Building Personal Connections to Organic Chemistry Through Writing

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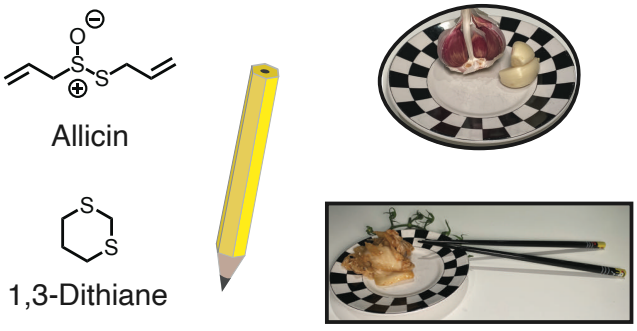
ABSTRACT

Organic chemistry courses enroll students from many majors with diverse interests. Although instructors may strive to appeal to these interests by relating course content to real-life, it is challenging to intrinsically appeal to students at the personal level, particularly in high enrollment courses like organic chemistry. When students identify personal connections with course content, they may be more interested or motivated to continue learning course content. To help students identify connections, we designed and implemented a writing assignment prompting students to select an organic compound that personally relates to them and write about this personal connection. Herein, we discuss the implementation and evaluation of the assignment. Student feedback survey responses and interviews indicate that the assignment allowed students to identify how organic chemistry is relevant to their lives. We believe the assignment could be effectively implemented at other institutions and in other chemistry courses.

GRAPHICAL ABSTRACT



KEYWORDS
Second-Year Undergraduate, Organic Chemistry, Writing, Applications of Chemistry, Molecular Properties / Structure

INTRODUCTION

Organic chemistry is perceived as one of the most difficult classes in the undergraduate chemistry curriculum and has a high withdrawal rate.[1] The content is quite different from general chemistry, and many students become frustrated and lose motivation to learn the subject early on in the course.[2] This may be especially problematic as organic chemistry is a prerequisite for other science courses and STEM majors; failure in the course can prohibit students from achieving their overall academic goals.[3] The affective experiences of students in chemistry courses is an active area of chemistry education research,[4] with various studies indicating the importance of student affect on performance in chemistry courses.[5-10] If we want students to persist in STEM pathways, it is critical that we provide avenues for positive affectual experiences that can support their motivation to learn in gateway courses like organic chemistry.[11]

Helping students develop and personal connections with course content can be a valuable method to engage students in STEM courses,[12] as student interest and recognition of the relevance of content has been tied to the affective domain of learning.[13-15] To help students build connections to chemistry content, instructors can incorporate real-world contexts into their instruction and the assignments they use in the course.[16] Although instructors may try to stimulate students' interest in organic chemistry content by including different real-world contexts, the students come from very different majors and backgrounds as well as having a wide range of interests. These factors can make designing personally relevant instruction in organic chemistry difficult.[17] Selecting contexts and connections that may appeal to students at the personal level is additionally complicated by the fact that students' reasons for studying organic chemistry may vary widely. Indeed, organic chemistry is both a common requirement for pre-professional students aiming to enter a health sciences field and often a requirement for chemistry, chemical engineering, and biochemistry majors. Some efforts within organic chemistry courses targeted the large pre-professional student population electing the course; though this may engage some students, not all students fit into this population and may then be

disinterested in the instructor-provided context.[18-20] If we want our instruction to be more student-centered, we should find ways of encouraging students to incorporate their own interests,[21] especially as intrinsically relevant connections may be more impactful on student learning than instructor chosen connections.[22]

Writing can foster student learning and engagement with science content in different contexts,[23-28] including organic chemistry courses and laboratories.[29-33] Within organic chemistry, context-based writing assignments have been found to support meaningful learning, contribute to positive affective learning experiences, and increase student confidence in their knowledge.[20, 30, 34] However, the contexts given to students in writing prompts are often provided by the instructor; few assignments have focused on students identifying their own relevant topics or contexts.[21, 32] Writing assignments are more meaningful to students when they allow students to draw upon their personal experiences when making connections to course content.[21] For this reason, we designed and implemented a writing assignment that allowed students to select an organic molecule or compound of their choice and write about their connection to the organic structure.[26]

PURPOSE OF THE ASSIGNMENT

The purpose of this assignment was to allow students to explore the ubiquity of organic compounds and the importance of organic chemistry, and to develop a personal connection to the course content. More specifically, the goal was for students to build that connection by choosing the organic molecule that is most important in their life and, further, to describe that importance. Additionally, students simultaneously explored the three-dimensional structure of the molecule and its two-dimensional representation, thereby introducing them to two software applications widely used by organic chemists.

IMPLEMENTATION AND EVALUATION OF THE ASSIGNMENT

Course Contexts

This assignment was first implemented in a first semester organic chemistry course at the University of Illinois at Urbana-Champaign, where it has been used in the course for five different semesters. The course provides an introduction to structural, synthetic, and mechanistic chemistry, and was designed specifically for STEM majors. Typically 150 to 200 students are enrolled in the

course, the vast majority of whom are Biochemistry, Chemical and Biomolecular Engineering, and Chemistry majors. Three hours of lecture with the instructor were supplemented with a one-hour discussion section led by a graduate student instructor. During the COVID-19 pandemic (Fall 2020), all lectures and discussion sections were held remotely with synchronous class meetings. Graded elements of the course included quizzes, exams, and the writing assignment. The writing assignment was given to students at the beginning of the semester, and they had a month to complete it. The assignment was scored out of 50 points and was worth about 8% of students' overall course grades. The instructor of the initial implementation did not use a rubric and instead opted for individualized feedback; as this was meant to be a low stakes assignment, most students received full points as long as the personal connection was clear. The main deduction was for late approval or late paper submission. In general, when a student submitted an incorrect computational model, they were told of their error and given an opportunity to fix it. This was rarely a problem except for complex molecular structures that were hard to draw so the goal was not to penalize students who selected a more difficult compound.

The assignment was subsequently used in a second-semester organic chemistry laboratory course at the University of Michigan during the Winter 2021 semester.[28] In this course, students attended a one-hour lecture with the course instructor and a four-hour laboratory section with a graduate student instructor each week. Due to the COVID-19 pandemic, students viewed asynchronous lectures and attended reduced capacity labs every three weeks. The writing assignment was the first of three in the course that were not laboratory reports, and was worth 11% of students' overall course grade; attendance, laboratory reports, quizzes, and the other two writing assignments comprised the remainder of students' grades. The writing assignments were scored by writing fellows (undergraduates involved in grading writing assignments incorporated in the course) which allowed for the assignment to be 'scaled up' from around 150 students to an 800-person course. The instructors chose to adopt a rubric to maintain consistency with grading among the fellows; the grading rubric can be found in the Supporting Information.

Description of assignment

The assignment first required students to select an organic compound or molecule of their choice that had a personal connection to them. This personal connection could be from their past or present and could relate to any aspect of their lives, the main requirement being that it must be "an important molecule in their life." The assignment description was intentionally broad to provide students with agency when personalizing their assignments (Box 1).[21] Once students selected an organic compound, they emailed the instructor of the course for approval. This was to ensure that the chosen compound (molecule) was, in fact, organic, as the assignment was assigned at the beginning of the semester when students had limited experience in organic chemistry. In addition, the instructor did not allow any students to have the same compound or molecule to ensure that students explored a variety of choices and add to the uniqueness of each personal connection. The selection process was done on a first come, first served basis. The instructor discouraged both overly simple (e.g., ethane) and complex choices (e.g., polymers, proteins), the latter not being easily amenable to drawing and structural modeling. In cases where students made a very strong connection to a synthetic polymeric material or biomacromolecule and were reluctant to choose an alternative, they were encouraged to draw and model a monomeric unit or subunit of the biomacromolecule.

Box 1. Assignment Description

The paper is to be at least one paragraph long (single spaced). For the paper, select an organic molecule/compound that is important in your life. Everyone should have a unique molecule that must be approved by Prof. X at least a week before the due date (approval by Oct. 2). You should explain why it is important in detail. The more specific it is to you and to your experiences, the higher the score. Please avoid obvious choices like ethanol/caffeine/etc. The paper must contain a good structural drawing done by a program such as ChemDoodle or ChemDraw and contain a good 3D minimized structure using molecular mechanics. The 3D structure and molecular mechanics can be performed using Avogadro. Both the 2D app ChemDoodle and Avogadro can be downloaded for free. The completed assignment should be sent to professorx@university.edu with the ChemDoodle and Avogadro files as attachments.

Once students picked a compound or molecule, they wrote about why they chose it, explaining their personal connection to it. Describing the personal connection was emphasized for this

assignment, and the only required chemistry content was a good structural drawing and a simple computational model of the chosen compound. A site-license for ChemDoodle allowed students to download and use this software for the structural drawing. Students were allowed to use other drawing applications, such as ChemDraw, if available. For the three-dimensional structure, the students downloaded the freeware app Avogadro and were instructed on how to perform a basic molecular mechanics minimization. It was possible for students to use other software packages such as WebMO or Spartan. Students were told to write a minimum length of a paragraph but not given any other guidance (e.g., genre, first or third person, etc.). This guidance reflects our intention of giving students agency with their writing, as so they were able to express their connection in the way that made the most sense for them.[21] Students could ask clarifying questions if needed, but few additional questions were posed. An example response is presented in the Supporting Information.

Evaluation of the assignment

For this article, our evaluation focuses on student experiences, rather than assessment outcomes, at the University of Illinois at Urbana-Champaign where the assignment was developed. Accordingly, we distributed pre- and post-surveys and interviewed students in the Fall 2020 organic chemistry I course to identify student perceptions of the assignment. Before distributing the surveys via Qualtrics, we received approval from the institution's Institutional Review Board. Students had roughly three weeks to complete each survey. We had a survey completion rate of 95%, with 139 of 147 total students enrolled in the Fall 2020 course completing the entire survey. Students did receive points equating to roughly 3% of their course grade for completing the surveys. Sections of the survey that we focused on for this study include Likert-scale and open-ended response questions about the writing assignment. Student agreement with the Likert-scale questions is presented in Figure 1. Responses to the open-ended questions were thematically grouped after the survey was finished. The thematic groups and their relative frequencies are presented in Figures 2 and 3. In addition to the questions about the assignment, the Qualtrics surveys were also used to obtain consent to use the students' writing assignments for this article and solicit participation in interviews.

Interviews were conducted to supplement our survey results and gain more specific insight into students' thoughts on the assignment. Eleven students agreed to participate in an interview about the

writing assignment. Interviews were conducted remotely via Zoom due to the COVID-19 pandemic and performed by the first author (NG), who is not affiliated with the University of Illinois at Urbana-Champaign. Interview questions focused on students' writing processes and their opinions about the writing assignment. To parallel the analysis of the open-ended questions, we focused on identifying what students appreciated and found challenging about the writing assignment when reviewing the interview transcripts. The surveys and interview protocol are included in the Supporting Information.

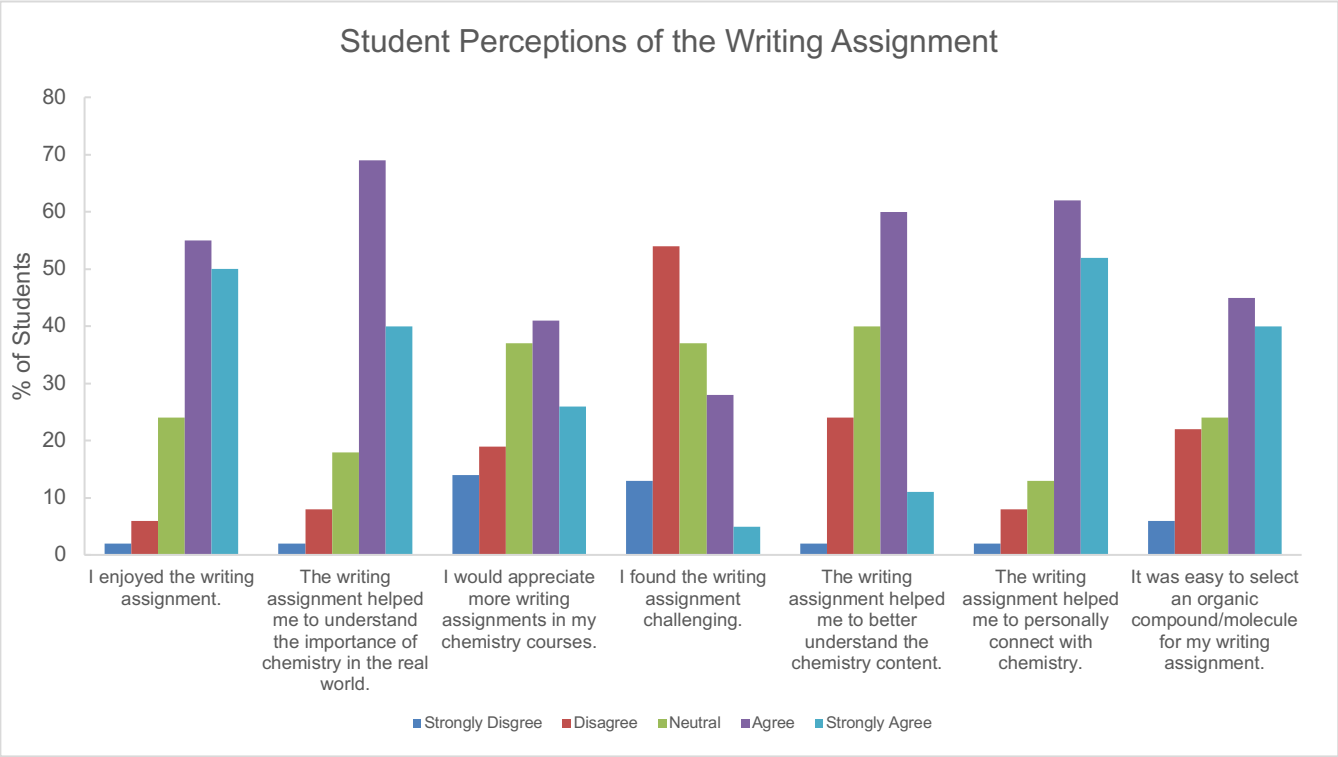


Figure 1. As part of the post-survey, students indicated how they agreed with the statements below using a 5-point scale from 'strongly disagree' to 'strongly agree.' (N = 139)

Student perceptions of the writing assignment were primarily positive. Over 80% of students agreed that the writing assignment helped them to personally connect with chemistry (Figure 1), which was our primary intent for implementing this assignment. Even in the remote classroom setting, students were able to make a personal connection with chemistry, which can be a valuable way to promote student learning of chemistry content.[12] For the most part, students largely enjoyed the writing assignment, with more than half of students agreeing or strongly agreeing when asked if they

enjoyed it (Figure 1). This positive perception of this type of assignment is encouraging, because it is quite novel and potentially unfamiliar to students in their chemistry education.[21]

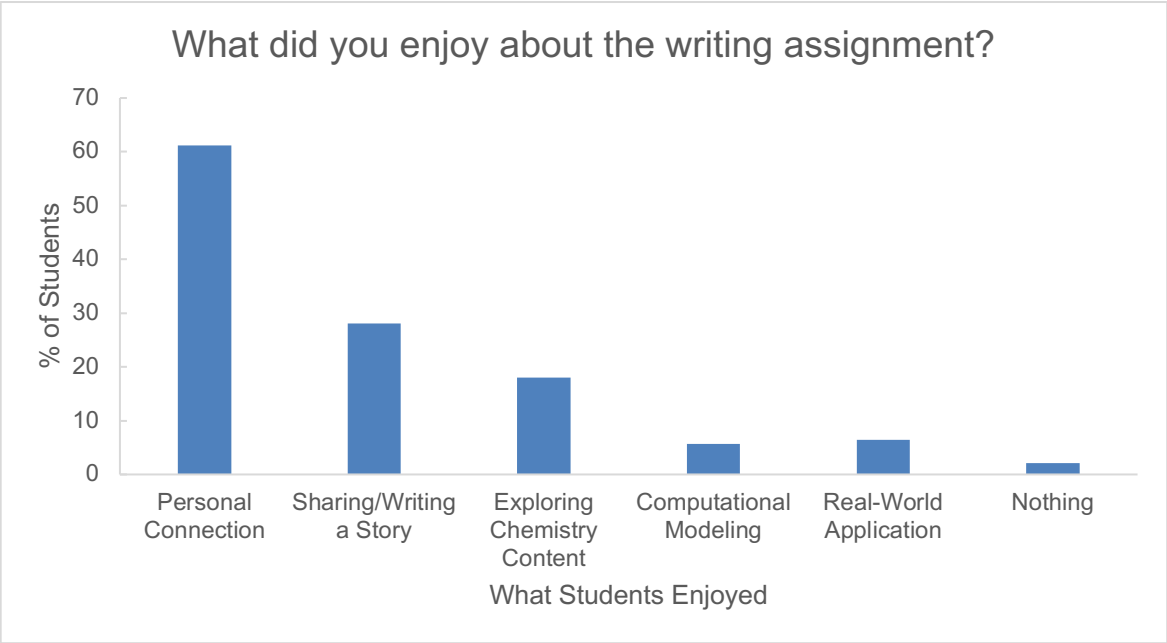


Figure 2. Grouped student responses to the question asking what they liked about the writing assignment (N = 139)

When asked to describe what they liked about the writing assignment, over half of the students said they appreciated the personal connection aspect (Figure 2). It is promising that students wrote about this, as it was one of our objectives for the assignment. This finding aligns with research indicating that assignments where students have agency in their writing (in this case, picking compounds unique to them) can be a powerful teaching tool.[21] Many students also enjoyed sharing their story through writing (Figure 2). STEM courses usually rely on more objective writing, such as lab reports over subjective writing, so this alternative approach provided a unique writing opportunity for students.[35] One interviewed student even remarked that it "would have been cool if we were able to read each other's assignments", suggesting the assignment could provide a unique lens through which students could learn about their peers.

The writing assignment also supported students in recognizing the applicability of chemistry in various contexts and thinking more about the content. Many students agreed that the assignment helped them see the importance of chemistry in the real world (Figure 1); a small number of students also mentioned this in the open-response question for what they liked about the writing experience. One of the students interviewed remarked how they are "actually interested in like reading ingredient lists on like chemical products and trying to figure out like, oh, what does this look like." Chemistry can have relevant real-world connections that support student learning, but this is not always apparent to students.[16, 36] Because this assignment was used early on in an organic chemistry I course, it was part of student's initial exposure to the discipline and allowed them to explore chemistry content in addition to the personal connection. In the open-response questions, some students remarked that the assignment helped them explore chemistry content (Figure 2). Over one-third of students surveyed agreed that chemistry courses should include more writing assignments (Figure 1).

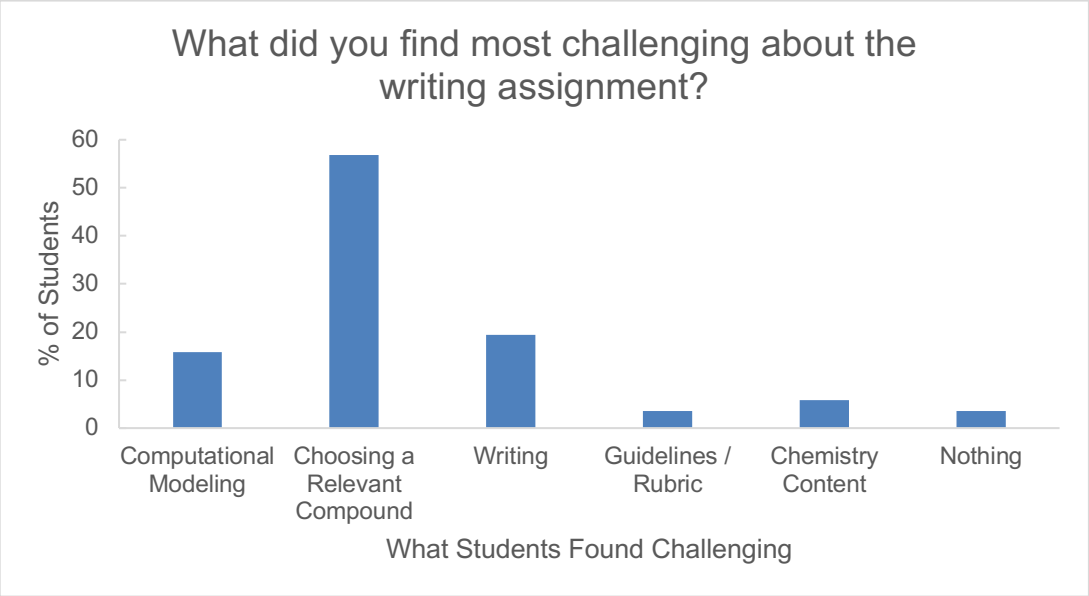


Figure 3. Grouped student responses to the question asking about what they found challenging about the writing assignment (N = 139)

Less than a quarter of students found the assignment overly challenging (Figure 1), which reflected our intent that the assignment be low stakes for students. Some students struggled with computational modeling, as this was a new experience for students (Figure 3). However, the majority of

students' difficulties were related to choosing a compound (Figures 1 and 3). As students are not often tasked with connecting chemistry to their personal lives, this was an understandable challenge and indicates the merit of including such an assignment in a course. Difficulties with molecule selection extended to the virtual sign-up process; as one interviewed student said, "there was a bit of frustration in picking a molecule just because again, everybody in the class having to have a different one… I was like, 'Oh, I wish I could do this compound, but somebody already took it.'" Small groups of students also noted that they found writing the assignment difficult; reasons for this included the novelty of this assignment in that it was quite different from the types of assignments normally found in STEM courses like laboratory reports and the broad guidelines for the assignment (Figure 3). Only a small number of students explicitly mentioned this. One student stated in their interview that they "think the vagueness was a benefit in this assignment because I think it gave every student the freedom to kind of take it as it is and kind of do what they will."

ADVICE FOR IMPLEMENTATION

The instructor who first developed this assignment has used it in their first-semester organic chemistry course five times to date, with all sections receiving similar guidelines. The only major difference between semesters was removing a medically-themed example from the assignment prompt, as the inclusion of the example may have inadvertently guided students towards therapeutic agents and limited their creativity on the assignment. Reading and grading the papers and returning comments to the students, even though often very brief, took 1-2 days of effort. Although this represents a considerable time investment, it provided the instructor a unique and manageable way of learning much more about the individual student's lives. Furthermore, the instructor found several of the stories moving, which made the exercise personally very meaningful. Connecting with students can be challenging in remote and online courses, yet building connections between faculty and students in STEM courses is still important.[37] Despite the considerable effort in reading each individual paper, the instructor found the overall process to be highly rewarding and meaningful. In a number of cases the paper provided an opportunity for follow up discussions with individual students.

For implementations in larger course settings, it may be difficult for the instructor to read and respond to each student's response. An alternate approach is the format that was used at the

University of Michigan, where undergraduate teaching assistants (writing fellows) graded the assignments. Graduate teaching assistants could play a similar role, which could be beneficial in courses where they are leading recitation or lab sections. Alternatively, the instructor could incorporate a peer feedback element to the assignment where students provide written feedback in response to their peers' assignments. However, instructors should carefully consider this approach due to the potential for highly personal responses, and we would suggest not having students *grade* their peers' responses. In addition, incorporating peer feedback may influence how students respond to the assignment.

As implemented, the emphasis of the assignment was on the personal connection without expectations for content learning. The vast majority of students indicated that they enjoyed the assignment and, in response to one of the open-ended survey questions, they appreciated the personal emphasis (Figures 1 and 2). A few students did acknowledge, though, that they felt some pressure to reveal personal information such as illnesses or medications for the assignment. For this reason, care should be taken when using this assignment so that students understand that they are not required to reveal deeply personal information.

Although we focused on the personal connection, almost half of the students perceived the assignment as helping them understand chemistry content better (Figure 1). Instructors interested in emphasizing chemistry content, could modify the assignments by having students include content related aspects, such as chirality. Though the assignment as designed targets organic chemistry students, it could be modified and implemented in other chemistry courses. For example, biochemistry students could select a protein with a personal connection, and general chemistry students could select an element from the periodic table. The beauty of this assignment is its flexibility, and it could be implemented into courses of various sizes and levels as described here.

CONCLUSION

The intention of this assignment was to harness the power of writing to help students relate chemistry to their own lives. Student feedback from the survey and interviews suggested that the assignment successfully supported students to reflect on how organic chemistry can be found outside the classroom. In addition, students also expressed that they enjoyed this opportunity (specifically

identifying a personal connection and crafting a story about that connection) as it was different from other assignments they had encountered in previous STEM courses. The assignment has been implemented at multiple institutions and, with some modifications of the assignment description, could be expanded to other subdisciplines outside of organic chemistry.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.XXXXXXX. [ACS will fill this in.] The supporting information includes a grading rubric, the feedback survey, and the interview protocol used to evaluate student perceptions of the assignment.

Supporting Information (PDF)

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