Specifications Grading in the Flipped Organic Classroom

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Abstract:

Specifications Grading, developed by Linda Nilson, is a system of course-long student assessment based on the division of learning objectives into clearly-defined skill tests or assignments. Each skill is evaluated at a mastery level, with opportunities for students to learn from their mistakes and then be re-evaluated for skill tests, or resubmit assignments. In this paper, the author explores the background that led him to adopt Specs Grading in his Organic Chemistry course, and then details both the implementation thereof as well as student results and feedback.

Introduction:

I love asking questions; I think I got that from my Mom. Throughout my education, from kindergarten through graduate school, I have always felt empowered whenever my questions were fielded in good faith by teachers, professors, and teaching assistants; I have also felt empowered whenever teachers, professors, or teaching assistants would ask me (or the class) questions, and allow the time and framework for me (or us) to figure out the answers on my (our) own.

The first part of this is a narrative evolution of my teaching style in Organic Chemistry, arranged around a sequence of questions that I've asked myself over the last decade. These questions and my good-faith attempt to answer them has led to my adaptation of Specifications (Specs) Grading into my flipped Organic Chemistry classroom. Specs grading, a system for student evaluation developed by Dr. Linda Nilson, is quite different than the classic exam-exam-exam-final method of assessing student learning (Nilson, 2014). Therefore, I believe it is important to describe how, when I first discovered the seemingly-radical system of Specs Grading, it instead felt like a natural answer to a culmination of pedagogical frustrations and questions that I had all along.

The second part of this paper is a description of Specs Grading and its implementation into the first semester of my Organic Chemistry sequence, including qualitative and quantitative results from that semester.

I have found Specs Grading to be part of the Organic Chemistry course that is authentic to me. I hope that some of the reflective questions and possible answers that I share herein will inspire the reader to contemplate many facets of her or his own class, and share ideas to help refine our courses as a community. I believe that as chemistry educators, we share the best job on earth, and I seek your feedback that we may hone our craft together.

Part I: The Road to Specifications Grading

While the purpose of this paper is present Specs Grading, and not to argue for a flipped classroom, I don't believe that I would or could have implemented Specs Grading without first flipping (both for practical reasons and the growth of my confidence to question the paradigms under which I was educated). Furthermore, I would not have embraced the flipped classroom without first being challenged to question the usage of inquiry-guided learning (IGL) in my "lecture" course. Therefore, I believe that a brief discussion of my discovery and usage of those pedagogical approaches provides an appropriate scaffolding to discourse about Specs Grading.

How on earth can we expect students to correctly figure out Organic Chemistry on their own?

Since I began teaching full-time in 2007, a number of my previously-held notions of "what a (science) course should look like" have been, and continue to be, shaken. This process began with long arguments with Lenoir-Rhyne's (LR's) then-Director of Institutional Research Dr. Ginger Bishop about Inquiry-Guided Learning (IGL) in the classroom. My main argument was that *surely* we can't expect students to figure out information that took trained chemists centuries to discover!

Even after joining an LR IGL faculty group with the goal of implementing in-class IGL in 2010, I could only see how this method could be applied to laboratory courses, where students had time to explore content that had already been covered in class. The lecture component, in my opinion, had to be carried out in the traditional fashion. *How on earth can we expect students to correctly figure out Organic Chemistry on their own?*

While I still believe that much of the information contained in an Organic Chemistry course is best delivered in some type of lecture form, I'm humbled to admit that Dr. Bishop was right. I committed one class period in the spring of 2011 to allowing students, in groups, to discern a mechanism that we had not "covered", but one that was reasonably within their grasps as second-semester organic students. Twenty minutes into the class period, to my surprise, they had proposed two different, but reasonable, mechanisms. With time to spare, I shared the two mechanisms with the class, and pushed them into the deep end of the inquiry pool by asking them to construct experiments that could allow them to provide evidence about which of the mechanism occurs. Again, they astounded me with their enthusiasm and ideas. But I shouldn't have been surprised, for I know (and previously expressed in the first paragraph of this paper) that a class period like that would have enthralled me at their age. Clearly, students can inquire their way to advanced knowledge, given enough basic information as a guide.

Many science faculty have published amazing works on inquiry in the science classroom; I especially encourage those interested to read Organic Chemistry: A Guided Inquiry by Andre Straumanis (Straumanis, 2012).

How can a student be expected to tackle difficult example problems when they had just seen concept for the first time?

Inquiry takes time, and I wasn't sure how to create more time/space for more in-class inquiry. Furthermore, while my course delivery has always included time for students to work problems during class, the problems offered to students during the same hour as they first saw the concept/skills were, by necessity, quite simple (a consistent complaint on my course evaluations was "the exam problems are always harder than the problems in class"; but *how could a student be expected to tackle difficult example problems when they had just seen concept* *for the first time?).* In the summer of 2013, I attended the cCWCS (Chemistry Collaborations, Workshops, and Communities of Scholars) conference on Active Learning in Organic Chemistry, and was exposed to the Flipped Classroom for the first time.

In a flipped classroom, lectures are recorded and delivered before class, and the class period is spent on problems. I could immediately envision the advantages: I could still give the students that baseline scaffolding of knowledge, and yet allow the time for inquiry, especially with applications to biochemistry and pharmaceutical science. I jumped in face-first, and spent summer 2013 (and the rest of the 2013-2014 academic year) recording on Explain Everything and uploading to YouTube the entire year of lectures. The newfound freedom and flexibility in class time afforded the opportunity to offer challenging problems and allow students time to work through (and productively struggle with) these problems with my support. I was also able to devote time to inquiry-guided lessons, generally allowing students to discover how the concepts and skills from organic chemistry could be applied to biochemical systems. The flipped classroom allowed and encouraged IGL in a way that I never expected.

How could you not see what I'm asking you to be able to do?

Organic Chemistry has always had a relatively high fail rate, and students often enter the course with little more than the expectation of a difficult weed-out course for potential M.D.'s. And like many courses, its true place in science education is easily missed. I know that maturity and perspective can often only come with age. However, I often asked myself how to communicate the importance and excitement that accompanies an understanding of why and how organic molecules act and react, and how Organic Chemistry can tie together physics, chemistry, and biology in a way that few other courses can.

I had a student three years ago memorably tell me "I love the way that police officer training courses are set up: we're given a learning objective, and then taught how to do it, practice it, and then are tested on it." I pointed out that I had listed the course learning objectives on the syllabus! But to be fair, I hadn't spent much time being explicit with students about transitions from one objective or skill to another; and the course was mostly structured around the textbook's chapters.

Me (grumpily): Do I really have to spell this all out for them?

Me (sheepishly): If it would help the students learn and improve perspective, is it that big of a deal?

Starting the week after that conversation, I began every class with a list of learning objectives for that class period, usually only one or two. The students were thrilled.

Me: Seriously? How could you not see what I'm asking you to be able to do?

Yet for most students, the "learning objectives" were reduced to "the stuff on exam 2". And I hadn't helped them change that viewpoint: exams in my course were still given every month or so, roughly three chapters at a time, instead of being structured around the learning objectives that I had just started explicitly sharing.

What if students know exactly what benchmarks they need to hit in order to pass (or to earn an A)?

When students would come to my office hours and review before exams, I could help them lump the seemingly disparate pile of skills and content into a concise list of skills that I thought was obvious, but usually left them saying "really, that's it?" *It struck me that if students weren't seeing the context naturally, then why wasn't I arranging the course around objectives to help them do so?* Certainly the feeling of being overwhelmed affects performance on exams (furthermore, I can remember entering exams being sure that I understood the information presented in class, but a several-page examination on it appeared to be so foreign that it may as well have been from a different class). *What if students know exactly what benchmarks they need to hit in order to pass (or to earn an A)?* At the same time, I was asking myself in laboratory, *why are students allowed to pass from general chemistry into organic lab without being absolutely, positively sure how to calculate percent yield?*

I resolved to attempt to restructure the course around learning objectives, instead of chapters; I was introduced to the concept of Backwards Design (McTighe, 2005), in which courses are designed around the end goals (e.g. students need to be able to quickly and correctly interconvert Lewis Dot Structures and Line-Angle Formulas). I was also determined to assess students on fewer learning objectives at time; intentional clarity could only help student performance, I assumed.

Yet the question remained, *how can I accurately assess student knowledge in a course like that?* I researched some ways in which faculty assess students using Standards-Based Grading, but while I know and respect many colleague who use that system, I struggled to combine my assessment goals with it.

Clearer objectives, higher standards, AND simplified grading? Where have you been all my life?

In January 2015, Robert Talbert came to LR to speak about the flipped mathematics classroom (I invite you to check out his Casting Out Nines blog at http://rtalbert.org/blog/). While it was great to hear his experiences and opinions about flipping, what truly caught my attention was an off-the-cuff remark he made to me after a session about how his math courses were organized around pass-fail learning outcome tests. To me, this sounded like an amazing system: giving students a list of outcomes (mostly skills, some factual knowledge, some application), and letting their grades be dictated by how many of those skills were mastered. Furthermore, there was no more partial credit; mastery means doing things right. My mind immediately drifted to the nightmare of assigning fair partial credit to students, considering the myriad of so-close-but-so-so-wrong answers that students can muster for even the most simple nomenclature problem. *Clearer objectives, higher standards, AND simplified grading? Where have you been all my life?*

Several months later, LR's Director of the Center for Teaching and Learning, Devon Fisher, turned me onto a book published in 2014 by Dr. Linda Nilson about a system of grading called "Specifications Grading", and over the course of a week in jury duty, I devoured the book, and began adapting it to my own course (I later found out that Dr. Talbert had adapted his grading system from the same book). In brief, Dr. Nilson's system is arranged objectives that are clearly established, and graded pass/fail (but with a passing grade set at a mastery level, instead of the commonly-assumed level of basic proficiency); overall course grades are dictated by how many objectives are mastered. Furthermore, Specs Grading includes the opportunity to retake (for tests) or redo (for assignments) failed objectives.

Part II: Experimental Methods of Specifications Grading adaptation into my Organic class:

In fall 2015, I presented to the students a new approach to grading in Organic Chemistry: the first semester of the course was arranged around 22 outcomes. Six were "Essential Outcomes" (Eos), these were outcomes that I considered fundamental to everything else in the first and second semester of the course; the students had to demonstrate mastery of each of the 6 in order to have a chance to pass the course. The remaining sixteen were "General Outcomes" (GOs), and each student's course grade would be be determined by how many of these outcomes were mastered. Grades were assigned as follows:

A: Pass 6 EOs + 15-16 GOs
A- : Pass 6 EOs + 14 GOs
B+: Pass 6 EOs + 13 GOs
B: Pass 6 EOs + 11-12 GOs
B-: Pass 6 EOs + 10 GOs
C+: Pass 6 EOs + 9 GOs
C: Pass 6 EOs + 7-8 GOs
C-: Pass 6 EOs + 6 GOs
D+: Pass 6 EOs + 5 GOs
D: Pass 6 EOs + 3-4 GOs
D-: Pass 6 EOs + 2 GOs
F: Pass less than 6 Eos and/or 2 GOs

Outcome quiz/tests, which the students began calling "quests", were given one-at-a-time, and were graded pass-fail with no partial credit. Students were generally given 5 questions and needed to answer 4 of them perfectly in order to provide evidence of mastery (i.e. pass).

The outcomes were arranged and ordered as follows. Like most textbooks, the first eleven outcomes were mainly focused on the nature of molecules by themselves, or simple non-reaction relationships to other molecules:

EO1: Drawing Lewis Dot Structures
EO2: Interconverting Lewis Dot Structures, Condensed Formulas, and Line-Angle Structures
EO3: Using Basic Nomenclature
GO1: Identification of Hybridization, Bond Angles, and Bond Types
GO2: Application of Intermolecular Forces
GO3: Indicating Stability of Molecular Conformations
GO4: Drawing Structural Isomers
GO5: Identifying and Designating Chirality
GO6: Identifying Stereoisomers

GO7: Using Advanced Nomenclature

The second half of the class began with, in my opinion, the most crucial block of skills in Organic Chemistry: understanding the stability of ions (EO4, including the introduction of resonance with intramolecular mechanism arrows) in order to begin understanding why reactions occur, predicting relative acidity and basicity based on structure (GO8, an application of ion stability, and also a simple introduction to intermolecular mechanism arrows), drawing intermolecular mechanism arrows in nucleophile-electrophile reactions (EO5), and identifying the reactive sites in molecules in order to predict reactions based on structure (EO6). These four skills were followed by the remaining general outcomes, which focused on specifics of substitution, elimination, and addition reactions:

EO4: Identifying and Explaining Charge Stability
GO8: Predicting Relative Acidity and Basicity
EO5: Drawing Elementary Reaction Steps (Acid-Base, S_N2, E2)
EO6: Understanding and Predicting Electron Motion
GO9: Understanding Multistep Substitution and Elimination
GO10: Predicting Reaction Mechanisms and Products (S_N2/E2/S_N1/E1)
GO11: Predicting Products of Advanced S_N2 Reactions
GO12: Identifying Reactants and Reagents for Substitution and Elimination Reactions
GO13: Understanding Electrophilic Addition Reactions
GO14: Predicting Products of Advanced Addition Reactions
GO15: Identifying Reactants and Reagents for Addition Reactions
GO16: Biochemical Application of Organic Chemistry

Three class periods (essentially the traditional exam periods) were devoted to quest retakes. Students who had failed any outcome evaluation would have another chances to learn the skill and pass a new test on that outcome; these exam periods essentially represented exams of various lengths and content, but tailor-made to fit their previously-exposed weaknesses. Furthermore, students who had passed every test the first time it was offered during class had the day off.

At the beginning of the two-hour final exam period, students were given a one-hour cumulative final exam. Final exam grades could impact their course grade slightly, with a maximum of approximately one grade either up or down. Depending on the student's grade entering the final exam, they were given a sliding scale with range of exam grades and their effects on the final course grade (e.g. a student entering with a C needed to score a B or A on the final exam to increase their course grade, an F to decrease their course grade, while scoring a C or D on the final wouldn't affect their final grade. Just like the quests during the semester, no partial credit was given on the final exam.

The second hour of the exam period was another allotment of time for quest retakes, exactly the same as the in-semester retake periods. There was no limit on the number of quest attempts beyond the end of the semester; nor was there any penalty for completing them later in the semester.

Data and Results:

At the beginning of the semester, student feedback was mixed, as I would expect for a grading system so different from their expectations. Some students felt like they were being tested too often, but several remarked that they had never "learned so much so quickly" in a class before. Personally, I think the two comments go hand-in-hand… while students (or perhaps humans in general) are trained to only study when an exam is in the near future, this course always had an exam in the near future, and therefore staying on top of the material was necessary. Later in the semester, students began complaining that other courses weren't testing often enough and that those tests involved too much material (which I suppose is positive feedback for this system), and many of the students expressed how comforting it was to know that they had a second chance (or third, etc.) to master an objective.

The single piece of feedback from my colleagues, which I had also considered, was the question of whether many small tests will result in a decrease in long-term retention of information. I continue to share the concern. However, I do not distribute graded final exams, therefore I was able to compare my cumulative final exam grades from the fall of 2014 (traditional model of 3 exams and 1 final exam) to the final exam grades from fall 2015 (Specs Grading). The first column shows the results on the final exam, as well as question types that were most comparable across both final exams. For data in the second column, I regraded the fall 2014 exams without allowing any partial credit, which provides a more accurate comparison to the way that the fall 2015 class (and final exam) were graded.

	Fall 2014, including partial credit (n=46)	**Fall 2014, regraded without partial credit**	**Fall 2015, no partial credit given (n=35)**
Final Exam Average	65.6%	41.4%	61.3%
Lewis/LA/CF*	63.7%	28.5%	67.8%
Naming	71.9%	24.7%	61.0%
Resonance	67.8%	39.6%	63.5%
Acid-Base Explanations**	68.3%	48.1%	50.5%
A + B → ?***	61.9%	49.4%	62.0%
A + ? → C****	61.0%	42.9%	72.5%

*****Questions about interconversions of Lewis Structures, Line-Angle Structures, Condensed Formulas

**Questions in which students were asked to compare structures and predict relative acidity/basicity

***Questions in which students were given reactants and reagents, and asked to give the products

****Questions in which students were given reactants and products, and asked to give the reagents

Overall as well as in most of the categories of comparable question types, the students in fall 2015 performed markedly better on their cumulative final exam. It is possible that these results are not due to the dramatically different Specs Grading style, but simply due to the increased rigor that accompanied a no-partial-credit rule over the course of the entire semester. However, I would not have implemented this increase in rigor, if I wasn't giving the students multiple chances to demonstrate mastery.

I am also aware of a relatively small sample size, but I intend to continue to collect data and hope to one day assimilate the data into a larger set from other classrooms in order to more accurately evaluate Specs Grading in Organic Chemistry.

Conclusions:

I believe that the system can work well for both excellent students and those that struggle. I hadn't considered this before implementing the system, but with the ability to learn from their mistakes after a failed first attempt at a test, many of the students who might otherwise flounder and give up instead found themselves seeking help from both me and from other students. The majority of those students ended up with C's instead of F's, and I believe that every student in the class earned their grades. In addition, by only allowing students to pass with completely correct responses, I eliminated the tedium of partial credit for my grading, and held these students to a higher standard than ever before.

For students, failing grades represent the fact that they haven't mastered the information **yet**. The course dedicates a lot of time to the in-class quests, but I believe the time is well spent. I always spend a few minutes providing the correct answers, and will field question from students about them. Students who pass the quest receive immediate feedback that they are ready to move on. More importantly, I encourage those who haven't passed to consider the attempt as a learning opportunity, and remind them that they have another chance to learn and master the outcome at hand.

The most striking benefit of this system for students, I believe, is that every student is provided with both the impetus and opportunity to learn from their mistakes.

Thank you for your time, and I look forward to answering any questions that I can.

Works Cited

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