Redesigning a “Writing for Chemists” Course Using Specifications Grading

Kate J. McKnelly, Michael A. Morris, Stephen A. Mang*

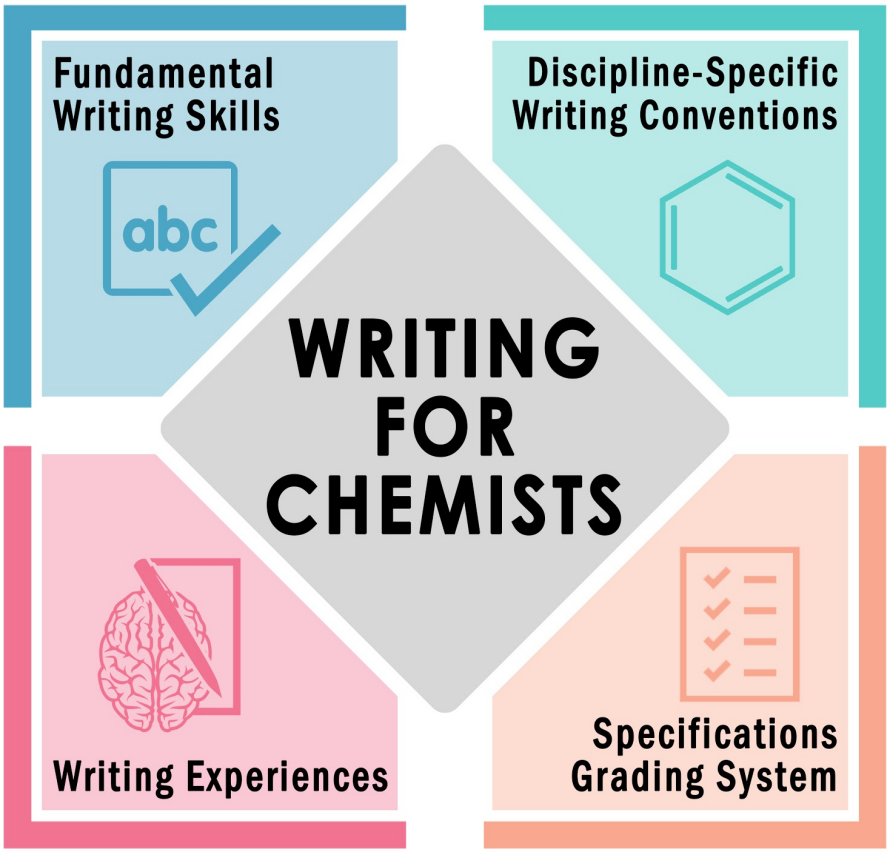
Department of Chemistry, University of California, Irvine,

Irvine, CA 92697, United States

ABSTRACT

The Department of Chemistry at the University of California, Irvine (UCI) instituted an upper-division “Writing for Chemists” course in fall 2017 that fulfills part of UCI’s writing graduation requirement. During the 2019-2020 school year, we re-designed the course using a specifications grading system with the following goals: 1) to teach students how to develop their own writing practice, while mastering chemistry discipline-specific writing conventions, 2) to provide students with frequent and constructive instructor and teaching assistant (TA) feedback by providing ample revision opportunities, 3) to increase transparency in how students can achieve course SLOs, and 4) to provide students with consistent and clear assessment rubrics. This specifications grading approach uses a high-pass, low-pass, unsatisfactory system predicated on whether students meet a certain number of criteria for each assignment. Achievement of Student Learning Outcomes (SLOs) was assessed using criteria instead of points so that instructors and students could more objectively measure student learning. Standardized rubrics and a student grade tracker helped students understand the relationship between meeting criteria, achieving SLOs, and earning grades. Students completed surveys at the end of the course to determine if their writing habits and attitudes towards writing changed. After the course, students self-reported increased propensities to pre-write and edit, and several students mentioned that they appreciated the transparency of the specifications rubrics and the control the specifications system gave them over their grades.

Graphical Abstract



Keywords
Upper-Division Undergraduate, Curriculum, Communication/Writing, Testing/Assessment, Student-Centered Learning

INTRODUCTION

The question of how to improve the communication skills of chemistry students is not new and has been noted as early as 1943.[1] Specific writing challenges faced by chemistry students include using discipline-specific language, structuring lab reports correctly, searching and reading the chemical literature, and identifying the appropriate audience for lab reports and other writing assignments.[2–12] Instructors have incorporated various teaching strategies to address these challenges, such as incorporating student peer reviews, using journal articles to improve student writing, focusing on reflective writing rather than traditional laboratory

reports, and teaching writing through inquiry.[13–19] Some teaching strategies involve combining English language education with STEM courses to help students improve their use of discipline-specific language, presentation of arguments and data, and an appropriate writing style.[4,20] The variety of writing challenges faced by students in chemistry courses suggests that chemistry programs should include dedicated upper-division writing courses that blend elements of composition and technical writing courses.

At the University of California, Irvine (UCI), students have the option to complete upper-division writing instruction in their major field of study as part of a campus-wide Writing Across the Curriculum model.[21,22] In the fall of 2017, the Department of Chemistry at UCI created an upper-division writing course (Chemistry 101W, "Writing for Chemists") to allow students in the chemistry major to fulfill the university's upper-division writing requirement in their home department. The goals of the course were to introduce students to the discipline-specific writing conventions used in chemistry and to train students in searching, reading, and citing the chemical literature.

The first two offerings of Chemistry 101W focused on developing writing skills that could be applied to any writing task a chemist might encounter, from preparing a CV to writing the introduction section of a journal article. These skills included, but were not limited to: communicating results with writing and figures, writing proper sentences and paragraphs, and supporting arguments with evidence. These writing skills are immediately useful to our students as they move into more writing-intensive upper division chemistry courses, like labs, and are necessary for a variety of future careers, such as those in academia, industry, and science communication.

Chemistry majors beginning their upper-division studies are often several years removed from their most recent lower-division writing course. The writing preparation that undergraduates received prior to enrolling in our course provided them with a foundational knowledge of writing, but the students did not seem prepared for the conventions and styles relevant to the chemistry discipline. In addition, any training in chemistry writing that students had received was in lower-division laboratory courses. During the first two offerings of

Chemistry 101W, the majority of our students did not make connections between the writing skills they had learned in their lower-division writing courses and the writing experiences they were having in our course. Many students struggled to communicate discipline-specific material, in part because they were not demonstrating mastery of fundamental writing skills — such as using correct standard English grammar, writing with the audience in mind, and transitioning clearly between sentences and paragraphs — or they did not connect those skills as transferable from their previous writing experiences to the upper-division chemistry writing course.[23]

Students entering an upper-division chemistry writing course are asked to learn discipline-specific conventions, to connect these new skills to their prior knowledge, and to consider how their writing will be understood by an audience. Students who are trying to hone their fundamental writing skills while attempting to adjust to academic writing will have multiple demands — such as recalling prior knowledge, learning new conventions, and generating new ideas — placed on their working memory.[24] This situation leaves students susceptible to cognitive overload and potentially reduces the quality of work of which they are capable.[24–26] Additionally, students struggle to transfer writing skills between different courses, especially if they cannot recognize that writing tasks in discipline-specific courses require knowledge they acquired in their first-year composition courses.[23,27–30]

In fall 2019 we created a new version of Chemistry 101W that was designed to reinforce writing skills and practices while introducing discipline-specific writing conventions, and we have now offered the new course twice. The course was redesigned within the framework of the following course goals:

1. Teach students how to develop their own writing practice, while mastering chemistry discipline-specific writing conventions.
2. Provide students with frequent and constructive instructor and teaching assistant (TA) feedback by providing ample revision opportunities.

3. Increase transparency in how students can achieve course Student Learning Outcomes (SLOs).
4. Provide students with consistent and clear assessment rubrics.

We redesigned Chemistry 101W to emphasize writing skills and practices in the course curricula and to facilitate student revision opportunities and achievement of SLOs. We adapted assignments from a textbook on the practice of nonfiction writing,[31] and we designed rubrics using a specifications grading system. Specifications grading has been used in writing-intensive courses in disciplines ranging from political science to mathematics.[32–39] Specifications grading has also been used in lower-division chemistry courses,[40,41] but to our knowledge, this is the first example of an upper-division chemistry writing course organized with a specifications grading sytem. Students were surveyed at the end of the course to determine their opinions on the practice of writing and the specifications grading system. Students' free-response comments revealed emerging trends regarding students' writing practices.

COURSE DESIGN

To refocus Chemistry 101W on general writing skills and chemistry writing conventions, we designed the course using a guidebook on nonfiction writing, *The Writer's Practice: Building Confidence in Your Nonfiction Writing*.[31] The writing experiences from the guidebook were adapted to focus more on general science and chemistry-specific topics. We also created new assignments that encouraged students to connect academic and discipline-specific writing.

To clarify the SLOs associated with each assignment, we used a specifications grading system for assessment. Specifications grading is a modern approach to assess student achievement of SLOs.[32] In a specifications grading system, the instructor develops a set of criteria based on SLOs that students must meet to achieve a specific grade in the course. The specifications grading rubrics are designed to be more transparent and less subjective than a traditional points-based rubric. The criteria that students must meet informs them not only on what they are being evaluated, but also where they need to improve to achieve the SLOs for a

given assignment. In addition, grading with a specifications rubric should be faster and more consistent between instructors, allowing more instructor feedback and student revision opportunities to be offered over the course of an academic term.[8] This grading system addresses our second course goal: to provide students with frequent and constructive instructor and TA feedback by giving ample revision opportunities.

On each assignment, students could earn a high-pass, low-pass, or unsatisfactory assessment by meeting a defined set of criteria. The criteria were based on the SLOs for a given assignment, but were often similar to criteria for other assignments. The rubrics were kept similar from assignment to assignment, which helped students acclimate to the new grading system. Using criteria instead of points to assess student achievement of SLOs enabled students and instructors to measure student learning. Students had access to standardized rubrics and a student grade tracker to clarify the relationship between meeting criteria and earning final course grades (see the Supporting Information for the student grade tracker).

Student Learning Outcomes for Chemistry 101W

For a course at UCI to fulfill the upper-division writing requirement, it must meet several guidelines.[22] Students who complete the course must demonstrate proficiency in discipline-specific research methods, genres, and formal conventions. Students must develop information literacy skills appropriate to the discipline, and they must produce a final work of revised writing for an appropriate audience (academic, public, or professional). Guided by these expectations, the original version of Chemistry 101W was designed to align with the SLOs shown in Table 1. These SLOs did not change during the redesign of Chemistry 101W. The redesigned course was organized with the modules of Professional Skills, Engaging with the Chemical Literature, Writing Mechanics, Scientific Ethics, and Presentations on the course learning management system (LMS) to align with the SLOs (Table 1).

Table 1. Course modules and associated SLOs

Course Student Learning Outcomes After successful completion of this course, students will be able to: 1. Create professional papers, proposals, reports, and other forms of scientific writing. 2. Efficiently search the chemical literature and other sources relevant to chemistry researchers. 3. Communicate the results of experiments and the meaning of data in both written and oral formats.	
Course Modules	**Associated SLOs**
Professional Skills	1, 2
Engaging with the Chemical Literature	1, 2
Writing Mechanics	1, 3
Scientific Ethics	1, 2, 3
Presentations	2, 3

Specifications Grading System

The goals of Chemistry 101W are to train students in the practice of writing in the chemistry discipline, to provide students feedback and revision opportunities, to have transparent SLOs, and to provide consistent and clear assessment rubrics. To align course assessment with these goals, we designed discrete assessment categories (Table 2). Small writing assignments (less than 500 words) and "complete or incomplete" assignments are included as formative assessments to provide students with lower-stakes writing practice and opportunities for feedback. Large writing assignments are designed as summative assessments to determine students' abilities to synthesize their knowledge into the following pieces of writing: a cover letter to accompany a job or graduate school application, an essay on scientific ethics, and journal-style experimental and introduction sections that follow the *ACS Style Guide*. These large writing assignments comprise 1000 words minimum, as the writing program at UCI requires that students submit 4000 words of edited writing. Reading helps students improve as writers,[42–45] so reading and reflection assignments were also included as a formative assessment category. Lecture and presentation participation categories are tracked to incentivize student engagement because most class meetings include discussion and group

work, which only benefit students if they attend class and participate. Presentations and the final presentation are included as formative and summative assessment categories to train students not only in written communication, but also in oral communication and active listening. Table 2 shows the total number of high- or low-passes students must earn in each evaluation category to achieve a specific final letter grade in the course.

Table 2. Course letter grade requirements for each assessment category

Assessment Category	Criteria Met to Earn Letter Grade			
	A	**B**	**C**	**D**
Small Writing Assignments (19 total)	17 high-pass + no unsatisfactory	14 high-pass OR 13 high-pass + 4 low-pass	11 high-pass OR 15 low-pass	< 11 high-pass OR 15 low-pass
Large (1000-Word) Writing Assignments (4 total)	3 high-pass + 1 low-pass	4 low-pass	3 low-pass	< 3 low-pass (no high-pass)
Readings & Reflections (17 total)	16 complete	15 complete	13 complete	<13 complete
Complete/ Incomplete Assignments (17 total)	15 complete	13 complete	12 complete	<12 complete
Presentations (5 total)	4 high-pass	2 high-pass + 2 low-pass	4 low-pass	<4 low-pass
Presentation Participation	4 satisfactory	4 satisfactory	3 satisfactory	<3 satisfactory
Lecture Participation	5 complete	4 complete	2 complete	<2 complete
Final Paper	high-pass	low-pass	not required	not required

Students were provided with the criteria they had to meet to earn a given course letter grade, including plus and minus grades (see the Supporting Information for the full student grade tracker). For simplicity, Table 2 only shows whole letter grades. To earn a specific letter grade, students must pass each evaluation category at a defined threshold. Categories include formative and summative assessments we deem necessary for the students to achieve course

SLOs; the participation categories are the only evaluation categories that do not fall under formative or summative assessment types.

To provide additional opportunities to revise and resubmit writing assignments and to give students flexibility and increased agency over their learning, we implemented an intangible token economy for the course.[32,46] Each student began the course with three tokens. Students could earn additional tokens by filling out surveys, revising and resubmitting several of the small writing assignments, or keeping a reading log of chemistry journal articles. Students could redeem tokens for an opportunity to submit an assignment late, to resubmit a revised assignment, or to replace a low-pass assessment with a high-pass. A full list of the token trade-in rules is included in the Supporting Information. Every student in both offerings of the course used at least some tokens to improve their grades or offset late penalties. We managed the token economy using the Assignments feature in the course LMS. Token balances were updated directly in the gradebook, which resulted in minimal management time required from the instructor and course TA.

Specifications Grading Rubric Design

The new specifications grading rubrics, like the course grading system, were designed to align with the course goals and SLOs, particularly the third course goal: to increase transparency in how students can achieve course SLOs. Two template rubrics — one for small writing assignments and one for large writing assignments — were constructed to provide a consistent grading system for students (Table 3) and to address the fourth course goal: to provide students with consistent and clear assessment rubrics. These templates were used for the majority of course assignments and were adjusted as needed to better assess assignments for which learning outcomes did not fit well in either template, such as presentation rubrics (see Supporting Information for examples of alternative rubrics). Each template was divided into three main categories — Sentence Level, Paragraph Level, and Assignment Level criteria — that were common to all assignments.

Table 3. Specifications grading rubrics for small and large writing assignments

Small Writing Assignment Rubric Criteria	Met	Not Met	**Large Writing Assignment Rubric Criteria**	Met	Not Met
Sentence Level: The writing is grammatically correct according to the rules of Standard Edited Written English.	▢	▢	Sentence Level: The writing is grammatically correct according to the rules of Standard Edited Written English.	▢	▢
Sentence Level: Words are spelled and used correctly.	▢	▢	Sentence Level: Words are spelled and used correctly.	▢	▢
Sentence Level: Sentences are constructed correctly according to the rules of Standard Edited Written English.	▢	▢	Sentence Level: Sentences are constructed correctly according to the rules of Standard Edited Written English.	▢	▢
Paragraph Level: Each paragraph has a clear and coherent topic sentence.	▢	▢	Paragraph Level: Each paragraph has a clear and coherent topic sentence.	▢	▢
Paragraph Level: Each paragraph has one clear and coherent main idea that relates to the thesis of the piece of writing.	▢	▢	Paragraph Level: Each paragraph has one clear and coherent main idea that relates to the thesis of the piece of writing.	▢	▢
Assignment Level: The writer clearly addresses the intended audience.	▢	▢	Paragraph Level: The order and flow of paragraphs is clear and logical.	▢	▢
Assignment Level: The author adequately responds to all parts of the assignment.	▢	▢	Assignment Level: The writer clearly addresses the intended audience.	▢	▢
			Assignment Level: The thesis of the work is supported by the rest of the paper.	▢	▢
			Assignment Level: The writer clearly supports all assertions with evidence.	▢	▢
			Assignment Level: The writer has constructed a consistent and coherent narrative.	▢	▢
High-Pass: 6/7 **Low-Pass: 5/7** **Unsatisfactory: ≤ 4/7**			**High-Pass: 8/10** **Low-Pass: 6/10** **Unsatisfactory: ≤ 5/10**		

The specifications grading rubrics display the number of criteria students must meet to achieve a high-pass, low-pass or unsatisfactory on each assignment; the numbers vary by rubric type (Table 3). For small writing assignments, the last criteria, “the author adequately responds to all parts of the assignment,” is used to assess whether students address all

specific goals of individual assignments. Those specific goals are described in each assignment prompt on the course LMS (all prompts given to students in our course can be found in the Supporting Information). Large writing assignments are assessed with more criteria as they have more learning objectives associated with them and students must go through a process of revision and resubmission when completing them. The first drafts are ungraded and receive extensive comments on writing for an appropriate audience, paragraph organization, and thesis continuity and unity throughout the piece of writing.[47] The final drafts are graded using the large writing assignment rubric.

Assignment Design

Most of the small writing assignments were adapted from writing experiences in John Warner's *The Writer's Practice*.[31] Warner designed his book as a guide to practice the art of writing, with particular emphasis on purpose and target audience. Chemistry students can benefit from developing their own writing practice with these emphases, as communicators of science must consider their purpose and audience carefully to write a coherent, logical, and engaging piece.[27,48] Warner's method of thinking about writing also agrees with UCI's guidelines for an upper-division writing course, and addresses the frequently observed difficulty that undergraduate students have when structuring a chemistry paper and identifying the appropriate audience.[2–12]

In *The Writer's Practice*, each writing experience is generally divided into a series of steps (*Audience*, *Process*, *Reflect*, and *Remix*) to teach students the cognitive and practical steps they must take when writing for any genre or discipline. In Chemistry 101W, using these writing experiences as templates for our assignments allows us to emphasize the importance of a writing process where students plan, draft, revise, edit, polish, and reflect on their own writing. The writing experiences in the guidebook were not specific to scientific writing, so they were adapted to focus on scientific and chemistry topics. Scaffolding course assignments so that students have to perform a series of P*rocess* steps in each small writing assignment addresses our first course goal: to teach students how to develop their own writing practice, while mastering chemistry discipline-specific writing conventions.

Assignment Design Example

The adapted writing experiences meet the course SLOs for Chemistry 101W because they represent chemistry-specific and professional development writing tasks. The required changes to the writing experiences in *The Writer's Practice* were minimal (Tables 4, S2-S5). In the example described below, the guidebook "How do I…?" writing experience was adapted to guide students through writing an experimental section of a laboratory report or journal article. In the adapted assignment, students were asked to describe important experimental details and to consider audience expectations (SLOs 1 and 3, Table 1). This assignment also required students to briefly search the scientific literature to find examples of how other authors have accomplished the same, or a similar, writing task (SLO 2, Table 1). Students received feedback on their adapted assignment from the specifications grading rubrics (Table 3) completed by the instructor.

Table 4. Adapting the Process steps of *The Writer's Practice* "How Do I…?" writing experience for a chemistry writing assignment

Writing Experience Process Step	Guidelines from *The Writer's Practice*	Adapted Assignment Guidelines used in Chemistry 101W*
1. Select Subject	What one skill do you think best lends itself to this particular writing-related problem? Why have you chosen that skill?	Same questions, with the stipulation that students had to write about a chemistry experiment.
2. Plan	A good way of preparing to write the solution to this writing-related problem is to do the action itself while taking careful notes along the way.	Students do not submit a response for this step, but they are prompted to think about it.
3. Audience Analysis	Who is your audience? What might their attitudes be toward this task? What is their background knowledge, and what background knowledge is required?	Same questions.
4. Find and Analyze Models	Look for models that serve similar purposes. Stay away from ones too closely related to your own task to prevent unintentional copying. How are these models formatted and structured? How do they begin? How is the information conveyed?	Same questions; in addition, students must provide at least one citation to a peer-reviewed journal article that works as a model.
5. Draft	Doing your best to meet your audience's needs, draft your document.	Instead of a full draft, students write a detailed outline of their experimental procedure.

*Our purpose for adapting this exercise was to help students start thinking about how to craft an experimental section that they would include in a thesis or journal article.

In the unmodified "How do I…?" writing experience, the student is first asked to consider the background of the *Audience*, to identify what the audience wants to know, and to determine how to best communicate with that audience. For the adapted writing assignment, our students were given a prompt that specified that their audience would be peers in their chemistry courses. In the adapted assignment, the students were then introduced to the *Process* of writing their instructions (steps 2-4 in Table 4). As part of the *Process* step, the students were advised to read examples of experimental procedures and to create a draft of their procedure. They wrote and formatted their experimental procedure using technical conventions described in the *ACS Style Guide*.[49] The final steps of the *Process* for the adapted assignment prompt the students to revise their draft based on feedback received through peer editing, and then to polish the edited draft to eliminate remaining errors.

When our students submitted their final draft of the adapted "How do I…?" assignment, they also described how they completed each *Process* step (Table 4). Note that the third step in the *Process* asks students to analyze the background and motivations of their audience; this is complementary to the *Audience* step that students had already completed. In the last two steps of the original writing experience, Warner asks the students to *Reflect* on their writing, and to *Remix* it by, for example, adapting it for another medium such as social media. In our assignment, students did not *Remix* their submission. Students were instructed to *Reflect* on their "How do I…?" assignment submissions when working on the Experimental section large writing assignment. The specifications rubric (Table 3) was available to students throughout the process, prompting them to think about eliminating grammatical errors and to determine whether they had addressed their audience properly, structured their paragraphs correctly, and addressed other items specified in the rubric.

STUDENT PERCEPTIONS AND LESSONS LEARNED

The specifications grading system has been used in two course offerings of Chemistry 101W, in fall 2019 (taught by K.J.M.) and winter 2020 (taught by M.A.M.). To determine students' perceptions about the practice of writing in a course with a specifications grading system, students were surveyed after the course concluded with open-ended questions (see the Supporting Information for the survey questions). Collection of student survey data was approved by UCI's Institutional Review Board (HS#2018-4211, e-Mod# 25389). Between the two course offerings, 19 out of 34 students responded to the survey. Comments from the free response questions allowed us to identify trends in students' opinions about the structure of the course and the specifications grading system (Table 5). The results from our survey do not imply improved student writing proficiency; they are included here to demonstrate only how the students felt about the new course.

Table 5. Trends from student feedback to free-response survey questions

Positive Responses	Concerns
Final grade expectations were clear and specific, students knew what to do to earn the grade they wanted	System is nerve-wracking because it is easy to be dropped a grade-level
Grading helped students identify how to improve their writing	Passing thresholds set too high
Having the opportunity to submit multiple drafts was helpful	Grading system does not adequately reward effort / time spent
Found token system helpful	

Students reported favoring the specifications grading system in general. Many of them commented that the specifications grading system made them more aware of the course expectations (Table 5) — one of our original motivations for using specifications grading. Another goal of the course redesign was to encourage students to revise and edit their writing, and most of our students reported that they found the revision process useful. Students were required to revise and resubmit all four of the large writing assignments, and they could earn tokens by polishing and resubmitting several small writing assignments. They could also redeem their tokens to resubmit other small writing assignments to improve a low-pass or unsatisfactory assessment. Feedback was provided at each step using the specifications grading rubrics and written comments in the course LMS. Peer feedback was also available from the peer review portion of the course. Students reported that the course helped them develop their writing skills because they could edit, polish, and resubmit multiple drafts of their assignments. All student comments can be seen in the Supporting Information.

While many student comments favored the specifications grading system, some common student concerns also emerged (Table 5). Students indicated that the system was stressful because of the ease with which their course letter grades could drop when they received either a low-pass or unsatisfactory assessment. Many students expressed concern that a single unsatisfactory or low-pass could lower their grade. These concerns apply to points-based

grading systems as well. Students also felt that passing thresholds were set too high and that the grading system did not adequately reward student effort and time spent on assignments. While effort is important to a student's success in any course, objectively measuring effort is challenging in any grading system. These comments reinforce the importance of ensuring student buy-in for any grading system or token economy that is unfamiliar to them.

Some students who voiced concerns about the grading system also reflected that the course improved their confidence in their writing ability, which has been reported in another writing course using specifications grading.[35] One student commented, "I personally dislike this grading method but I admit that it forces me to improve my writing skills." Student discomfort with unfamiliar educational strategies has been noted in courses that use active learning, where students report disliking the course structure despite learning more effectively.[50]

The instructors' perceptions about the effectiveness of the specifications grading system mirrored those of the students who saw improvement in their writing ability. Throughout each course offering, we observed noticeable improvements in student performance on each of the course SLOs (Table 1). Our impression is that students were more likely to turn in papers that demonstrated mastery of standard written English grammar, spelling, sentence structure, and paragraph construction, although we have not yet attempted to quantify this. We also observed that students were more mindful about their audience and the purpose behind each piece of writing.

The specifications grading system had advantages for the instructors as well as for the students. The specifications grading rubrics allowed us to keep grading time similar to prior non-specifications grading courses, while offering students more opportunities for revision. Grading with the specifications rubric is more efficient because there is no need to decide among levels of partial credit, as when using points-based rubrics.[32] The student responses and our observations suggest that the increased feedback and clearer grading criteria of specifications grading rubrics help students improve their writing skills, understand chemistry writing conventions, and develop a personal writing process.

Our students indicated that they were new to a specifications grading system and had trouble grasping how to track their grades. Some organic chemistry laboratory courses in our department use a specifications grading system but none that our students would have taken prior to our course.[41] At first, our students struggled to calculate their anticipated course grade based on work they had already completed, possibly because of their unfamiliarity with the grading scheme. To alleviate confusion, we spent lecture time helping students use the student grade tracker to calculate their anticipated final grade at different times during the quarter. An additional challenge we did not anticipate was that our LMS was not designed for specifications grading. In future course offerings, we plan to teach students how to use the student grade tracker earlier in the quarter to reduce confusion over final grade calculations.

While we plan to continue using this course format for future offerings of Chemistry 101W, we recognize a potential issue with the specifications rubric as it impacts non-native English speakers, namely the all-or-nothing nature of the criteria for edited standard written English. In practice, we allowed for a small number of editing mistakes, so that students could focus on the structure and content of their writing rather than putting all of their effort into finding grammatical errors.[51] We will explicitly modify the rubrics to reflect this grading practice in the future. Presentation rubrics will also be modified to focus on the professionalism, not the grammatical correctness, of spoken English.

We have also considered the possibility of adapting the course for remote delivery, as the COVID-19 pandemic has made remote instruction a current necessity. The redesign of the course did not involve any course features that must be done in-person, which makes the course compatible with remote delivery. Lectures mainly used active learning teaching strategies with minimal lecture time, so asynchronous videos could be developed with little difficulty. Since assignment feedback is given with rubrics and written comments on the course LMS, most aspects of the redesigned course will be easily delivered online. Additionally, peer review sessions can be accomplished using video conferencing software with shared electronic

documents. We anticipate that the SLOs and course goals are achievable if the course must be delivered remotely.

CONCLUSION AND FUTURE DIRECTIONS

We redesigned an upper-division "Writing for Chemists" course to focus on developing student writing skills and practices in addition to chemistry discipline-specific writing conventions. We designed a specifications grading system and adapted writing experiences from *The Writer's Practice* to provide students with a process by which they could hone their chemistry writing skills. Students were able to practice and refine their writing through multiple rounds of instructor and TA feedback and assignment resubmission. Student responses to survey questions indicated that they thought the course was transparent about how students could earn specific grades and meet the course SLOs, and that the grading rubrics were consistent and fair.

Specifications grading proved particularly useful for grading student writing. Beyond grading standard written English and grammar conventions, assessing writing quality can be subjective. Using standardized specifications grading rubrics made it possible to assess student writing with increased consistency and hopefully objectivity. The amount of time dedicated to grading did not significantly increase despite offering students more opportunities for revision and resubmission. We believe specifications grading rubrics would be useful in other chemistry writing-focused courses, such as those which have many laboratory reports. Despite our impressions that student writing improved as a result of the redesigned course, we do not include any quantitative analysis of their perceived improvement. In the future, we plan to investigate if the quality of student writing improved as a result of the redesigned course structure.

Acknowledgments

We thank Renée Link for her discussions on specifications grading and Hayley Glicker for her teaching assistance with Chemistry 101W during winter 2020. We also thank Sergey

Nizkorodov for help with developing the original version of Chemistry 101W and Denise Bui for help in designing a TOC graphic.

REFERENCES

(1) Wall, F. E. The Importance of Technical Writing in Chemical Education. *J. Chem. Educ.* **1943**, *20* (12), 580.
(2) Pyle, J. L.; Trammell, G. L. Contemporary Chemical Essays: Dealing with the Writing Problem in a Freshman Chemistry Course. *J. Chem. Educ.* **1982**, *59* (11), 959.
(3) Steiner, R. Chemistry and the Written Word. *J. Chem. Educ.* **1982**, *59* (12), 1044.
(4) Bailey, D. N.; Markowicz, L. Chemistry and English: A New Bond. *J. Chem. Educ.* **1983**, *60* (6), 467.
(5) Rosenthal, L. C. Writing across the Curriculum: Chemistry Lab Reports. *J. Chem. Educ.* **1987**, *64* (12), 996.
(6) Sherwood, D. W.; Kovac, J. Writing in Chemistry: An Effective Learning Tool. *J. Chem. Educ.* **1999**, *76* (10), 1399.
(7) Wallner, A. S.; Latosi-Sawin, E. Technical Writing and Communication in a Senior-Level Seminar. *J. Chem. Educ.* **1999**, *76* (10), 1404.
(8) Schepmann, H. G.; Hughes, L. A. Chemical Research Writing: A Preparatory Course for Student Capstone Research. *J. Chem. Educ.* **2006**, *83* (7), 1024.
(9) Alaimo, P. J.; Bean, J. C.; Langenhan, J. M.; Nichols, L. Eliminating Lab Reports: A Rhetorical Approach for Teaching the Scientific Paper in Sophomore Organic Chemistry. *WAC J* **2009**, *20*, 17–32.
(10) Carr, J. M. Using a Collaborative Critiquing Technique to Develop Chemistry Students' Technical Writing Skills. *J. Chem. Educ.* **2013**, *90* (6), 751–754.
(11) Van Bramer, S. E.; Bastin, L. D. Using a Progressive Paper to Develop Students' Writing Skills. *J. Chem. Educ.* **2013**, *90* (6), 745–750.
(12) Wackerly, J. W. Stepwise Approach To Writing Journal-Style Lab Reports in the Organic Chemistry Course Sequence. *J. Chem. Educ.* **2018**, *95* (1), 76–83.
(13) Beall, H. Expanding the Scope of Writing in Chemical Education. *J. Sci. Educ. Technol.* **1998**, *7* (3), 259–270.
(14) Hunter, A. D. A Capstone Writing Experience in Polymer Chemistry: Writing a Proposal for an Instrument Purchase. *J. Chem. Educ.* **1998**, *75* (11), 1424.
(15) Tilstra, L. Using Journal Articles to Teach Writing Skills for Laboratory Reports in General Chemistry. *J. Chem. Educ.* **2001**, *78* (6), 762.
(16) Whelan, R. J.; Zare, R. N. Teaching Effective Communication in a Writing-Intensive Analytical Chemistry Course. *J. Chem. Educ.* **2003**, *80* (8), 904.
(17) Burke, K. A.; Greenbowe, T. J.; Hand, B. M. Implementing the Science Writing Heuristic in the Chemistry Laboratory. *J. Chem. Educ.* **2006**, *83* (7), 1032.
(18) Cacciatore, K. L.; Sevian, H. Teaching Lab Report Writing through Inquiry: A Green Chemistry Stoichiometry Experiment for General Chemistry. *J. Chem. Educ.* **2006**, *83* (7), 1039.
(19) Gragson, D. E.; Hagen, J. P. Developing Technical Writing Skills in the Physical Chemistry Laboratory: A Progressive Approach Employing Peer Review. *J. Chem. Educ.* **2010**, *87* (1), 62–65.
(20) Harrison, R. L.; Parks, B. How STEM Can Gain Some STEAM: Crafting Meaningful Collaborations Between STEM Disciplines and Inquiry-Based Writing Programs. In *Writing Program and Writing Center Collaborations: Transcending Boundaries*; Myatt, A. J., Gaillet, L. L., Eds.; Palgrave Macmillan US: New York, 2017; pp 117–139.
(21) Kiefer, K.; Palmquist, M.; Carbone, N.; Cox, M.; Melzer, D.; Clearinghouse, W. A. C. An Introduction to Writing Across the Curriculum. *Fort Collins, CO: The WAC Clearinghouse. Retrieved from https://wac. colostate. edu/intro.* **2000**.
(22) Upper-Division Writing Courses

http://writing.uci.edu/resources/facultyinstructor-resources/udw-courses/ (accessed Oct 4, 2020).
(23) Bergmann, L. S.; Zepernick, J. S. Disciplinarity and Transfer: Students' Perceptions of Learning to Write. *WPA* **2007**.
(24) Hodges, L. C. *Teaching Undergraduate Science: A Guide to Overcoming Obstacles to Student Learning*; Stylus Publishing, LLC, 2015.
(25) Chandler, P.; Sweller, J. Cognitive Load Theory and the Format of Instruction. *Cogn. Instr.* **1991**, *8* (4), 293–332.
(26) Sweller, J.; van Merrienboer, J. J. G.; Paas, F. G. W. C. Cognitive Architecture and Instructional Design. *Educ. Psychol. Rev.* **1998**, *10* (3), 251–296.
(27) Bacon, N. Building a Swan's Nest for Instruction in Rhetoric. *College Composition and Communication* **2000**, *51* (4), 589–609.
(28) Driscoll, D. L. Connected, Disconnected, or Uncertain: Student Attitudes about Future Writing Contexts and Perceptions of Transfer from First Year Writing to the Disciplines. *Across the Disciplines* **2011**, *8* (2).
(29) Hayes, H.; Ferris, D. R.; Whithaus, C. DYNAMIC TRANSFER IN FIRST-YEAR WRITING AND "WRITING IN THE DISCIPLINES" SETTINGS. *Critical transitions: Writing and the question of transfer* **2017**, 181–213.
(30) Kim, D.; Olson, W. M. Using a Transfer-Focused Writing Pedagogy to Improve Undergraduates' Lab Report Writing in Gateway Engineering Laboratory Courses. *IEEE Transactions on Professional Communication*. 2020, pp 64–84. https://doi.org/10.1109/tpc.2019.2961009.
(31) Warner, J. *The Writer's Practice: Building Confidence in Your Nonfiction Writing*; Penguin, 2019.
(32) Nilson, L. B.; Stanny, C. J. *Specifications Grading: Restoring Rigor, Motivating Students, and Saving Faculty Time*, Reprint edition.; Stylus Publishing: Sterling, VA, 2014.
(33) Bonner, M. W. Grading Rigor in Counselor Education: A Specifications Grading Framework. *Educational Research Quarterly* **2016**, *39* (4), 21.
(34) Elkins, D. M. Grading to Learn: An Analysis of the Importance and Application of Specifications Grading in a Communication Course. *Kentucky Journal of Communication* **2016**, *35* (2), 2016.
(35) Mirsky, G. M. Effectiveness of Specifications Grading in Teaching Technical Writing to Computer Science Students. *J. Comput. Sci. Coll.* **2018**, *34* (1), 104–110.
(36) Blackstone, B.; Oldmixon, E. Specifications Grading in Political Science. *Journal of Political Science Education* **2019**, *15* (2), 191–205.
(37) Carlisle, S. Simple Specifications Grading. *PRIMUS* **2019**, 30, 926-951, https://doi.org/10.1080/10511970.2019.1695238
(38) Prasad, P. V. Using Revision and Specifications Grading to Develop Students' Mathematical Habits of Mind. *PRIMUS* **2019**, 30, 908-925. https://doi.org/10.1080/10511970.2019.1709589
(39) Martin, L. J. Introducing Components of Specifications Grading to a General Chemistry I Course. In *Enhancing Retention in Introductory Chemistry Courses: Teaching Practices and Assessments*; ACS Symposium Series; American Chemical Society, 2019; Vol. 1330, pp 105–119.
(40) Ring, J. ConfChem Conference on Select 2016 BCCE Presentations: Specifications Grading in the Flipped Organic Classroom. *J. Chem. Educ.* **2017**, *94* (12), 2005–2006.
(41) Howitz, W. J.; McKnelly, K. J.; Link, R.. Developing and Implementing a Specifications Grading System in an Organic Chemistry Laboratory Course, **2020**. https://doi.org/10.26434/chemrxiv.12276701.v3.
(42) Bannister L & Kearns. Reading, writing, thinking and creating across the curriculum: An immodest proposal. Unpublished manuscript https://eric.ed.gov/?id=ED263521 (accessed Oct 4, 2020).
(43) Cunningham, L. M. Involving Students in Learning through a Reading/writing Approach. In *Focus: A Forum on Teaching and Learning in Utah*; ERIC, 1995; p 11.
(44) King, S. *On Writing: A Memoir Of The Craft*; Simon and Schuster, 2000.

(45) Graham, S.; Liu, X.; Bartlett, B.; Ng, C.; Harris, K. R.; Aitken, A.; Barkel, A.; Kavanaugh, C.; Talukdar, J. Reading for Writing: A Meta-Analysis of the Impact of Reading Interventions on Writing. *Rev. Educ. Res.* **2018**, *88* (2), 243–284.
(46) Doll, C.; McLaughlin, T. F.; Barretto, A. The Token Economy: A Recent Review and Evaluation. *Aust. J. Basic Appl. Sci.* **2013**, *2* (1), 131–149.
(47) Kovac, J.; Sherwood, D. W. *Writing Across the Chemistry Curriculum: An Instructor's Handbook*; Prentice Hall, 2001.
(48) Herrington, A. J. Writing in Academic Settings: A Study of the Contexts for Writing in Two College Chemical Engineering Courses. *Research in the Teaching of English* **1985**, *19* (4), 331–361.
(49) Banik, G. M.; Baysinger, G.; Kamat, P. V.; Pienta, N. The ACS Guide to Scholarly Communication. ACS Publications 2020.
(50) Deslauriers, L.; McCarty, L. S.; Miller, K.; Callaghan, K.; Kestin, G. Measuring Actual Learning versus Feeling of Learning in Response to Being Actively Engaged in the Classroom. *Proc. Natl. Acad. Sci. U. S. A.* **2019**, *116* (39), 19251–19257.
(51) Bean, J. C. *Engaging Ideas: The Professor's Guide to Integrating Writing, Critical Thinking, and Active Learning in the Classroom*; John Wiley & Sons, 2011.