Journey towards competency-based grading for mechanical engineering computer applications

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Abstract

Over the past several years, increasing effort has been invested interrogating the very structure of assessment in higher education. In addition to a rising awareness of the mental health impacts of high-stakes assessment, questions have arisen around accessibility and equity in our assessment practices. From this conversation, the practice of competency-based or mastery-based education has become a hot topic in pedagogically minded circles. To summarize, competency-based assessment is the practice of developing targeted assessments and standards of performance for each individual skill or outcome present in the course and building an assessment scheme based on how many of those outcomes are sufficiently mastered in the allotted time. A defining trait of these schemes is the ability to repeat individual outcome assessments as needed to demonstrate mastery, significantly lowering the stakes of any individual attempt. Efforts have manifested at every level, up to and including entire mastery-based programs.

In this work, the five-year-long reinvention of a mechanical engineering computer applications course is examined as it was transformed from traditional to flipped to competency-based, navigating the onset of COVID along the way. In the most recent iteration, the course involves a framework of repeatable assessments across an array of outcomes, including both traditional exam format assessment as well as more involved project-based assessments, a set of video modules, and a group project. The rationales for and lessons learned from this journey are explored, along with student comments and evaluations, and an examination of overall course grades and achievement of course outcomes.
Background

Over the past few decades, increasing effort has been invested interrogating the very structure and role of assessment in education [7]. From this questioning, standards- or criteria-based grading has seen a surge of interest [19, 21]. Muñoz [14] provides a case for standards-based grading as a clear next step in educational assessment.

Standards- or criteria-based grading, also referred to as competency-based assessment, is a method by which students are measured directly with respect to course learning outcomes. Under a traditional assessment scheme, students complete a fixed sequence of assessments and their performance on each is aggregated as an approximate measure of their abilities. Under a competency-based model, students are assessed on their ability to demonstrate mastery of course content through a series of repeatable assessments. Overviews of the approach are provided by Carberry [2], Siniawski [20], and Hylton [11].

While the full effects on student learning of a standards-based course model are the subject of much discussion and research, a few trends are becoming clear. Central among these is the notion that student achievement should be judged on the basis of continual development, rather than a one-time score. As such there is tremendous opportunity for formative assessment and reflection. Additionally, Sadler [19] noted that such a scheme offers a number of advantages, including personalized, meaningful feedback, clear connections between assessment and stated course objectives, and transparency in the grading process.

Carberry [2] began to quantify these benefits, noting positive impacts in both affective and cognitive behaviors, including an increase in self-efficacy and a sophistication of epistemological beliefs. Further research outlined by Atwood [1] builds on this finding, with students at both large public institutions and smaller private colleges reporting a significant boost in self-efficacy and rating the approach as having a greater value than cost. This increased motivation has also been observed to be independent of student performance, meaning that the observed effect for high performing students was comparable to that observed for low performing students [8]. Guskey [6] goes so far as to observe that, if properly constructed with sufficient detail, a standards-based assessment approach “facilitates teaching and learning better than almost any other grading method.”

Various forms of competency-based learning have been applied in mechanical engineering to thermodynamics [16], fluid mechanics [17], mechanics [9], and dynamics [3], among others. The scheme has also been used in design courses [1], as well as senior capstone [15] and first-year engineering courses [10, 18]. It has also been applied to various programming courses [4, 13] as far back as a FORTRAN course circa 1981 [5].

Context and Course Progression

This study outlines a five-year-long reinvention of a mechanical engineering computer applications course at Ohio Northern University (ONU). ONU is a private, comprehensive university. The TJ Smull College of Engineering at ONU has approximately 600 students, offers 6 undergraduate degrees, and has been offering engineering degrees for nearly 140 years. The mechanical engineering program makes up roughly half of the college. The course in question is typically taken in students’ fourth semester in the program with an off-term offering available. The course is required for all mechanical engineering
majors and is almost exclusively taken by that population. Prerequisite content is also covered in a first-year engineering course typically taken during their second semester. Course content includes primarily programming concepts, covered using MATLAB, as well as smaller topics touching on solid modeling, digital logic, programmable logic controllers (PLCs), and microprocessors.

Prior to Spring 2019, the course was offered in a highly active, but traditional instruction mode. Lectures typically consisted of content delivery interspersed with example activities for students to complete. Outside of class, students completed regular homework assignments and three mid-term exams and a comprehensive final exam were used as the primary assessment tools for student learning.

In Spring of 2019, the course was moved to a flipped instruction mode. The details and impacts of this model were previously discussed [12]. To summarize, this iteration of the course utilized a series of short instructional videos, assigned in small batches on a weekly basis and accompanied with a short one-to-two question quiz relating to the video content. The following class period would include a review of the assigned videos and short supplemental content delivery, with the balance of class time dedicated to in-class activities and work time for homework and projects, similar to those assigned in the traditional course model. The three mid-term exams were split into a total of six quizzes and the comprehensive final exam was retained. A weekly journaling assignment was also introduced, to guide students in appropriately directing their time during the open class periods.

In Spring of 2020, the course was moved to a full competency-based assessment mode. Under this structure, the content of the projects and quizzes were organized into a set of competency checkpoints, the details of which are discussed later. The pre-existing structure of video modules, assigned in small batches weekly, was retained from the flipped structure. The previous homework sets were converted to optional practice problems and the final exam eliminated in favor of a final opportunity to attempt competency quizzes. Shortly after this implementation was underway, the COVID-19 pandemic arrived in full force and instruction was shifted to a remote mode. While this necessitated some creativity in terms of how to conduct a flipped course remotely and required competency quizzes to be moved online, the fact that most content delivery was already asynchronous turned out to be exceptionally fortuitous. The course was subsequently offered in Spring 2021 and Fall 2021 and the model iterated upon. For the purposes of this work, only data from the 2021 offerings is included. The 2020 data was complicated both by the rapid shift to virtual learning and a temporary move university-wide to a pass-fail system. The pass-fail approach had significant ramifications on student effort given the competency-based model being deployed in this course, making it nonviable for evaluating the impact of the competency-based approach.

**Current Course Model**

**Grading Structure**

The current course model is built upon a competency-based assessment scheme. In this scheme, 80% of the course grade is accrued through achievement of assessment checkpoints. These checkpoints are arranged into four tiers – completion of which roughly demarcates the D, C, B, and A grade lines. The checkpoints are a mix of quiz and project assessments. Tier One, completion of which approximately marks achievement of a D, consists of four quizzes (Fundamentals, Functions, Logical Programming, and Loops) and two projects (3D Modeling and Applied Logical Programming). Tier Two, completion of which approximately marks achievement of a C, consists of two projects requiring synthesis of Tier One quiz
content. Tier Three, marking a B, consists of one quiz (Solving Ordinary Differential Equations (ODEs) with ODE45) and one project (Solving ODEs in Simulink). Tier Four, marking an A, consists of two less defined projects allowing students to explore deeper content of their own interest (e.g. application of Graphical User Interfaces (GUIs), advanced plotting, etc). Table 1 describes the learning outcomes associated with each tier. In order to receive credit for higher tier assessments, the previous tier must be fully complete. So, a student may successfully complete a project from Tier 2, but this will not be reflected in their course grade until all six Tier 1 assessment points are passed.

Table 1: Learning Outcomes by Assessment Checkpoint

<table>
<thead>
<tr>
<th>Tier</th>
<th>To complete...</th>
<th>You should be able to...</th>
</tr>
</thead>
</table>
| 1.Q1 | Fundamentals  | • Navigate the MATLAB interface  
|      |               | • Perform basic calculations  
|      |               | • Create and manipulate arrays (vectors and matrices)  
|      |               | • Create and manipulate variables  |
| 1.Q2 | Functions     | • Use MATLAB help and doc resources  
|      |               | • Apply built-in MATLAB functions, including basic plotting and regression  
|      |               | • Write custom functions, with inputs and outputs  |
| 1.Q3 | Logical Programming | • Apply logical and relational operators  
|      |               | • Apply logical and relational functions  
|      |               | • Create and use conditional structures (eg IF)  |
| 1.Q4 | Loops         | • Create and apply FOR and WHILE loops  
|      |               | • Track variables through loops  |
| 1.P1 | Solidworks    | • Create objects from part drawings  
|      |               | • Combine parts into an assembly  
|      |               | • Use advanced mates to make an assembly function properly  
|      |               | • Create properly formatted part and assembly drawings  |
| 1.P2 | Applied Logical Programming | • Perform basic logical operation using ladder logic  
|      |               | • Upload and test ladder logic on a PLC  
|      |               | • Use Simulink to perform logical operations  |
| 2.P1 | Constrained Optimization | • Create a properly formatted script  
|      |               | • Apply programmatic thinking to break down a complex problem and develop a solution scheme  
|      |               | • Use Tier 1 concepts to optimize a set of parameters given some constraints  |
| 2.P2 | Searching Robots | • Create a properly formatted script  
|      |               | • Apply programmatic thinking to break down a complex problem and develop a solution scheme  
|      |               | • Use Tier 1 concepts to simulate a hide-and-seek game using randomized movements at various levels of complexity  |
| 3.Q1 | Functions/ODE | • Use built-in ODE solvers to solve ODEs  
|      |               | • Use state space methods to reduce higher order ODEs to systems of single order equations  |
| 3.P1 | Car Simulation | • Use Simulink to simulate a system involving ODEs  |
| 4 | Varies | • Content needed varies by project |

Mathematically, the four Tier 1 quizzes are each worth 10% of the overall course grade and each of the other assessment points is worth 5%. The remaining 20% of the course is a combination of a semester-
long design project (10%) and completion of daily work (10%). This means that a score of at least 50% on the project and daily work places the overall course grade at the grade level associated with the highest completed tier (Tier 1 = D, Tier 2 = C, Tier 3 = B, Tier 4 = A). A score of at least 75% on the daily work and project will allow a student to secure the associated letter grade with one fewer checkpoint completed. For example, a student with a 75% project and daily work score (15% contribution to overall grade) and who has completed all of Tier 1 (+50%) and one of the Tier 2 assessments (+5%) would have a 70% overall grade and a C in the course. Hypothetically a score of 100% on the project and daily work would allow the bypass of two checkpoints, but this has never been observed in practice. Conversely, a score below 50% on the daily work and project will require completion of an additional assessment checkpoint to secure the indicated grade. For example, a student with a 25% project and daily work score (5% to overall grade) and who has completed all of Tier 1 (+50%) and all of Tier 2 (+10%) would still have a 65% overall grade and a D in the course. Completing one Tier 3 checkpoint (+5%) would be needed to secure a 70% and a C. A score below 25% on the project and daily work would require two additional checkpoints to be completed – an effective letter grade reduction which, like the hypothetical 100% case, has never been observed in practice. Table 2 below outlines the three exemplar cases outlined above. This structure was designed intentionally to incentivize students to put their best effort into the project and daily work while leaving the tiered mastery structure as the primary driver of course grade.

Table 2: Exemplar student grades under competency-based scheme

<table>
<thead>
<tr>
<th>Case</th>
<th>Daily work and project grade (overall grade)</th>
<th>Tiers completed (% overall grade)</th>
<th>Course grade in percent</th>
<th>Letter grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal</td>
<td>50% (10%)</td>
<td>Tier 1 (50%) and Tier 2 (10%)</td>
<td>70%</td>
<td>C</td>
</tr>
<tr>
<td>One fewer check point</td>
<td>75% (15%)</td>
<td>Tier 1 (50%) and half of Tier 2 (5%)</td>
<td>70%</td>
<td>C</td>
</tr>
<tr>
<td>One more check point</td>
<td>25% (5%)</td>
<td>Tier 1 (50%) and Tier 2 (10%) and half of Tier 3 (5%)</td>
<td>70%</td>
<td>C</td>
</tr>
</tbody>
</table>

Across the most recent two offerings of the course, both under the full competency-based structure (N=84 students), one student (~1%) has fallen below 25% on the daily work/project score, none have fallen between 25%-50%, and seven (~8%) have fallen between 50%-75%. This means that most students are typically performing in the range allowing them to bypass one competency checkpoint and therefore are taking the daily work and project components seriously. Notably, the one and only student to fall below 25% is also the only student across those two offerings to have failed the course. Of the seven between 50%-75%, five received D’s and two received C’s.

**Quiz Assessment Points**

Completion of a given tier assessment requires the student to demonstrate mastery of the associated content. In the case of a quiz, this means achievement of A-to-A+ level work. Students may retake quizzes as many times as needed, limited to one attempt per quiz per opportunity (approximately once per week, usually Fridays) and by the number of such opportunities, dictated by the length of the semester. On each quiz day students may select one or more quizzes to attempt from among those that are available. Quizzes are made available beginning the week that the relevant modules have been
completed and remain available for the remainder of the semester. Quizzes are written to take 20-25 minutes, meaning that a student with a firm grasp of the content can attempt up to two in a given class period. Historically however, most students focus only on a single quiz at a time and many consume the entire 50-minute class period completing that one quiz.

To prepare for quizzes, practice quizzes are provided at the start of the term and each week the solutions to all previously given quizzes are posted. To alleviate the instructor load, the structure of the quiz remains consistent week-to-week and a bank of questions has been developed from which to generate the quizzes. For example, 1.Q1 will always include one question asking students to identify which names from a list are valid variable names. A large bank of such names is available from which to randomly pull in any given week. Similarly, 1.Q4 will always include a question asking students to write a short script using a single for- or while- loop structure. A bank of a dozen such questions is on hand for populating that quiz. In this way, quizzes year-to-year are variable, avoiding the need to generate wholly new problems ad-infinitum while still providing solutions to students for studying purposes. It is the opinion of the instructors that, if a student truly locates and commits to memory all possible variants of a problem, they have, despite their best efforts, likely learned the intended content.

After the initial offering of the competency-based model, it was observed by the instructors that there was a group of students who often fell into a grey zone – not quite at the level to pass, with some minor misunderstanding in the way, but clearly on the cusp. Students who found themselves repeatedly in this “not quite” result space would grow frustrated and eventually disengage. To alleviate this, it was decided to allow these borderline cases the opportunity to answer one or more verbal questions probing the underlying misunderstanding. If they were able to successfully demonstrate the missing competency, they were given a passing score. If not, the misconception was explained and they received a failing score and encouragement on what they needed to do to be successful on the next attempt. Though it has not been tracked what percentage fall into this category, anecdotal observations reveal that this is a highly effective differentiation method. Many students will respond quickly and accurately with the correction, often noting that they were bothered by the problem after submission and went back to look it up before realizing their mistake. Others will be very clear that they do not understand or answer confidently but incorrectly, revealing a common underlying misunderstanding in need of correction.

Students on average require two attempts to pass any given quiz, with six attempts being the highest recorded over the most recent two offerings. Looking at the most recent offering, students ultimately receiving an A required 1.75 attempts on average per Tier One quiz. Students receiving a B required 2.15, those receiving a C needed 2.31, and those receiving a D required 1.67. Other than the D level, which is discussed further below, this supports the general trend that those who are able to pass more quickly receive a higher grade (or, vice versa, those deserving of a higher grade are able to pass more quickly) but the relationship is not nearly as pronounced as might be expected.

The fact that D level students appear to be able to pass more quickly than any other group is an interesting observation. On the one hand, the N here is very small (N=3 D’s). Anecdotally however, those who struggle under the competency model tend to fall into one of two buckets – those who struggle with content and those who struggle with motivation. The ones who struggle with content often make many attempts with little progress before either realizing that they will not achieve their target grade and dropping the course or finally achieving the “A-Ha” moment and pushing through to a C, fueled by
renewed motivation. That leaves primarily the ones who are capable but unmotivated to linger and receive the D and F grades, simply running out of time to complete the requisite body of work. Indeed, this is supported by the data – all three of those receiving a D in the most recent offering of the course had not even attempted the second quiz before mid-semester and did not make a first attempt at the third until the final month of the term. Though they were able to buckle down and pass once pushed to do so, they were so delayed in doing so that there simply was not enough time to accumulate the necessary body of work to improve their score beyond passing.

Examining a case study from the other group, those who struggle with content, we see a prime example of the benefits of a competency-based model. This student required 5 or more attempts each to complete three of the four Tier One quizzes but ultimately achieved mastery of that content. That student went on to complete the Tier Two projects and ultimately received a C in the course. Under previous models, that student likely would have gotten grades in the C-D range throughout the term and ended the course with a similar final grade but with a very poor understanding of any of the constituent content. Under the competency model, the student did not attempt the B and A tier work, but truly mastered that at the lower tiers. The result is a much more capable individual who has learned the value of persistence.

**Project Checkpoints**

In addition to the quizzes, several checkpoints are achieved through the completion of projects. In Tier 1 these projects are largely stand-alone in terms of content. One requires the completion of a five-part assembly model in SolidWorks and the other is an application of digital logic using Excel, Simulink, and PLC programming. The Tier 2, 3, and 4 projects are applications of the quiz content, with Tier 2 being complex problems involving loops and conditional structures, Tier 3 using Simulink to solve ODEs, and Tier 4 being advanced topics building on the other tiers. In all cases, the projects are evaluated against the same A-to-A+ standard for successful completion. If a student submission does not meet that bar, the work is returned with commentary and the student prompted to correct their mistakes. This is repeated as often as needed and at whatever pace the student is comfortable with. In the case of the SolidWorks project, for example, submissions are often returned due to errors in the dimension precision, missing tolerances, or improperly defined dimensions. Nearly all students require 2-3 submissions of most projects before achieving mastery, though this has not been formally tracked.

In order to incentivize students to work together but eliminate the risk of oversharing, three preventative measures have been incorporated. First, the projects are designed with a large number of variants. Each variant will utilize similar programming concepts but with alterations that affect not only the values involved but also the structure of the program. Students are made aware of this fact and enter into the project knowing that, in addition to the fact that not all students are working on the project at the same time, they are also each working a slightly different problem. As with the quizzes, a bank of such problems has been compiled, meaning that there is not a continuing burden on the instructor to generate variations ad infinitum.

The second preventative measure is a required verbal debrief upon submission. If the submitted project is determined to achieve the mastery threshold, the student is required to meet individually with the instructor to discuss their program. They are asked to explain the logic or flow in various segments of their code, to describe what a particular line is doing or how a given function works, and generally demonstrate that they understand fully the work that they have submitted. In theory a student could
receive code from a third-party source and study it in sufficient detail as to pass this verbal questioning, but in the same spirit as noted previously — they have therefore learned the content in spite of their best efforts. A student who is unable to pass this verbal check with sufficient proficiency is given an alternative version of the project to complete, meaning that they must now start over with that assignment. A student who is determined to have committed academic dishonesty is given a permanent zero on the project. They are permitted to continue advancing up the tiers, but are handicapped by the value of the assessment (-5% to their overall grade). Repeat offenders fail the course and face additional disciplinary action. These policies are made clear to the students and rarely has a student entered into the verbal review unprepared.

Thirdly, students are required to begin each project with a flowchart or pseudocode outlining their approach. It is made clear that questions relating to syntax and debugging will not be answered until the outlining document is produced. Until it is explained what you want the code to do, you cannot ask questions about how to implement it. In addition to forcing students to practice good habits, this also requires that students cannot simply have a friend dictate code to them – they must first take the time to carefully consider what their code needs to do.

Unlike quizzes, projects operate on a much less structured timeline. Students may submit them on a rolling basis as they are ready and may continue to iterate on them until the cutoff date at the end of the term. The one restriction is that the Tier 2 projects may not be started until the student has at least attempted all four Tier 1 quizzes, since that content is prerequisite. They do not need to have fully completed Tier 1 before they gain access to Tier 2, though they are reminded that completion of the Tier 2 project will not add to their grade until Tier 1 is completed. The thought process behind providing access prior to finishing Tier 1 is to allow students who are still struggling with, for example, the loops quiz to see that content in application while they continue to attempt the quiz (hopefully improving their understanding in the process and aiding in passing said quiz).

**Daily Work**

The daily work component of the course (making up 10% of the overall grade) consists of a combination of weekly modules, in-class activities, and journals. The weekly modules are the flipped video modules previously discussed and the associated one-question quizzes that accompany them [12]. Generally, modules are assigned in groups of 3-5 and are due every Monday for most of the term.

The in-class activities are short, one or two problem activities that apply the content of the recently assigned modules. A small number of these activities are unrelated to modules and are instead in-class activities designed to support an upcoming project, such as completion of a SolidWorks tutorial in advance of beginning 1.P1. In-class activities are assigned weekly on Mondays, in conjunction with the weekly module deadlines, and students are expected to submit them by the end of class time on Friday. The intention of these activities was to reinforce student learning from the modules and to ensure that students have an opportunity to apply all module content, even if they do not progress far enough through the course structure to attempt the associated tier assessment. In early iterations of the competency model, it was observed that students were not self-motivating as intended or using class time as effectively as hoped and therefore required some additional structure to get them to engage with the provided practice sets. These in-class activities were a solution to that problem and have been highly beneficial in helping students uncover misconceptions and knowledge gaps prior to making a quiz.
The additional practice problems are also made available for students to utilize if, after completing the in-class activity, they feel that they need additional practice.

The weekly journals are intended to prompt students in setting and evaluating their own learning goals as they advance through the course. They are prompted each week to identify what they achieved/worked on over the past week, whether or not they achieved their goals and why or why not, and what their goals are for the coming week. They are graded on the quality of their journal in each of those three areas.

These journals tend to be moderately predictive of student success in the course (Pearson Correlation Coefficient of 0.63, N=84). When combined with the module and in-class activity scores into a single daily work score, that correlation is particularly strong (Pearson = 0.827). This is despite that body of work contributing only 10% to the final grade and by nature of the course model being nearly inconsequential from a mathematical perspective. What has not been made clear is if there is a causal relationship. In theory, students who take the daily work seriously should be able to progress more quickly through the course and thereby achieve a higher final grade. Conversely, it may be that those who are able to move more quickly are simply more motivated to complete the daily tasks. Additional study in this area would be needed to fully understand the relationship.

### Impact on Course Grades

To examine the impact of the switch to a competency-based system, student performance was compared. Because of the nature of the new model, it is not possible to do a one-to-one comparison on something like a final exam. Similarly, final course percentages could not be compared due to the stair-step nature of the competency-based assessment structure generating unnaturally binned scores. Instead, the average GPA generated were compared using a standard scale (A = 4, B = 3, C = 2, D = 1, F = 0). Scores from the final two offerings under the traditional course model (Sp17, Sp18; N = 102) were compared to scores from the most recent two offerings under the competency model (Sp21, Fa21; N = 91). Sp 19 is omitted because it was a transition year from traditional to full competency, so it does not fit in either bin, and Sp20 is omitted due to the hybrid nature of that semester resulting from the COVID-19 pandemic. Additionally, note that Fa21 was the first semester this course was offered in the Fall. The results of that comparison are represented in Table 3. The average GPA generated were nearly identical between the two models and had a very similar grade distribution.

<table>
<thead>
<tr>
<th>Table 3: Comparison of GPA points generated</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Traditional</td>
</tr>
<tr>
<td>Competency</td>
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</table>

Future work is needed to explore student performance on follow-on assignments in later courses. For example, a project in a junior-level course immediately following this one in the curriculum map will provide an interesting marker for student performance independently of the course model used.
**Student Perceptions**

Student comments under the traditional style of instruction were similar to what one might expect from a typical course – concerns about insufficient partial credit, timeliness of grading, and perceived disconnects between examples, homework, and exams. Several students mistook attempts to push them towards self-guided learning as lazy or bad teaching. Overall, students seemed mostly apathetic about the course with only 50-60% providing comments at all and many of those of minimal substance.

Instructor reflections noted that students were overly focused on the final answer to problems rather than on the coding and problem-solving process that led them there. The final iteration of this instruction mode, in Spring 2018, experimented with providing the answers to homework problems and shifting additional focus on the process rather than the result, which was appreciated by students but did not alleviate the concerns above.

Interestingly, comments about grading and feedback seemed to disappear with the shift to the flipped model in Spring 2019, perhaps an artifact of more time spent in class talking through problems. Students did note that they enjoyed the videos but wanted more instruction on some topics and that the workdays were where some of their best learning occurred. One student noted having no prior programming experience and feeling overwhelmed by the pace of the course and how much they needed to absorb to keep up. Others expressed a desire to be able to retake quizzes and to work more at their own pace, essentially describing the competency-based model about to be adopted.

Engagement from students remained at a similar 50-60% providing comments.

Once the course had settled into the competency-based model, however, student engagement with course evaluations seemed to spike and, for the last several offerings, has held steady with around 80% of students providing commentary. Generally, reviews of the course and grading mode are positive. Students seem to be cognizant of the depth of learning that they are required to adhere to, with comments such as:

> The teaching style that was used in this class was very helpful. I may not have reached all the tiers but what I did learn I feel like I mastered unlike some of my other courses.

Others appreciated the ability to accelerate or decelerate at their own pace as needed:

> Learning at my own speed and through my own research seemed like a lazy way to teach at first, but it was instrumental in me accomplishing everything I did throughout the semester… Learning through mistakes is a great way to learn when those mistakes don’t set you back hours of work and in the scope of this class, it worked to perfection.

> I like the way that we were allowed to re-attempt things as many times as necessary. This made it so we actually learned the content very well. While failing over and over was frustrating, I think it ultimately helped to actually learn the content.

More negative comments made clear the importance of student self-discipline in enabling their success under this model:
I was not a big fan of the flipped classroom, and the tiered grading system. I like to have real deadlines, so that I actually get projects done. With the tiered system, none of the projects or quizzes had hard deadlines, which made it difficult to feel motivated to get them done.

The major weakness of this course is the lazy college student. If students don’t stay on schedule they do not learn the material as well as they should.

These student comments illustrate the importance of the instructor engagement. The weekly journals, while perhaps not directly related to the course topic itself, are critical in gauging and enabling targeted follow-up with students who may be struggling to find this motivation. This also demonstrates the need for a pacer to guide students on what they should be expected to complete when.

Some comments also demonstrated what is perhaps a flaw in the current breakdown of tiers:

Make the tiers easier to get through to keep students from being discouraged and help them find ways to pass if they are falling behind rather than just allowing them to struggle.

It is believed that this sentiment stems from the fact that the first tier, required to achieve a D, is exceptionally large – covering roughly 60% of the course content. Mathematically, this makes sense. Practically however, it becomes discouraging to students not to see any significant progress until they are halfway through the semester if not well beyond that point. It may be worthwhile to consider breaking the first tier into multiple tiers solely to provide the sense of achievement needed to keep some students engaged and motivated to press forward.

Looking at the quantitative evaluations, student hours on the course seem to have increased markedly. Student self-reported hours per week spent on the course outside of lecture went from 2.8 (average across Sp17 and Sp18) to 3.7 (average across Sp21 and Fa21). As a three-credit hour course, this is a positive change and more in line with expectations for student workload. Other evaluations show slight improvements from the traditional to the competency model but no marked changes. This in itself is a positive, as that means that student perceptions of instruction, course fairness, value of the course, etc. did not change with the overhaul of the grading system.

Summary

The journey towards a competency-based model of instruction has been presented. A detailed explanation of the model was presented along with various exemplar cases as to how a student might progress through the course. It was found that, under this model, the average student took multiple attempts to complete any given assessment, largely due to the high bar required of them before mastery was awarded, but that overall grades were nearly identical to those under the traditional course model. This indicated that the new framework was not impacting the grade distribution but was bolstering student learning. It was also demonstrated that scores on daily work tasks, despite being a minimal contribution to the course grade, were nonetheless strongly correlated with the overall grade (Pearson Correlation = 0.827, N = 84). Additional work is needed to determine causality in this relationship. Finally, student perceptions of the course were presented along with some contextualization and interpretation from the instructors.
References


