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Use of specifications-based grading in an online, asynchronous graduate organic chemistry course

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Specifications-based grading is an alternative grading scheme that emphasizes student proficiency of learning objectives. Course grades are determined by the number of objectives completed rather than the number of points accumulated. At the University of Saint Joseph, CHEM 510 Intermediate Organic Chemistry is the foundation course that all incoming graduate students take in their first semester of the fully online, asynchronous MS programs in Chemistry and Biochemistry. Students in CHEM 510 complete the entire course online and at their own pace within the structured due dates, which presents unique challenges compared with synchronous learning modalities. With these considerations in mind, CHEM 510 was revised to use a specifications-based grading scheme with an a la carte assessment menu and token system. Generally, students found the alternative grading scheme helpful, but they needed additional instructions and time to adjust to the new grading system. By the end of the semester, students expressed their appreciation for the ability to choose their assessment method, work at their own pace, and use the token system for extensions/retakes. The instructor found that implementation of specifications grading took greater time for the initial course setup, but did not require more time than points-based grading once the course began. One large positive outcome was that student-instructor interactions were more frequently about the content of the course rather than grades. Overall, there was a slight increase in the course's pass rate compared to the pass rate prior to the change in grading modality. We believe that the implementation of the a la carte assessment menu accommodates a more diverse population of learners without sacrificing the integrity of student learning. Additionally, we believe that the diverse assessment opportunities were critical for the successful implementation of specifications-based learning in the online classroom environment, though further extension of the menu in synchronous, in-person classroom settings may be challenging.

KEYWORDS

organic chemistry, graduate education, specifications-based grading, online instruction, alternative grading

1 Introduction: background and rationale for the educational activity innovation

Students often identify Organic Chemistry as one of the most challenging subjects in the college curriculum (Johnstone, 2010) and with the recent expansion of online education initiated by the COVID-19 pandemic (Sunasee, 2020), the academic needs of these students have increased (Crucho et al., 2020). One approach to mitigating negative student perceptions of college-level chemistry courses involves changing the way that grades are distributed by employing various alternative grading methods (Herman, 1992; Brookhart et al., 2016). Instead of using the traditional points-based grading system, alternative grading methods such as standards-based learning (O'Connor, 2002), contract grading (Danielewicz and Elbow, 2009), mastery or competency-based learning (Bloom, 1968), and "ungrading" (Blum, 2020) have become popular alternatives. Alternative grading methods have seen positive results in the classroom setting (Atifnigar et al., 2020; Cain et al., 2022), but none are without their drawbacks: often, the change from traditional grading to alternative grading is associated with increased workload for instructors and/or increased stress for students (Peters and Buckmiller, 2014).

To mitigate these drawbacks, specifications-based grading (Nilson and Stanny, 2023) has emerged as a method for assessing student learning that focuses on clearly communicating learning objectives and encouraging student engagement with material (Howitz et al., 2021). Within Chemistry, specifications-based grading has been used in small lecture settings (Ring, 2017; Donato and Marsh, 2023) and large ones (McKnelly et al., 2023), and even has been implemented in lab-based (Bunnell et al., 2023; Howitz et al., 2023) and writing-based (McKnelly et al., 2021) courses. Among these successful implementations of specifications-based grading, several were done in Organic Chemistry; however, few, if any, publications have explored the impact of specifications-based grading in an online, asynchronous course or graduate level course. In this article, we explore the impact of specifications-based grading in CHEM 510 – an online master's level course in Organic Chemistry – designed for the university's online asynchronous master's programs in chemistry and biochemistry. We comment on the results and give insight into adjustments made to the course over the span of several academic semesters.

2 Pedagogical framework(s), pedagogical principles, competencies/ standards underlying the educational activity

Specifications-based grading (specs grading) is one of several different alternative forms of grading developed by educators to enhance student learning. The design of specs grading was informed by the successes and shortcomings of other, older alternative grading methods (Nilson and Stanny, 2023). Below, we highlight the main features of some of the most prominent alternative grading methods and their strengths and weaknesses identified by previous publications.

2.1 Standards-based grading

Standards-based grading (SBG) courses are designed around specific learning objectives and use formative and summative assessments to determine whether a student has grasped the material of each objective (Marzano, 2010; Boesdorfer et al., 2018). Early and frequent informal assessment is used to provide feedback to students on their progress toward the ultimate performance goal without receiving a grade on their work (Iamarino, 2014). Since students are not penalized for misunderstandings exhibited during these early assessments, students are more willing to revisit difficult material to prepare for the formal scored assessments later in the course. Student grades on the formal assessments are determined by rubrics with clear guidelines for determining the level of student achievement in each of the learning standards (Curley and Downey, 2023). Instead of awarding points, a rubric specifies the criteria for distinct levels of student proficiency in each standard (Boesdorfer et al., 2018). Since student work cannot be scored as falling between proficiency levels in the rubric, each rubric is written with clear language to eliminate grading bias. Often, students are given multiple attempts to prove proficiency in a standard through formal assessment. Most publications of standards-based grading indicate a positive response from students, who feel as though their perspective on learning was changed for the better (Iamarino, 2014); however, other students have confessed to difficulties with motivation and a lack of self-initiated study habits that may have hindered their learning experience (Guskey, 2001).

2.2 Mastery- and competency-based learning

Mastery-based learning courses, like SBG courses, are divided into concept groupings based on related course material. However, in mastery-based grading, students may not advance in the course without demonstrating mastery on the current topic (Block and Airasian, 1971). Where standards-based grading provides multiple, though limited, opportunities for students to demonstrate proficiency, mastery-based learning allows students practicably limitless attempts, giving constructive feedback on their answers after each attempt. This prevents students from advancing to a new module without vital knowledge from a previous concept and allows them to focus on their weaknesses to master the objective (Bloom, 1968).

Competency-based grading builds on mastery-based learning, adding additional course-related work students may complete to increase their grade (Diegelman-Parente, 2011). This often means that students achieving mastery in a module will earn a letter grade of a B, while an A can be earned by the completion of additional work.

Students in mastery-based learning courses report drastically reduced anxiety over assessments and increased confidence in material (Peters and Buckmiller, 2014). The downside to these grading styles is the strain it places on instructors, who must find ways to generate and grade multiple assessments for each module and provide timely feedback to students (Bangert-Drowns et al., 1991). Instructors also must coordinate between students who progress through the material at different rates, adding to the complexity of maintaining student grades.

2.3 Contract grading

In contract grading, students generate a contract that outlines in detail what coursework they must complete to get a desired letter grade in the course (Taylor, 1980). Students present their contract to the instructor at the beginning of the year, then modify it until both parties are satisfied (Lindemann and Harbke, 2011). Contracts indicate how many assignments from each category (quizzes, discussions, laboratory experiments, etc.) must be passed to earn a given letter grade for the course.

This approach emphasizes transparency of expectations, the main strength of contract grading and a consistent weakness of points-based grading (Danielewicz and Elbow, 2009). When students and instructors find a compromise during the contract negotiating period, student autonomy and buy-in is balanced with the expectations of the instructor, leading to positive impressions for both the student and instructor (Hiller and Hietapelto, 2001).

2.4 Ungrading

"Ungrading" is slowly becoming a popular method of deemphasizing grades, in favor of enriching student engagement without the pressure of grades and assessments. Instructors who use ungrading reduce the number of graded assessments given to students to encourage students to focus on the learning experience instead of on the grade they might receive for their work (Blum, 2020). Students are often given a chance to grade themselves or their peers, allowing them to reflect critically and engage with course material instead of receiving a verdict from the instructor (Stommel, 2023). Though examples are limited, those who are implementing ungrading in their classes report greater student engagement, a class culture focused on understanding over completion, and lower levels of student anxiety about coursework (Masland, 2023). Potential drawbacks include a lack of effort from students due to a lack of accountability, a lack of student preparedness for the rigor of challenging work environments, and tensions between the student and instructor caused by different standards for nongraded work.

2.5 Specifications-based grading

Specifications-based grading combines aspects of several of these grading styles, leading to a better learning experience for students and instructors. Nilson and Stanny (2023) seminal book provides many positive outcomes of specs grading, which can be summarized by three major goals:

- Design a course that focuses on student learning rather than completion and achievement
- Remove ambiguity in assigning grades by providing clear expectations to students
- Balance a manageable workload for instructors while providing ample learning opportunities for students

Specs-grading focuses on giving students the opportunity to truly grasp difficult content while still holding them accountable for their learning by balancing the concessions and expectations given to students. Various aspects of specs grading came from the inspiration of other alternative grading methods such as those listed below:

- Specs grading divides course content into several small learning objectives, assessing student proficiency of each objective (Townsley, 2014). Like SBG, assessments are graded using rubrics which provide clear criteria that graders use to organize student work into various levels of proficiency such as "high pass," "pass," or "no pass" (Howitz et al., 2023).
- Students have multiple attempts to show proficiency in each objective and, like mastery-based learning, students only cover one at a time before assessment and advancement to the next objective (Bunnell et al., 2023). In specs grading, students have multiple (though not infinite) attempts on each assessment to reach passing criteria. However, in specs grading students advance to the next objective once the assessment due date passes or a student has used the maximum number of attempts, even if they do not achieve proficiency for the current outcome.
- Instead of students writing a contract, the instructor provides the contract detailing the assignments that must be completed for a student to earn a particular letter grade (Houseknecht and Bates, 2020). This maintains transparency of instructor expectations without requiring an instructor to endure the time-consuming meeting process with each student as is customary in contract-grading courses. Often, the contract will bundle objectives instead of assignments, grouping the outcomes into "Essential" and "General," designating how many of each objective must be passed for a student to earn a letter grade in the course (Howitz et al., 2021).

Specs grading has several strengths that make it a favorable option for instructors and students. The first is the focus on student learning; specs-based courses encourage students to build more regular study habits by breaking course material into smaller, more manageable outcomes that do not exceed the cognitive load of most students (Kishbaugh and Cessna, 2018). The emphasis on pairing smaller, more frequent assessments with timely instructor feedback helps students to focus on their mistakes and resolve learning gaps more quickly in comparison to traditional points-based courses that rely on large summative assessments to evaluate student learning (Schneider and Hutt, 2014).

Specs grading has also decreased grading issues between students and instructors by clearly articulating expectations and removing the ambiguity of partial credit, which is a commonly observed fault in classes with large enrollments and multiple graders (McKnelly et al., 2023). Instead, rubrics used to assess student performance use clear criteria, making it easy for graders to correctly identify whether the work submitted by a student has reached the desired level of proficiency (Howitz et al., 2023). Some assessments may require students to reach a certain benchmark – 80% is a common passing threshold when multiple-choice quizzes are used for assessment.

Other alternative grading methods provide students with multiple attempts on a given assessment, but the increased grading expectations that comes with multiple attempts can become exhausting for instructors (Bangert-Drowns et al., 1991). To mitigate this, a "token economy" is frequently implemented in a specs-grading classroom; students are provided a set number of "tokens" that can be spent to redo a failed assessment or extend a deadline on an assignment (Howitz et al., 2021; McKnelly et al., 2021). This allows the instructor to limit the number of retakes while still providing the freedom to reattempt any assessment that is particularly challenging. Additionally, the token economy removes the burden from faculty charged with arbitrating what is a valid reason for need of a retake or extension.

Various approaches have been taken toward the administering of a cumulative final. Some instructors choose to administer a summative

TABLE 1 Course learning objectives for CHEM 510.

Course objective	Specs module
Explain the unifying structure–property and structure-reactivity relationships upon which organic chemistry is based.	Across all modules
Describe molecular shape and stereochemistry and apply its effect on reactions.	EO1 (shape), EO2 (stereochemistry)
Propose reasonable mechanisms for organic transformations using curved arrow notation and apply these common reactivity pathways to unfamiliar reactions.	EO3
Predict structural effects on the acidity/basicity of an organic molecule.	EO4
Define and predict products for the major reactions involving nucleophiles and electrophiles, including nucleophilic addition, nucleophilic substitution at a carbonyl group and at a saturated carbon atom.	Across all GOs by functional group
Apply the numerous reactions that result in functional group transformations to the synthesis of organic compounds.	Across all GOs by functional group
Apply retrosynthetic analysis to the synthesis of organic molecules.	EO5, EO6
Evaluate and discuss current research in organic chemistry.	RP2, RP3

TABLE 2 Grading summary of intermediate organic chemistry prior to spring semester 2021.

Category and percent	Description
Exams (38%)	Midterm and final, each composed of five 60-min sections
Discussion Boards (31%)	6 collaborative problem sets
Quizzes (12%)	2 timed multiple choice/multiple answer questions
Project (10%)	Named Reaction slides presentation
Modules (9%)	2 60-min timed sections in long answer format

final as a necessary part of achieving a particular grade in the class and will include it in the grading contract (Bunnell et al., 2023). Other instructors choose to administer a final in an alternative format or as a type of competency-based assignment, offering a grade incentive to those who score well on it (Ring, 2017; Howitz et al., 2023). There is no standard way to approach final exams in specs grading.

While specs grading continues to gain traction in face-to-face instruction, the impact in an online setting has not been extensively studied. There have been reports of courses using specifications-based grading in a hybrid setting or in response to COVID-19 (Houseknecht and Bates, 2020; Noell et al., 2023), but few organic chemistry courses were initially designed to be online and utilize specifications-based grading.

3 Learning environment (setting, students, faculty); learning objectives; pedagogical format

Since 2010, the University of Saint Joseph (USJ) has offered Master of Science (MS) degrees in Chemistry and Biochemistry through fully online, asynchronous instruction. This asynchronous online format helps working professionals pursue a degree while continuing a normal working schedule, and over two thirds of the students enrolled in the program work in a full-time job. All courses in these programs are capped at 20 students. The first semester for students in both the MS Chemistry and Biochemistry programs includes CHEM 510 – Intermediate Organic Chemistry, a class designed to ensure that students are prepared for the rigor of the program by establishing a unified foundation of organic chemistry knowledge among all enrolled students. During our study, 97 students enrolled over 7 semesters in CHEM 510, making the average enrollment 14 students per semester, though class sizes varied from 7 students to the maximum enrollment of 20 students.

CHEM 510 covers the fundamental concepts of organic chemistry from undergraduate level classes, then builds upon them at the graduate level, preparing students for advanced coursework. Central topics covered in the course include organic structures, stereochemistry, mechanisms, acid/base reactions, selectivity, retrosynthesis, reactions of various functional groups, literature searching, proper citations, and named reactions. Table 1 lists the departmentally developed course learning objective associated with these topics. Historically, this course has been graded on a traditional points-based grading system with various categories of assignments, with the bulk of the points coming from discussion board assignments and the midterm and final examinations (see Table 2).

In Spring 2021, a new specifications-based grading structure was implemented in CHEM 510. The course material was divided into weekly modules arranged by content, including 6 Essential Objectives (EOs), 7 General Objectives (GOs), and 4 Required Projects (RPs). As detailed in Table 1, the course learning objectives were divided into foundational topics such as structure, stereochemistry, mechanisms, and acid/base chemistry (EOs 1–4); reactions of specific functional groups (GOs), tools for organic synthesis (EOs 5–6), chemical literature (RP2), and named reactions (RP3). RP1 contained the course introduction module and RP4 the final exam for the course.

A grading contract was developed by the instructor (Figure 1) to clearly communicate the number of objectives that must be met to earn each letter grade in the course. While this grade contract changed slightly during our study, the final iteration is described here. A grade of a B- is the minimum grade necessary to pass the course, requiring students to complete 5 EOs with a minimum assessment score of 80%,

Base grade	Minus	Standard	Plus
A	6EO + 4RP + 6GO	7GO	
		OR: %increase in RP4/RP1 >1 SD	
B	5EO + 4RP + 2GO	4GO	4GO and %increase in RP4/RP1 >1 SD
		OR: %increase in RP4/RP1 >1 SD	OR: 6GO
		OR: 6EO + 4RP + 3GO	OR: 6EO + 4RP + 4GO
Grades below here are not passing			
C	4EO + 3RP + 2GO	4GO	4GO and %increase in RP4/RP1 >1 SD
		OR: %increase in RP4/RP1 >1 SD	OR: 6GO
		OR: 4RP	OR: 4GO and 4RP
D	3EO + 2RP + 2GO	4GO	4GO and %increase in RP4/RP1 >1 SD
		OR: %increase in RP4/RP1 >1 SD	OR: 6GO
		OR: 4RP	OR: 4RP and 4GO
F	<3EO		

FIGURE 1
Grading matrix for intermediate organic chemistry for the 2023 summer semester.

a minimum of 2 GOs with an 80% score, and completion of all 4 RPs with a passing grade. To achieve a higher score, students could complete the 6th EO, additional GOs, or increase their score from the initial pretest (RP1) to the final post-test (RP4) by greater than one standard deviation. For example, to earn an A in the course, a student would need to meet the criteria for an A- (6 EO, 4 RP, and 6 GO) plus complete an additional GO or increase their score by greater than one standard deviation for pre−/post-test increase.

Weekly deadlines for the EOs and RPs were given, though students could work ahead if they chose. Students had six weeks to complete two to seven GOs with a suggested weekly schedule for students to follow culminating in a firm deadline for the GO section.

4 Results to date/assessment (processes and tools; data planned or already gathered)

To meet the proficiency criteria for EOs/GOs, students were offered three different forms of assessment:

- Timed multiple-choice quiz (two attempts)
- Timed written response test
- Open-ended tutorial presentation teaching how to solve a multi-step problem

Students could attempt one or more assessments before the due date. The quizzes were automatically graded, so students could complete two quiz attempts; whereas the exams and tutorials were manually graded, so they only had to be turned in before the due date.

After an assessment, the instructor would give the student feedback to inform them of any mistakes or misunderstandings displayed in the assessment. Quizzes generated instant feedback to students, while tests and tutorials required instructor feedback, which was usually provided within 24 h of completion. If the student did not reach the 80% minimum passing score, they were encouraged to read the feedback provided and strengthen their understanding of the material. Then, students were free to attempt another assessment before the due date or use a token for additional attempts (*vide infra*).

RPs were graded on completion only and were distributed throughout the semester. The RP modules included an introductory module with a pre-test, a section on finding, citing, and reading scientific literature, a named reaction project, and the post-test final exam.

After the first semester, a token economy was adopted as an opportunity for students to improve their standing in the course and remove the need for faculty to approve reasons for extensions or retries. Three tokens were provided to each student at the beginning of the semester. The instructor planned to modify the number of tokens if needed, but this number was adequate for most students and still low enough to encourage participation to earn more tokens. To spend a token, students would submit a Microsoft Form to request a deadline extension, additional quiz attempts beyond the two standard attempts, or changing assessment type after the due date (e.g., switching to tutorial after not passing the exam). Additional tokens could be earned by identifying errors in the course materials and completing course surveys (e.g., midterm course survey, office hours poll). Students also submitted their token earned requests through a Microsoft form. Both the "tokens earned" and "tokens used" were tracked in the LMS for easy student reference.

5 Discussion on the practical implications, objectives, and lessons learned

5.1 Results

Four semesters of data from the points-based grading system (two instructors) and eight semesters of data from the specifications-based grading system (one instructor that had also taught in the points-based system) were analyzed to see whether any general trends in course grades could be seen. When comparing the number of passing students between the two modalities, we see that more students earned a passing grade with specifications-based grading, with an increase of 10% more passing scores (Figure 2). The increase in passing scores in this introductory course also coincided with a decrease in students being put on probation or dismissed from the program for poor grades and increased retention of students beyond the first semester.

When every student passed in that first semester, it raised questions about potential grade inflation caused by the grading scheme. To compare student knowledge to their final letter grade, two 50-question pre- and post-tests were added to the course for the following seven semesters. Test questions covered all content from the 13 objectives in the course, and completion was mandatory for students to pass the course. Although it is a challenging assessment, students are told in advance that their score cannot negatively impact their grade, but that a good score may increase their final letter grade in the course (Figure 1).

We analyzed the pre-test and post-test scores completed by recent students in the course (Figure 3). All students who passed the class had an increase in their score from the pre- to post-test, with the A students showing larger increases than the B students. None of the students who failed the course had an increase in pre/post, and most of them did not take the post-test. In addition, 54% of passing students had more than a 50% increase in their score from the pre-to the post-test, a significant growth in knowledge over the course of one semester. We can see that a majority of passing students experienced substantial growth in their organic chemistry knowledge, with only a few students experiencing less than 25% increase. This collective increase in performance on the summative post-test makes a compelling case for the efficacy of specifications-based grading.

We noticed that students who experienced less growth in their test score generally entered the course with significant prior knowledge of organic chemistry, as indicated by higher-than-average pre-scores. Since this is an entry-level course taken by all newly admitted students, a wide range of abilities and experience is represented by the data. Students with stronger organic chemistry backgrounds had less room to grow and accounted for most of the lower growth scores. Since this course's goal is to bring all students to a similar level of proficiency in organic chemistry, varying degrees of growth are expected between students with varying degrees of prior knowledge in organic chemistry.

We also noted the general trend that students who completed more objectives during the semester - earning a higher letter grade in the course - also scored higher on the post-test and experienced more growth. This is promising, as it shows the efficacy of specs grading for increased student absorption and retention of course material. We believe this data confirms that the increase in passing scores from the traditional points-based grading scheme to the specifications-based grading scheme is due to increased student knowledge of the course materials.

When looking at the raw grades on the post-test considering the growth data, we see a few additional trends that may be noteworthy

FIGURE 2
Grade comparison between traditional points-based grading system and specifications-based grading system in intermediate organic chemistry at the University of Saint Joseph. A and B are passing scores and C and D are not. Grade data included is from Fall 2019-Summer 2023. *N* = 183.

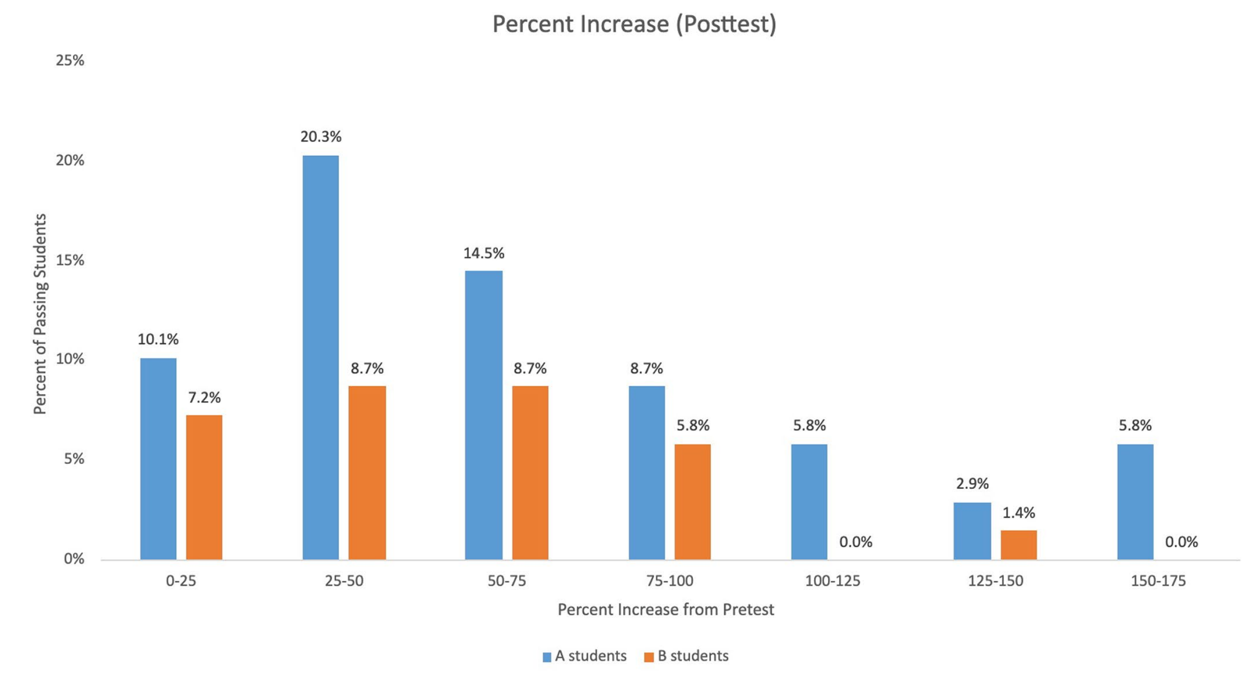

FIGURE 3
Increase in score from the pre-to the post-test for students with a passing grade in the course since the summer semester of 2021. *N* = 69.

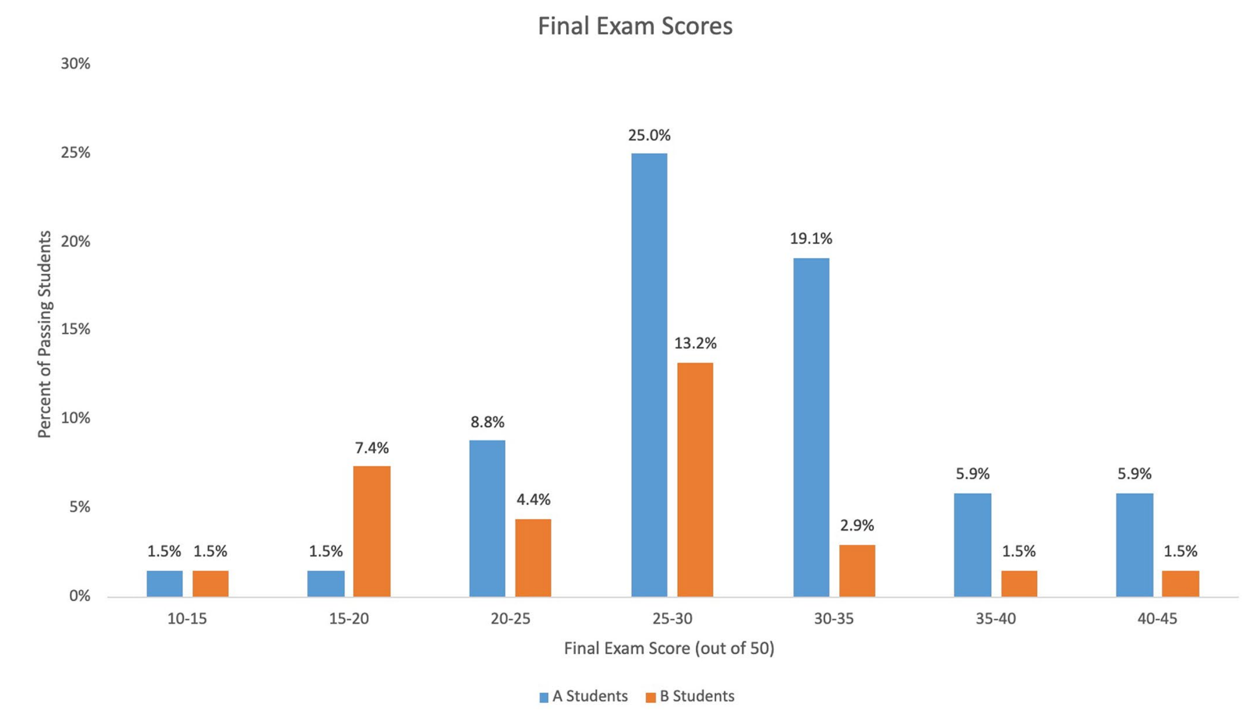

FIGURE 4
Post-test scores (out of 50) of students who passed the specifications-based style of the course. *N* = 69.

(Figure 4). Since students were required to complete a minimum of 5 EO modules and 2 of the 7 GO modules, passing students had to demonstrate proficiency in 54% of material covered in the course before taking the post-test. Since proficiency in an objective of this course is 80% accuracy, this means that passing students should have been able to answer a minimum of 43% of questions in the course correctly to earn the grade they received. As discussed above, 90% of passing students achieved this benchmark by answering a minimum of 22 questions correctly, with a vast majority scoring higher than that. The average score on the final was 29.125/50, 58.25%, which is the equivalent of a student achieving 80% proficiency on 9 course objectives. By this metric, student scores on the post-test are indicative of proficiency in organic chemistry.

It also should be noted that since many of these students did not take a long-form exam once during the course, the testing format of the post-test was likely unfamiliar to most participants. Additionally, since the post-test does not have much weight over the score a student earns in the class, it is possible that scores were lower due to a lack of motivation for students to adequately prepare for the test. Ultimately, the course was not designed with a focus on testing; it was focused on designing individual modules to maximize content exposure and retention. However, it is worth considering whether the delivery of the course or the thresholds for passing grades should be modified to improve the scores on the post-test.

5.2 Impressions

While data from the pre-and post-test provide a quantifiable indication of student learning, the numbers do not tell the whole story; student and instructor feedback reveal a more complete picture of the impact of specs grading on CHEM 510. To get feedback from students about their general impression of the course, an optional survey was offered during the week of midterm and final exams, which students could complete to earn an additional token for the course. Overall, student impressions were positive. The main strengths highlighted in these responses were centered around the multiple assessment options, reduced test anxiety, and the ability to improve upon previous mistakes in the learning process on the way to achieving proficiency.

While many students reported initial confusion about how final grades were distributed in the course, an overwhelming majority of students indicated that once the grading procedures were understood, they felt positively toward the specifications-based grading system. The most common comment made by students on the survey was the positive impact that multiple attempts and multiple assessment options had on the learning experience; students reported a greater sense of autonomy, reduced stress levels, and an enriched learning experience. When asked about the grading scheme, one student summarized a common sentiment: "It helps the student re-attempt the material no matter how low of a grade they achieved [on their first attempt]. It shows they need to brush up on a section they did not understand, [and builds confidence] down the road." (Response 37) Another student felt that they were "given the opportunity to actually learn the material without the pressure of trying once and failing" (Response 18) and appreciated the chance to review mistakes before attempting another assessment. These students asserted that the multiple attempts were essential to the reduced levels of stress they felt and added that they believed they learned more as a result.

In addition, several students had strong preferences for one method of assessment over another, with different students preferring each of the three assessment methods. One student wrote: "I feel much more comfortable with the tutorials because I can fully express in my own words what I think the goal of that module is." (Response 18) Another student preferred the instantaneous feedback offered by taking quizzes, writing "sometimes I would take the quiz feeling like I understood the concepts... but there was always feedback on the missed questions that [supported further learning]." (Response 24) Yet another student preferred exams because "the exams are structured in a way in which I am able to display a top-to-bottom understanding of the material." (Response 42) Each of these three students expressed preferences for different forms of assessment and felt positively that they had the freedom to choose the method that worked best for them. Though this is not a requirement of specifications-based grading, and is uncommon in chemistry courses, we believe that this is one of the greatest strengths of the specs grading scheme used in CHEM 510 and assert that it is an essential part to diversifying the learning experiences of the students.

When students' success and satisfaction are increased, a positive impression is left on the instructor as well, and many of the positive comments made by the instructor are identical to those made by the students. In addition, simplified grading processes in this specifications-based course benefited the instructor, who commented on the lack of ambiguity when grading quizzes, tutorials, and tests. Quizzes were automatically graded and provided instant feedback to students, reducing the amount of time the instructor spent grading and providing direct feedback to the student. Tests did not require additional time to grade, and the rubrics provided clear, unambiguous criteria for differentiating the student's level of proficiency. Even tutorials provide student work that – in our experience – usually provides a clear picture of a student's aptitude in the material, allowing for easy identification of proficiency. The instructor had previously felt frustrated that their feedback in traditional points-based courses was not looked at by the students but saw an increase in students accessing and applying the feedback in the specs-based system. Thus, the instructor could spend more time focused on giving feedback that would be used by students who would implement it.

The instructor appreciated the ways in which the course was designed to accommodate multiple learning styles from an instructional standpoint, as a wide variety of educational tools and resources were provided to the students. There were several passages from the textbook that students were expected to read, but the integration of lecture videos, instant chat features, and handwritten or electronic handouts allowed the instructor to generate a diverse learning experience for students. This diversity of instruction led to increased ways for students to engage with the material and contributed to the virtual classroom culture of inclusivity in assessment and instruction. However, providing a diversity of assessment and instructional methods is not without drawbacks: the initial design of the course was a considerable time commitment for the instructor, and grading multiple types of assignments submitted at inconsistent times throughout the week adds to the complexity of grading. In the semesters with more students (for example, 19 students in Fall 2022), the time spent on grading was increased and the instructor would not recommend exceeding the 20 student cap unless additional graders are used, or grading can be automated.

The instructor would also like to note that certain accommodations made in this class may not provide students the best chance to succeed in future classes taken later in the program, as no other course is graded in this way. The freedom offered to the students may come at a price: students who grow accustomed to this way of learning may not be prepared for the long discussion posts and high-stakes exams they will encounter in other courses later in their program. The token system added freedom for students to adjust their grade in a straightforward way but places the responsibility of processing token requests and adjusting due dates on the instructor and not the student. The autonomy experienced by students in this course is unique, as the flexibility and freedoms offered to students in future, traditional courses is significantly reduced.

6 Conclusion

Efforts to develop and implement sound grading practices continues to yield unique and promising alternatives to traditional points-based grading schemes. Specifications-based grading shows promise as a potential alternative that assigns student grades that reflect the student's understanding of content rather than effort given or points earned. We have found that in an online, asynchronous setting, specifications-based grading serves as a viable option for educators looking to improve student learning; our results show that specs grading courses can lead to improved assessment scores, targeted learning opportunities, and a more positive overall experience for students and instructors. We found that a critical piece in the success of specs grading is the opportunity for students to attempt assessment multiple times, and in our online asynchronous course, students found additional success by accessing multiple different assessment types, including short quizzes, long tests, and tutorial assessments. The positive impact that specs grading has had in CHEM 510 comes primarily from offering multiple types of assessment to students and providing multiple attempts to complete them. We would like to encourage other instructors considering specs grading for their online class structure to also consider including multiple assessment methods to reduce stress and increase learning opportunities for students, without adding excess time commitments to the instructor in the process.

7 Acknowledgment of any conceptual, methodological, environmental, or material constraints

Limitations to this report include the small sample size and the fact that the course design was being evaluated retroactively rather than prospectively. In addition, there was only one instructor implementing teaching this course and multiple minor changes were made each semester to improve the specs grading design.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: the datasets could be provided upon reasonable request. Requests to access these datasets should be directed to SZ, szingales@usj.edu.

Ethics statement

The studies involving humans were approved by the University of Saint Joseph Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because this was a retroactive study looking at data collected by the instructor for formative feedback and no identifying information was used.

Author contributions

CM: Writing – original draft, Writing – review & editing. SZ: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Atifnigar, H., Alokozay, W., and Takal, G. M. (2020). Students' perception of alternative assessment: a systematic literature review. *Int. J. Ling. Lit. Transl.* 3, 228–240.

Bangert-Drowns, R. L., Kulik, C. L. C., Kulik, J. A., and Morgan, M. T. (1991). The instructional effect of feedback in test-like events. *Rev. Educ. Res.* 61, 213–238. doi: 10.3102/00346543061002213

Block, J.H., and Airasian, P.W. (1971) *Mastery learning: theory and practice*. New York: Holt, Rinehart and Winston.

Bloom, B.S. (1968). *Learning for mastery. Instruction and curriculum. Regional education laboratory for the Carolinas and Virginia, topical papers and reprints, number 1*. Regional education Laboratory for the Carolinas and Virginia, mutual plaza (Chapel Hill and Duke Sts. 1, 1–12. Available at: https://eric.ed.gov/?id=ED053419 (Accessed: 28 January 2024).

Blum, S. (2020). *Ungrading: Why rating students undermines learning (and what to do instead)*. Morgantown, WV, USA: West Virginia University Press.

Boesdorfer, S. B., Baldwin, E., and Lieberum, K. A. (2018). Emphasizing learning: using standards-based grading in a large nonmajors' general chemistry survey course. *J. Chem. Educ.* 95, 1291–1300. doi: 10.1021/acs.jchemed.8b00251

Brookhart, S. M., Guskey, T. R., Bowers, A. J., McMillan, J. H., Smith, J. K., Smith, L. F., et al. (2016). A century of grading research: meaning and value in the most common educational measure. *Rev. Educ. Res.* 86, 803–848. doi: 10.3102/0034654316672069

Bunnell, B., LeBourgeois, L., Doble, J., Gute, B., and Wainman, J. W. (2023). Specifications-based grading facilitates student–instructor interactions in a flipped-format general chemistry ii course. *J. Chem. Educ.* 100, 4318–4326. doi: 10.1021/acs.jchemed.3c00473

Cain, J., Medina, M., Romanelli, F., and Persky, A. (2022). Deficiencies of traditional grading systems and recommendations for the future. *Am. J. Pharm. Educ.* 86:8850. doi: 10.5688/ajpe8850

Crucho, C. I. C., Avó, J., Diniz, A. M., and Gomes, M. J. S. (2020). Challenges in teaching organic chemistry remotely. *J. Chem. Educ.* 97, 3211–3216. doi: 10.1021/acs.jchemed.0c00693

Curley, B., and Downey, J. (2023). Implementation of alternative grading methods in a mathematical statistics course. *J. Stat. Data Sci. Educ.*, 1–11. doi: 10.1080/26939169.2023.2249956

Danielewicz, J., and Elbow, P. (2009). A unilateral grading contract to improve learning and teaching. *Coll. Compos. Commun.* 61, 244–268. doi: 10.58680/ccc20099471

Diegelman-Parente, A. (2011). The use of mastery learning with competency-based grading in an organic chemistry course. *J. Coll. Sci. Teach.* 40, 50–58. doi: 10.2505/3/jcst11_040_05&print=true

Donato, J. J., and Marsh, T. C. (2023). Specifications grading is an effective approach to teaching biochemistry. *J. Microbiol. Biol. Educ.*, e00236–e00222. doi: 10.1128/jmbe.00236-22

Guskey, T. R. (2001). 'Helping Standards Make the Grade', *ASCD*, 59. Available at: https://www.ascd.org/el/articles/helping-standards-make-the-grade.

Herman, J.L. (1992) *A practical guide to alternative assessment*. Association for Supervision and Curriculum Development, 1250 N: 1–98. Available at: https://eric.ed.gov/?id=ED352389 (Accessed January 28, 2024).

Hiller, T. B., and Hietapelto, A. B. (2001). Contract grading: encouraging commitment to the learning process through voice in the evaluation process. *J. Manag. Educ.* 25, 660–684. doi: 10.1177/105256290102500605

Houseknecht, J. B., and Bates, L. K. (2020). Transition to remote instruction using hybrid just-in-time teaching, collaborative learning, and specifications grading for organic chemistry 2. *J. Chem. Educ.* 97, 3230–3234. doi: 10.1021/acs.jchemed.0c00749

Howitz, W. J., Frey, T., Saluga, S. J., Nguyen, M., Denaro, K., and Edwards, K. D. (2023). A specifications-graded, sports drink-themed general chemistry laboratory course using an argument-driven inquiry approach. *J. Chem. Educ.* 100, 672–680. doi: 10.1021/acs.jchemed.2c00860

Howitz, W. J., McKnelly, K. J., and Link, R. D. (2021). Developing and implementing a specifications grading system in an organic chemistry laboratory course. *J. Chem. Educ.* 98, 385–394. doi: 10.1021/acs.jchemed.0c00450

Iamarino, D. L. (2014). The benefits of standards-based grading: a critical evaluation of modern grading practices. *Curr. Iss. Educ.* 17, 1–12. Available at: http://cie.asu.edu/ojs/index.php/cieatasu/article/view/1234

Johnstone, A. H. (2010). You can't get there from here. *J. Chem. Educ.* 87, 22–29. doi: 10.1021/ed800026d

Kishbaugh, T.L.S., and Cessna, S.G. (eds) (2018) *Increasing retention of under-represented students in stem through affective and cognitive interventions*. Washington, DC: American Chemical Society (ACS Symposium Series).

Lindemann, D. F., and Harbke, C. R. (2011). Use of contract grading to improve grades among college freshmen in introductory psychology. *SAGE Open* 1:215824401143410. doi: 10.1177/2158244011434103

Marzano, R.J. (2010) *Formative assessment & standards-based grading*. Bloomington, IN: Marzano Research Laboratory.

Masland, L. C. (2023). Ungrading: the joys of doing everything wrong. *Zeal: A Journal for the Liberal Arts.* 1, 88–93.

McKnelly, K. J., Howitz, W. J., Thane, T. A., and Link, R. D. (2023). Specifications grading at scale: improved letter grades and grading-related interactions in a course with over 1,000 students. *J. Chem. Educ.* 100, 3179–3193. doi: 10.1021/acs.jchemed.2c00740

McKnelly, K. J., Morris, M. A., and Mang, S. A. (2021). Redesigning a "writing for chemists" course using specifications grading. *J. Chem. Educ.* 98, 1201–1207. doi: 10.1021/acs.jchemed.0c00859

Nilson, L.B., and Stanny, C.J. (2023) *Specifications grading: Restoring rigor, motivating students, and saving faculty time*. (*1st Edn.*). New York: Routledge.

Noell, S. L., Rios Buza, M., Roth, E. B., Young, J. L., and Drummond, M. J. (2023). A bridge to specifications grading in second semester general chemistry. *J. Chem. Educ.* 100, 2159–2165. doi: 10.1021/acs.jchemed.2c00731

O'Connor, K. (2002). *How to grade for learning: linking grades to standards*. (*2nd Edn.*). SkyLight professional development, 2626 South Clearbrook drive, Arlington Heights, IL.

Peters, R., and Buckmiller, T. (2014). Our grades were broken: overcoming barriers and challenges to implementing standards-based grading. *J Educ.Lead. Action* 2, 1–26. doi: 10.62608/2164-1102.1070

Ring, J. (2017). Confchem conference on select 2016 BCCE presentations: specifications grading in the flipped organic classroom. *J. Chem. Educ.* 94, 2005–2006. doi: 10.1021/acs.jchemed.6b01000

Schneider, J., and Hutt, E. (2014). Making the grade: a history of the A–F marking scheme. *J. Curric. Stud.* 46, 201–224. doi: 10.1080/00220272.2013.790480

Stommel, J. (2023) *Undoing the grade: Why we grade, and how to stop*. Denver, CO: Hybrid Pedagogy.

Sunasee, R. (2020). Challenges of teaching organic chemistry during covid-19 pandemic at a primarily undergraduate institution. *J. Chem. Educ.* 97, 3176–3181. doi: 10.1021/acs.jchemed.0c00542

Taylor, H. (1980). *Contract grading*. ERIC clearinghouse on tests, measurement, and evaluation, Educational Testing Service, Princeton, NJ. 1–28.

Townsley, M. (2014). 'What is the Difference between Standards-Based Grading (or Reporting) and Competency-Based Education?', *Competency Works Blog*, 11 November. Available at: https://aurora-institute.org/cw_post/what-is-the-difference-between-standards-based-grading/ (Accessed January 28, 2024).