were required to answer every question correctly. During each quiz attempt, students were given the ability to check their answer once for each question, except for true/false questions. If the submitted answer was incorrect, students were provided with a hint and allowed to submit an additional attempt. At the end of each quiz, students were given immediate feedback as to whether they had passed or not. Additionally, students were able to see correct answers (not a worked out solution) after completing the quiz, and they were able to access this quiz throughout the rest of the term.

**Table 2:** Competency Quizzes for Structural Design in Reinforced Concrete

| Quiz Number | Students must correctly… | # of Possible Attempts | Time Allotted for Quiz |
|---|---|---|---|
| Quiz 1 – *Uncracked Behavior* | • Calculate the maximum bending stress in an uncracked determinant beam.<br>• Identify where reinforcement should be located for the given loading condition<br>• Identify fundamental reinforced concrete concepts. | 6 | 30 min. |
| Quiz 2 – *Nominal Moment Capacity* | • Calculate the cracking moment of a reinforced concrete beam with a rectangular or T-shaped cross-section.<br>• Calculate the nominal moment capacity for a reinforced concrete beam with a rectangular or T-shaped cross-section.<br>• Determine if a determinate beam with given applied loading satisfies the flexural safety equation. | 5 | 30 min. |
| Quiz 3 – *Flexural Design* | • Design a tension controlled rectangular beam meeting ACI318 design requirements. The design may not be more than 30% overdesigned. | 4 | 50 min. |
| Quiz 4 – *Shear Design* | • Calculate the shear capacity of an unreinforced concrete beam.<br>• Design shear reinforcement for a determinant beam with a rectangular or T-shaped cross-section with given applied loading.<br>• Identify locations on a determinant beam where shear reinforcement is not required according to ACI318. | 3 | 30 min. |
| Quiz 5 – *Column Design* | • Calculate the maximum axial capacity of a tied or spiral reinforced concrete column.<br>• Determine the axial capacity of a column given an applied moment by using a non-dimensional interaction diagram.<br>• Identify the required spacing of column ties. | 2/3* | 30 min. |

*Three versions of Quiz 5 were offered for the 1718 iteration of the course.

## Student Performance and Perception

This paper focuses on an assessment of student performance on the competency quizzes and student perception of the grading scheme for the course. All students were required to attempt each quiz at least one time. Students were given the opportunity to take alternative versions of each quiz if their original attempt was unsuccessful. Table 3 shows the number of attempts for each quiz and each version. Table 4 shows the average number of attempts per student for each quiz. The difference between Table 3 and Table 4 illustrate the fact that students can take their make-up quizzes out of numerical sequence.

**Table 3:** Number of Attempts for Each Competency Quiz by Version and Year.

| Quiz Version | 1617 (# of Pass / # of Total Attempts)<br>1718 (# of Pass / # of Total Attempts) | | | | |
|---|---|---|---|---|---|
| | Quiz 1 | Quiz 2 | Quiz 3 | Quiz 4 | Quiz 5 |
| 1 | 6/35<br>10/28 | 2/33<br>8/29 | 5/35<br>2/29 | 21/35<br>14/29 | 9/34<br>0/29 |
| 2 | 11/23<br>2/19 | 14/19<br>12/16 | 4/12<br>7/17 | 6/6<br>8/13 | 10/12<br>7/24 |
| 3 | 2/11<br>0/4 | 7/12<br>5/6 | 7/12<br>5/5 | 5/7<br>1/5 | - / -*<br>12/12 |
| 4 | 3/8<br>0/3 | 2/5<br>2/3 | 7/10<br>4/7 | | |
| 5 | 3/5<br>2/3 | 5/8<br>1/2 | | | |
| 6 | 3/5<br>2/5 | | | | |

(*A third version of Quiz 5 was only offered during the 1718 iteration)

**Table 4:** Average Attempt per Student for Each Competency Quiz.

| Academic Year | Average Number of Attempts per Student | | | | |
|---|---|---|---|---|---|
| | Quiz 1 | Quiz 2 | Quiz 3 | Quiz 4 | Quiz 5 |
| 1617 | 2.5 | 2.2 | 2.0 | 1.4 | 1.3 |
| 1718 | 2.1 | 1.9 | 2.0 | 1.6 | 2.2 |

The cumulative percentages of students passing each quiz by attempt are shown in Figure 1 and Figure 2 for the 16/17 and 17/18 iterations of the course, respectively. As can be seen according to Figure 1 and Figure 2, for every quiz, there is a significant increase in the total number of students passing each quiz between the first and second attempts. The trend continues for third attempts, while at a slower rate. Finally, 4$^{th}$ and 5$^{th}$ attempts for the relevant quizzes show that the rate has drastically reduced. Comparing the results displayed in Figure 1 and Figure 2 with the average number of attempts suggests that students can typically demonstrate course content if they are provided with between two and three attempts.

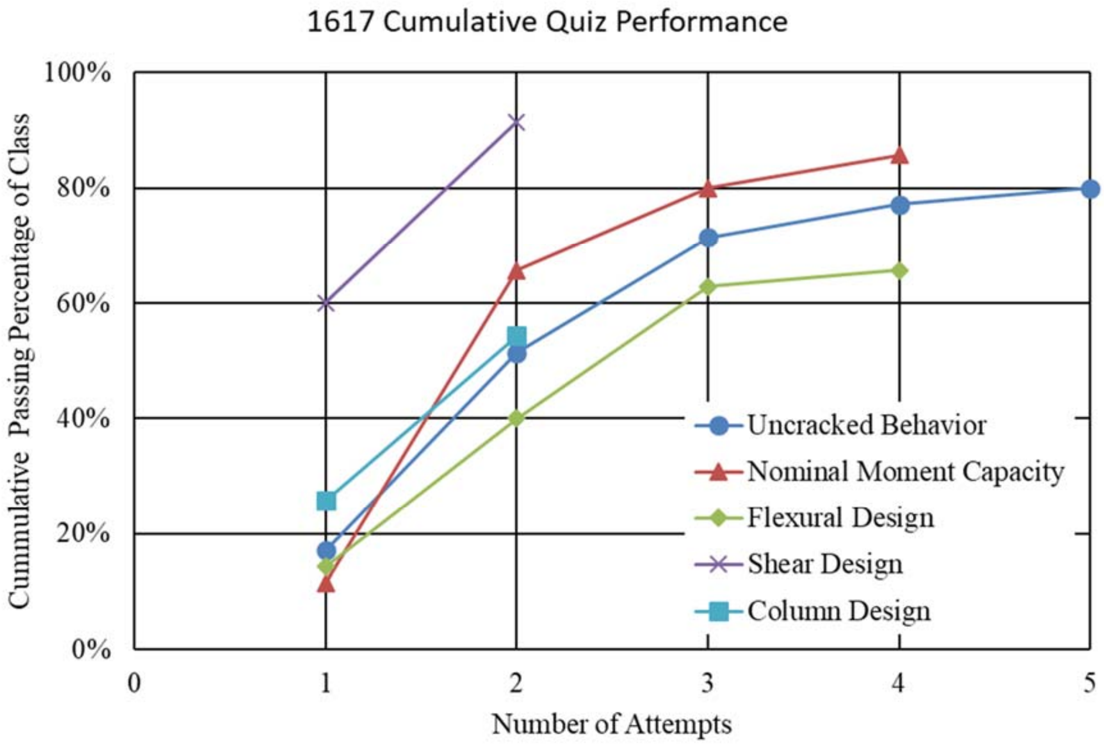


**Figure 1:** Cumulative Competency Quiz Performance for 2016-2017

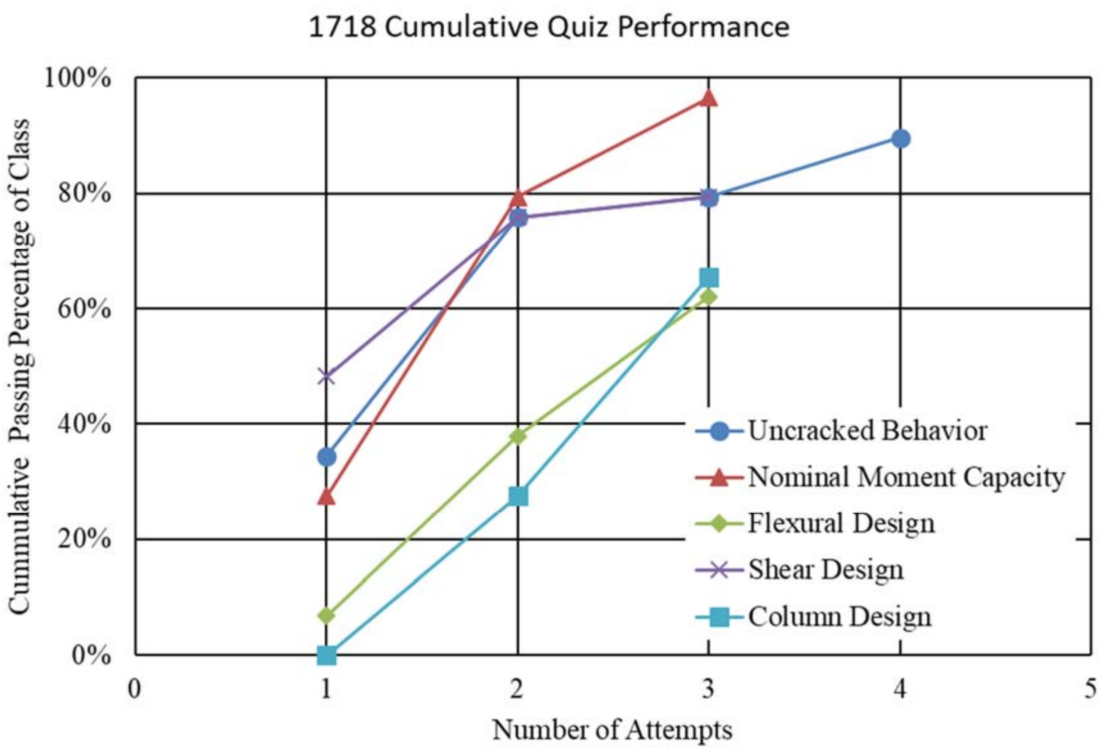


**Figure 2:** Cumulative Competency Quiz Performance for 2017-2018

In addition to collecting and comparing quiz scores, a survey was conducted to solicit student perception of the modified grading scheme. Figure 3 and Figure 4 shows the survey questions and associated results for the 16/17 and the 17/18 academic years, respectively. There are several positive outcomes from the survey. Students in the 16/17 iteration of the course indicated that this type of grading scheme caused them to study and review course material more than they would in another course (73% agree or strongly agree). However, the reported value for the 17/18 iteration of the course was not as impressive (46% agree or strongly agree). Students in both iterations of the course did report feeling very confident about identifying the content from the course that they do or do not understand (70% and 84% agree or strongly agree, respectively). Students in both years also reported that they felt confident that they could successfully apply the content covered (76% and 81% agree or strongly agree, respectively). Students did report 66% and 88% agree or strongly agree, respectively, that having to get all the answers correct on the quiz was very stressful.

In addition to a numerical survey, students were asked to provide open comments. A few selected comments have been provided below:

- "*I like that it made me study better. Because of the quizzes, I would study a lot more intensely because I knew I had to get it completely right, so I had to understand everything. This helped me prepare for the exams.*"
- "*It was clear-cut about what was required and if you did not meet those specs, you didn't earn the grade. It didn't stress me out like other classes have.*"
- "*I like the fact that if you put in the effort to pass the class with a good grade it is possible. I feel that I have understood other classes better and have put in an equal amount of work but have still come out with an unsatisfactory grade. This grading scheme makes sure that does not happen.*"
- "*I liked that my grade wasn't largely defined by two or three exams, and I think the scheme really helped me learn and retain the covered material since retaking quizzes is a requirement for an improved grade.*"
- "*Because the homework was not worth any credit, I did not take it seriously either. I was able to throw some things on paper to get the completion grade without actually learning anything. Taking the time to do the homework like it was for a grade is a personal discipline that I failed to develop until the end of the quarter*."
- "*The grading rubric allows us as students to see exactly what is required of us to obtain a certain grade. It allows for mistakes to be made during the trimester, but if the student is persistent and driven, than an A level of learning can still be demonstrated by showing knowledge of the objectives*."
- "*Rather than having to focus on how many points I am getting per assignment, quiz, test, etc., I only have to worry about understanding the material and showing I know it. The all-or-nothing idea behind this grading scheme does help in that regard*."
- "*Even though we got quiz retakes, I still wish the quizzes would be done differently. For example, if you get the first part wrong, there is no chance (most of the time) that you can get the other parts right.*"

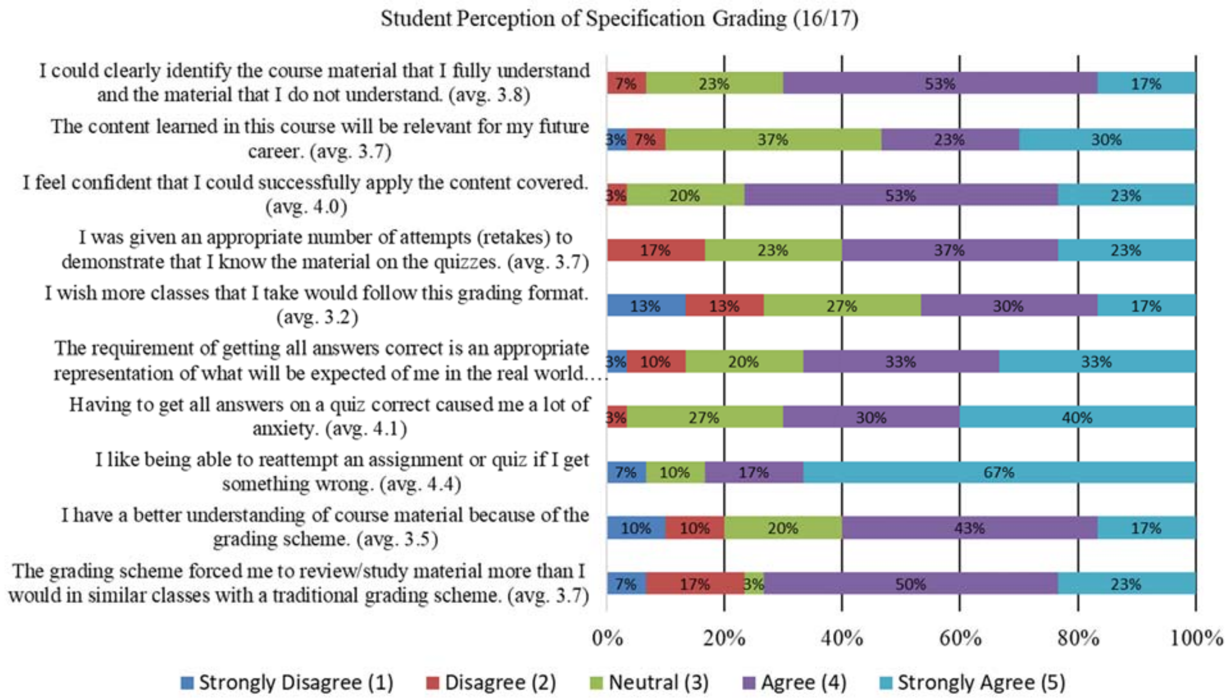


**Figure 3:** Student Perception of Specification Grading from the 1617 Academic Year

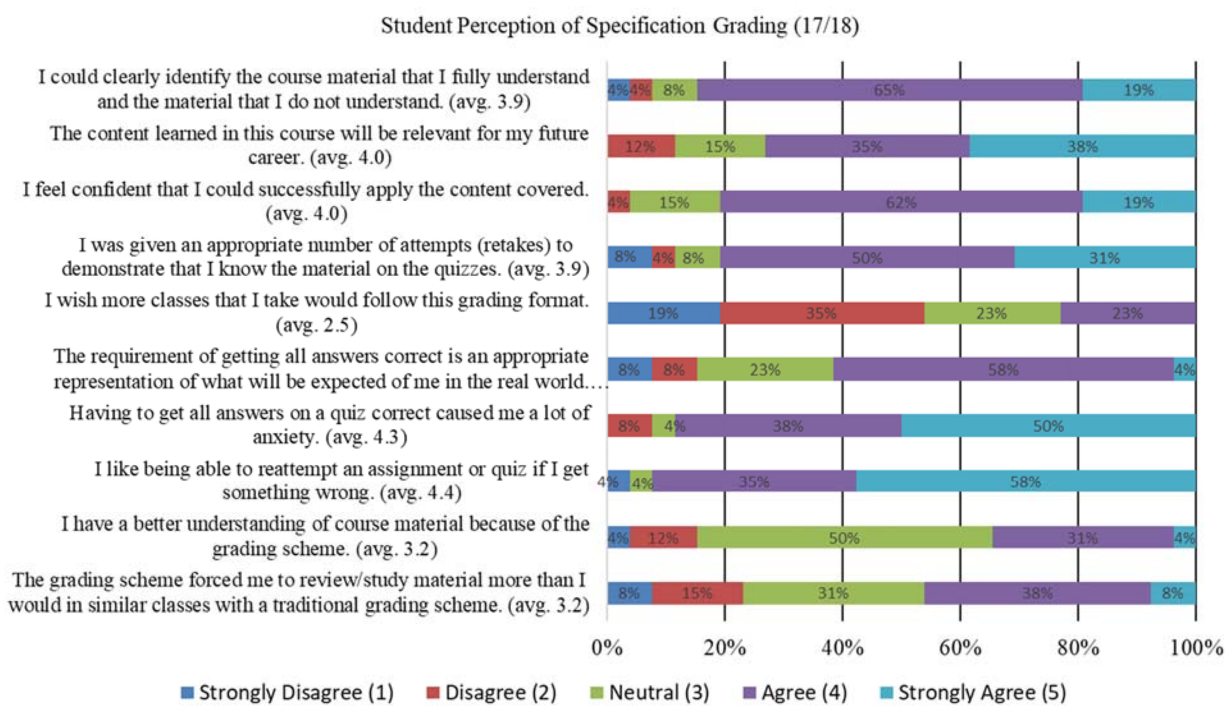


**Figure 4:** Student Perception of Specification Grading from the 1718 Academic Year

**Faculty Reflection, Conclusions, and Recommendations**

As Nilson (2015) proposed, a good grading scheme will satisfy 15 criteria. Table 5 includes reflections and comments by the instructor on each of the 15 criteria with respect to the specific application of specification grading in a Structural Design in Reinforced Concrete undergraduate course.

**Table 5:** Reflection on Specification Grading and Nilson's Grading Scheme Criteria.

| Effective Grading Scheme Criteria (Nilson, 2015) | Criteria Met / Not Met | Comments / Reflection |
|---|---|---|
| 1. *Uphold high academic standards* | Met | Students receiving passing grade have successfully (perfectly) demonstrated at least three course objectives. |
| 2. *Reflect student learning outcomes* | Met | Competency quizzes were built from course outcomes. |
| 3. *Motivate students to learn* | Met | Students had to complete three quizzes to pass the course. If a student failed, they were very motivated to meet with the instructor to improve their understanding. |
| 4. *Motivate students to excel* | Met | Students were given a clear understanding with respect to what they had to demonstrate to achieve a particular grade. A's were awarded at a much higher rate when compared to traditional grading schemes. |
| 5. *Discourage cheating* | Met | Quizzes were randomized and secure, so cheating would be very difficult. Homework was awarded credit for completion. |
| 6. *Reduce student stress* | Not Met | While contrary to the instructor's assumption, this grading scheme increased student stress. Students reported not liking to have to answer questions "perfectly correct." |
| 7. *Make students feel responsible for their grades* | Met | Student comments indicated that students felt responsibility for their grades. |
| 8. *Minimize conflict between faculty and students* | Not Met | While discussions over point allocation did not occur, students expressed frustration when credit was not awarded for "simple" mistakes (calculator error, transcription error, etc.). |
| 9. *Save faculty time* | Not Met | While less time was devoted to grading, more time was devoted to developing assignments and meeting with students. |
| 10. *Give students feedback they will use* | Not Met | This implementation of specification grading did not change the feedback amount or type that students received. |

| | | |
|---|---|---|
| 11. *Make expectations clear* | Met | Performance levels were clearly articulated for students. |
| 12. *Foster higher cognitive development and creativity* | Not Met | The implementation of specification grading did not change the expected Bloom's level of attainment for students. |
| 13. *Assess authentically* | Met | Students were awarded grades based on what they were able to demonstrate. |
| 14. *Have higher interrater agreement* | Met | Grades were less subjective as credit was awarded only for completely satisfying specification. |
| 15. *And be simple."* | Met | Overall, the grading scheme was relatively simple to implement. There was a bit of up front work to define the specification levels, but overall the workload was manageable. |

In addition to the 15 criteria for a quality grading scheme, after two iterations of modifying a course to include specification grading, the following benefits seem to be clear:

- Student grades are directly tied to the students' ability to demonstrate mastery of course content. This grading scheme creates a catalog of objectives that students have demonstrated perfectly at least one time. A mapping can be generated to show which objectives a student has met and which grade they will receive.
- Students are provided multiple attempts to demonstrate mastery. It is clear, based on the results of the quiz assessment, that many students require multiple attempts before they can demonstrate mastery. With this grading scheme, students are not penalized for learning at a slower pace.
- Students have a clear understanding of what is required for a particular achievement level. Students have the option to select a lower performance level if the subject does not appeal to them.

In addition to benefits, there are some considerations that a faculty member might take prior to engaging in specification grading.

- Specification grading requires a great deal of time developing specifications for your course. The instructor must articulate the various levels of performance for their course. Following the principles of backwards design will help to define the objectives that are important to the course.
- By allowing students multiple attempts on assignments or quizzes, the grading load can amplify. While you are reviewing assignments on a pass/fail basis, this can still add to the grading time. It is recommended to make use of computer software (i.e. LMS) to automate grading for assignments and quizzes.
- While the amount of time required for grading can be reduced when compared to a traditional grading scheme, it was observed that office hours and ad hoc meetings with students increased. Student were persistent in understanding what was preventing them from passing quizzes.

- Adding quizzes to class takes away from classroom instruction time. However, allowing quizzes to be conducted outside of class allows for improper collaboration. Faculty should weigh the risk for each alternative.

In summary, specification grading has proven to be an effective grading scheme addressing many of the frustrations associated with traditional grading. Students are accurately assessed based on their performance which is tied directly to course outcomes. Students are incentivized to be relentless at mastering course content and they are rewarded by their efforts. Students that require more time to learn content are accommodated. Students' grades are less tied to test performance that are not real world, but rather tied to mastery of content. After the initial setup, the grading load on the faculty member may be reduced through the use of automated grading. The faculty member is free to spend less time on figuring out how to distribute points for mistakes on homework, and the faculty member can have confidence about assigning a grade related to student performance.

**References**

Nilson, Linda B. "*Specification Grading: Restoring Rigor, Motivating Students, and Saving Faculty Time.*" Stylus Publishing: Sterling, Virginia, 2015.