

Reflections on Learning: Revision Reflections as Insight into the Influences on Students' Revisions on a Writing-to-Learn Assignment

SOLAIRE A. FINKENSTAEDT-QUINN, ISABELLA
SPERRY, ALICIA ROMERO, AND GINGER V. SHULTZ

Peer review and revision have the potential to support the use of writing pedagogies across disciplines. The MWrite Program supports faculty across disciplines incorporate writing-to-learn (WTL) assignments in their classrooms. The WTL assignments incorporate peer review and revision to engage students in a collaborative co-construction of knowledge while alleviating the need for instructor feedback. Our study builds upon prior literature by examining how students view peer review as influencing their revisions in a WTL context. We analyzed the revision reflections students wrote as part of a WTL assignment in an introductory statistics course, characterizing the revisions students described and the sources to which they attributed their revisions. Students primarily described revising their arguments or adding missing content. They predominantly attributed revisions to receiving feedback, but they also valued reading their peers' drafts. This study adds to prior literature by demonstrating that students viewed peer review as a valuable and supportive exercise enabling them to make productive revisions.

Introduction

There have been calls for greater incorporation of writing in undergraduate STEM classrooms, and specifically for writing that supports learning (National Research Council, 2012). Accordingly, writing-to-learn (WTL) has been increasingly used in STEM to support conceptual learning and disciplinary thinking (Gere et al., 2019; Reynolds et al., 2012). Drawing on the benefits of WTL and in response to calls for increased writing in STEM, we developed the MWrite Program, which supports the use of an evidence-based design for WTL assignments in courses across the University of Michigan, with an emphasis on large introductory STEM courses.

The MWrite team supports instructors to develop and implement WTL through access to resources, such as writing fellows, and works with instructors to develop writing assignments for their course. Importantly, we guide instructors through a process of developing assignments that include the features found in effective WTL assignments—namely, meaning-making tasks, providing students with clear writing expectations, incorporating interactive writing processes, and supporting metacognitive reflection (Anderson et al., 2015; Gere et al., 2019; Klein, 2015).

Including peer review and revision stages into a writing assignment can incorporate the features of effective WTL assignments, namely, creating interactive writing as students interact with their peers; providing clear writing expectations in the form of a rubric that guides peer review; and supporting metacognitive reflection as students read their peers' writing, consider the feedback they receive, and revise their writing. Research on peer review for supporting revision is extensive and indicates that students benefit from the process (Chang, 2016; Huisman et al., 2019). Students can provide feedback to their peers that is similar to that of instructors and leads to higher-order revisions (Anson and Anson, 2017; Cho and MacArthur, 2010; Cho et al., 2006; Huisman et al., 2019; Patchan et al., 2009). Furthermore, research indicates that while both aspects of peer review (i.e., reading the work of peers and providing feedback and receiving feedback) inform students' revisions, reading the work of peers and providing feedback to them may be more impactful (Cho and Cho, 2011; Cho and MacArthur, 2011; Huisman et al., 2018; Lundstrom and Baker, 2009). This may be due to the fact that students engage in a reflective process as they read their peers' writing and draft feedback (Nicol and McCallum, 2022). However, students utilize peer review to different extents when they revise (Leijen and Leontjeva, 2012; Lu et al., 2023), and revision is tied to development in writing ability, where higher-order revisions lead to greater improvement (Cho and MacArthur, 2010; Wu and Schunn, 2020). In addition to variable engagement with peer review and revision, it can be difficult for students to transfer knowledge about writing across contexts, and incorporating stages for reflection can support them to do so (Adler-Kassner et al., 2016; Moore and Felten, 2019). While peer review and revision can support reflection, incorporating an explicit stage for reflection may more directly support students to engage in the practice. However, it is important to note that reflective writing can be prescriptive, and one must balance scaffolding student reflection with providing room for genuine reflection and not leading students to craft rote responses catering to the assessor (Scott, 2005). As part of our research program, we are interested in enhancing students' engagement with peer review and revision to ultimately enhance the benefits of WTL. In this article, we describe an exploratory study of how students described their peer-review and revision processes in revision reflections that were incorporated into the WTL process.

Investigations into MWrite WTL's Support of Learning

In alignment with the goals of the MWrite Program, we have undertaken a series of studies examining students' responses to MWrite WTL assignments to identify whether and how the assignments are supporting the intended learning goals (Finkenstaedt-Quinn et al., 2023). Our findings indicate that the assignments successfully support conceptual learning and disciplinary thinking due to the rhetorical features included in the assignment prompts (i.e., relevant context, genre, and audience) and, most pertinent to this work, the inclusion of peer review. Analyses of students' writing (i.e., feedback and revisions), survey responses, and interviews indicate that students can provide constructive, content-focused feedback to their peers that is related to content-focused revisions in biology, chemistry, and statistics contexts (Finkenstaedt-Quinn et al., 2020; Finkenstaedt-Quinn et al., 2019; Gupte et al., 2021; Halim et al., 2018; Moon et al., 2018; Petterson et al., 2022; Schmidt-McCormack et al., 2019; Watts et al., 2022). Furthermore, in alignment with other research on peer review and revision (e.g., Cho and Cho, 2011; Lundstrom and Baker, 2009), quantitative analyses comparing students' initial and revised drafts suggest that their revisions are also informed by reading their peers' draft and providing feedback, and that this aspect of peer review may have a greater impact than the feedback students receive (Finkenstaedt-Quinn et al., 2021; Watts et al., 2022); but the results have been mixed across studies (Watts et al., 2024). Additionally, in a case study analysis of students' writing artifacts from a WTL assignment focused on mechanistic reasoning in organic chemistry, we found a range in the extent to which students engaged with the processes of peer review and revision (Finkenstaedt-Quinn et al., 2024). Specifically, some students made meaningful revisions that related to both the feedback they received and the peers' drafts they read, while others made smaller-scale revisions tied only to feedback they received. As this study primarily drew from written artifacts, we were interested in exploring how students themselves described their revisions and the relationship to peer review. By better understanding both what students are doing and how they see themselves as doing it, we hope to gain insight into how to enhance students' engagement in the peer review and revision aspects of the MWrite Program's WTL assignments and thus increase the learning benefits of this pedagogy.

This study focuses on a MWrite WTL assignment in an introductory statistics course where the instructor recently incorporated student reflections into the revision stage of the assignments as a way to support student revisions. In the reflections, students are asked to write about how the revisions they made were informed by the peer-review process. This presented us with the opportunity to examine students' reflections as a representation of how students perceived aspects of the peer review process informing their revisions. Our thinking draws on the cognitive processes

involved in revision as described by Flower et al. (1986) and Hayes et al. (1987). As the writer begins the revision process, they read their text to evaluate how it addresses their goals for the text and how it aligns with criteria related to the task. As they evaluate their text, they identify problems within it. They then consider what strategies to use in approaching revision—such as what problems they can ignore, if they need more information to address the problem, and the extent of revision that is needed—before actually beginning to revise their text. In our context, as students revise they consider how well their initial draft addresses the writing prompt and the peer review criteria, the feedback they received, and they also compare their peers' drafts to their own work. Based on these factors, they reflect on their initial draft, identify problems in their writing, and consider how they should address those problems. Students' revision reflections thus serve as external representations of their revision process that we, as researchers, can then examine to gain insight into their thinking.

We describe a focused examination of three students' final drafts and the corresponding revision reflections in response to one of the WTL assignments implemented in the statistics course. This is followed by an exploratory analysis across a subset of students' revision reflections. Our aim from this analysis was to develop a better understanding of how students revise in a WTL context, both what they revise on (e.g., content, reasoning, writing mechanics) and what informs their revisions (e.g., reading peers' drafts, receiving peer feedback, writing fellows, outside readings). This provides insight into the extent to which students are engaged with revision and utilizing their peers as resources, which can inform efforts to enhance the benefits of WTL through peer review and revision mechanisms. As such, the following research questions guided our analysis:

1. What types of revisions do students comment on making?
2. What sources do students identify as informing their revisions?

Methods

Study Overview

We qualitatively analyzed students' written reflections about their revision process, which formed one of the MWrite WTL assignments incorporated into an introductory statistics course. From this course, twenty students consented to participate in the study and allowed us to analyze their writing. We examined three students' final drafts and corresponding revision reflections as exemplar cases for how students performed and described their revisions. Additionally, we thematically analyzed the written revision reflections of all twenty students via an inductive coding process. This study is considered exempt by the institutional review board, and pseudonyms are used throughout when referring to specific students.

Course Context and Assignment Details

The introductory statistics course is primarily taken by sophomore and junior undergraduates across various disciplines and introduces basic statistical concepts. The course consists of a lecture session three times a week, as well as a lab once a week with a graduate-student instructor that focuses on the use of RStudio in the context of various data sets. Students are primarily assessed through exams supplemented by weekly homework, lab assignments, and two MWrite WTL assignments. Each WTL assignment consists of a supplemental assignment completed in the lab, an initial draft, peer review, and a final draft and revision reflection. Writing fellows assist with the WTL process—they are undergraduate students who previously performed well in the course and showed an advanced understanding of the topics covered by the assignments. Additionally, writing fellows are responsible for hosting office hours to answer questions and grading the initial drafts, peer reviews, and final drafts. When grading the initial drafts, the writing fellows provide students with feedback primarily focused on completion and deduct points if students' responses missed items asked for in the assignment description. They also typically provide a few directive comments for what students may want to focus on as they revise. Students receive the comments from the writing fellows after the peer review closes. Students also all receive a message describing common errors that the writing fellows identified in the first drafts.

The revision reflections examined herein were part of an assignment that appointed students as analysts for the American Hotel and Lodging Association (AHLA). They were given the larger goal of understanding the characteristics of a random sample of five hundred Airbnb listings in Chicago neighborhoods and asked to evaluate the characteristics in order to guide decisions in the hotel industry. Students were tasked with writing a five-to-seven-hundred-word memorandum that included a histogram, an analysis of two categorical variables in a grouped bar chart, an analysis of one quantitative variable versus one categorical variable, and recommendations to AHLA based on their findings. Finally, students were asked to close their memorandum with a summary of their findings and a response to the following query: "Your project manager suggests using the results from your analysis above to understand the characteristics of Airbnb's competitor, Vrbo. Do you agree with your manager that it is appropriate to do so? Why or why not?"

After writing an initial draft in response to the assignment, students read approximately three of their peers' drafts and offered feedback according to four content-focused criteria. They correspondingly received feedback from three peers, on average. Students were then tasked with revising their initial draft based on new or changed perspectives about the assignment. Lastly, they were asked to include a revision reflection in their final draft (see Figure 1).

Include a reflection on the revise and resubmit process. This reflection should be between 100 and 150 words. The reflection should be placed at the end of your memorandum. A complete reflection will include the following 2 items:

- A. Now that you have received feedback from some of your peers read through their comments. Based on the comments received, identify the areas that you could improve. Summarize the edits you thought were appropriate to make to your writing piece based on the feedback from your peers, your writing fellow's comments, or feedback you've received during office hours. If you choose not to make a suggested change, provide a thorough and respectful rationale explaining why you declined to make the edit.
 - If you did not receive any peer review feedback, identify the areas you decided to change. Summarize the edits you thought were appropriate to make to your writing and explain why you made such changes.
- B. How did the three peer reviews you completed help improve your draft? Identify two areas in your revised memorandum that benefited from reading submissions from your peers.

Figure 1. Prompt guiding students' revision reflections.

Data Analysis

We selected three students as cases for close analysis of their revision reflections and final drafts. Marcie, Yael, and Phillip were selected as they captured a range of experiences in their revision reflections. For each case, two researchers individually read through the student's revision reflection and final draft (in which the revisions were clearly marked) and wrote a memo noting how the student described their revision process and how their reflection corresponded to their revisions. Next, the two researchers read and discussed each other's memos. One of the researchers then wrote up a case profile for each of the three students, got feedback from the other researcher, and revised in order to incorporate the feedback.

We also thematically analyzed the revision reflections of all twenty students included in the study (Braun and Clarke, 2006). We individually read through each revision reflection to familiarize ourselves with the data and noted features of students' responses related to the peer review and revision processes. We then discussed what we had noted in the responses and through discussion inductively developed

a coding scheme (Appendix, Table 1). We identified three groups of codes: type of change, source of revision, and evaluation. The type-of-change codes characterized the revisions students described making. The source-of-revision codes captured the resources students identified as influencing their revisions. The evaluation comment codes captured students’ reflective and affective comments about the writing process. We iteratively applied the coding scheme to a subset of students’ responses and discussed the coding to refine the coding scheme. We applied the final coding scheme to all of the revision reflections, comparing codes and discussing any differences to reach consensus on the applied codes. Finally, one researcher iteratively reviewed the reflections considering the applied codes and generated themes across the responses.

Results

To capture students’ thinking about their revisions, we first present three student cases detailing the ties between the revisions they made and their revision reflections. This is followed by our analysis across students’ revision reflections focused on the types of revisions they described making and the sources to which they attributed their revisions.

Table 1.
Codes applied to the revision reflections of the three cases.

Parent Code	Child Code	Marcie	Philip	Yael
Type of change	added missing content		x	x
	fixed incorrect content			x
	clarity	x	x	
	Explanation	x		x
	reasoning/argument	x	x	
	Grammar/structure		x	
Source of revision	Peer feedback	x	x	x
	Reading and providing feedback	x	x	x
	Writing fellows/office hours		x	
Evaluation	Did not make a suggested change	x	x	
	Reflection/metacognition	x	x	
	mentions revisions for audience	x	x	
	Affective comment about peer review process			x
	Total applied	8	10	6

Marcie. Marcie's reflection demonstrated a deep understanding of the strengths and weaknesses of their initial draft, and they noted how their final draft was shaped by receiving and giving peer feedback. Marcie provided two examples of clarity-focused revisions they made: explaining an important term and expanding on their reasoning for using specific variables. Marcie noted, "[I]n my revision, I added explanations concerning the meaning of super host status and elaborated on my reason for using the variables I chose for the side-by-side boxplot." Marcie adjusted their definition of the term "Superhost" to clarify it for readers. When one peer suggested adjusting the boxplot variables, Marcie instead elaborated on their choice of variables. Marcie demonstrated metacognition when discussing this decision, which they connected to their primary argument: "I chose not to change the variables I used in boxplots (which was recommended by one of the peer reviewers) because I thought the comparison helped further evidence my main argument that customer satisfaction seems to depend more on service quality than price." Based on what they had observed in their peers' drafts, Marcie also added a discussion in their revised draft on the variables related to Superhost status. Overall, Marcie made a series of minor but effective revisions that enhanced their memorandum rather than changed it. These changes were largely attributed to advice from their peers and reflection after reading the work of others.

Phillip. In their reflection, Phillip described how the peer-review process (both reading their peers' drafts and receiving feedback) helped them better understand the assignment objectives and informed their revisions. Phillip positively reflected, "Aside from peer reviews, reading other students' memorandums helped me better understand the project and prompt. For example, after spending more time interpreting the prompt and goal of the assignment, I related the distribution of Airbnb prices to the lodging company." This last addition was a crucial change because the memorandum's purpose was to translate statistical findings into recommendations. Phillip further noted that they had not sufficiently connected their findings and corrected this in their revised draft by providing a reasonable suggestion to the intended audience. They also improved their argument by adding the specific reasons why further research into the topic is needed. Additionally, Phillip defined outliers and added justification for their use of means rather than medians, which demonstrated their understanding of the material, and noted a clarity-based revision regarding changing their decimals to percentages. They also decided not to follow a suggestion from one of their peers that they include more of their calculations, as they felt the audience would not have the appropriate statistical background to be able to interpret them. Per a comment left by a writing fellow, they also added an introduction, which

helped structure their draft according to the correct format. Overall, informed by the peer review process, Phillip implemented significant changes that strengthened their piece considerably.

Yael. Yael's reflection largely focused on how, due to the feedback they received, they incorporated additional data and explanations that strengthened their arguments. Yael described their experience positively: "The reviewers overall also did a great job explaining what I should improve upon, while also telling me what I did a good job on and giving me positive feedback." Yael also identified areas to improve their argument and conclusion about the applicability of their statistical findings from reading their peers' drafts. Yael's most significant revision was to redo their description of conditional probabilities (i.e., the probability of one event occurring given the existence of another), which was in response to their peers identifying a computational error in Yael's draft. This revision resulted in a strong paragraph with numerical evidence supporting their overall argument. Furthermore, as with Phillip, Yael included a recommendation to the Lodging Association which was an essential aspect of the assignment. They also added further discussion of pricing data and sufficiently incorporated the findings from their graphs. Relatedly, they added text explaining key aspects of their first graph. Yael also improved their argument about whether Vrbo could use statistical analysis for their business model by pointing out other differences between the two data sets. Overall, they made both minor changes, such as adjusting their existing descriptions and explanations, and more considerable changes, such as switching out their incorrect analysis and tying their findings to the context given in the assignment.

Types of Revisions Students Describe Making

Similar to the three cases presented above, students described making a range of revisions that were primarily content focused. The content-focused revisions fell into three related categories: adding or revising content descriptions and analyses; adding or expanding on explanations of analysis; and enhancing arguments. Sixteen students described adding or revising content descriptions and explanations due to the peer review process. Of the sixteen, nine students attributed their additions to feedback they had received, two to information gleaned from reading their peers' drafts, and five to both receiving feedback and reading their peers' drafts. Students primarily described adding explanations describing their data or analyses. For example, Emily described how getting feedback led them to include more analyses in their revised draft:

"After reading my peers' feedback, I began to pick more specific elements and comparisons to comment on in my analyses. The peer reviews definitely

helped me get started in the right direction as my initial submission honestly did not have much content.”

Students also described adding numerical representations to support their analyses and revising numerical descriptions to address readability concerns. Lois said:

“I . . . unclearly used median and means in explaining why the presence of a pool doesn’t affect the ratings. So instead of using means, I [provided] the quartiles for a meaningful conclusion.”

Over half of the students discussed adding explanations or revising them. Students primarily added explanations that connected their data and analyses to the context given in the assignment. Some students also expanded existing descriptions of statistical concepts or the graphical representations of their data, explaining the choices they had made during data analysis (e.g., why they had used a certain data set) or describing the meaning and implications of their results.

Importantly, fourteen of the students described revising their reasoning or arguments. They almost entirely attributed this type of revision to receiving feedback, with one student stating that both aspects of the peer review process were helpful and two also recognizing the influence of writing fellows. Students primarily reflected on adding or revising the reasoning for their argument and final conclusion. As with the explanation-focused revisions, some students added contextual information to enhance and support their argument. Alternatively, some students described revising their analysis, or how it was posed, so as to better support their conclusions. Anne described this, as well as how they gained a better understanding of the significance of a specific statistical property:

“I feel I was able to edit and succinctly back up each of my claims with sufficient numerical evidence. The second part of my recommendations showed me that although I understood outliers, I did not understand the analytical importance of including them in my thought process and reasoning. After going back to where I was told I ignored the outliers, I was actually able to use them to create a more nuanced argument about the data I provided.”

Two students described making larger revisions to their arguments due to a change in perspective resulting from feedback they received from their peers. Alexis described gaining a new perspective on the meaning of their analyses that they used to revise their argument, and Mahvesh gained a new perspective on how to present their argument. In both cases, this feedback led them to make substantial revisions to their argument. Lastly, two students made smaller, clarity-focused revisions.

About half of the students also commented on making revisions related to organization and style. Although this type of revision was not the focus of the assignment or the peer review, students primarily attributed these revisions to feedback received from their peers, with two students also relating these revisions to reading their peers' writing and one to the feedback from a writing fellow. The primary revisions falling into this category entailed making their responses more concise. Students also discussed revising their drafts so that they aligned more with the genre and criteria of the assignment (e.g., adding an introductory paragraph, employing the formatting of a memorandum) and resolved issues with grammar, sentence structure, and confusing language.

Sources Students Identify as Informing Their Revisions

Students described making revisions based on both aspects of the peer review process (i.e., from feedback they received from their peers, and due to reading and providing feedback to their peers) as well as from interacting with the writing fellows for the course. They also discussed positive perceptions of the peer review process and how it supported reflection on their responses that prompted revisions.

All eighteen of the students described peer feedback as informing their revisions, albeit to various extents. Four of the students did not provide specifics about the feedback they received but did describe how they revised their draft in response, or how feedback helped them recognize issues with their initial drafts. For example, Anne said:

“Based on my peers’ comments, I realize that I was doing two main things wrong: lacking specification about my points given the provided data, and ignoring outliers.”

Three additional students broadly described the feedback they received, followed by a few specific examples and the revisions they made in response. The remaining eleven students detailed specific comments they got from their peers, followed by the revisions they made in response. They described receiving comments related to clarity, their explanations of the data they included, their analyses, and their final arguments. Students described two types of clarity-related suggestions: comments related to wording and sentence structure, and comments focused on the clarity of how they presented numerical and graphical information. Regarding their analyses, students primarily described receiving suggestions to add variables and quantitative evidence to their analysis, while some suggestions related to how they could interpret their findings. For example, Mahvesh said:

“Reviews for Q1 said that I had great numerical summaries, but I should explain how this relates to hotels in Chicago. . . . Q4 reviews said my reasoning for Vrbo was a bit subjective so I gave more objective reasoning.”

The comments on students’ arguments related to how their argument could be expanded, clarified, or supported with evidence. All the students who described specific comments they got from their peers described receiving comments related to either their analysis or their crafted argument, or both, which indicates that students were overall providing feedback that could support their peers in achieving the goals of the assignment.

In their written reflections, eight students described how their revisions were influenced by reading their peers’ drafts, with two students also mentioning that they benefited from providing their peers with feedback. Dave described the benefits of both reviewing their peers’ drafts and getting feedback:

“Overall, reading my reviews and reviewing others’ memorandums helped me make my memorandum a lot more specific and professional, as I could take advice and inspiration from my peers.”

Students described reviewing their peers’ drafts as helping them identify missing content, content they should expand on in their drafts, and how they could better describe or summarize their data and analyses. Specifically, from reading their peers’ drafts, students discussed how seeing their peers’ writing helped them revise for clarity in their own writing. One student, Phillip, also talked about how reading their peers’ responses helped them better understand the assignment itself, which led them to build additional connections that supported their final argument.

Five students also talked about making revisions due to feedback from the writing fellows affiliated with the MWrite WTL assignments. Four of them attributed revisions to both feedback from the writing fellows and feedback they received from their peers. The feedback primarily involved suggestions that students add data to their analyses and revise how they presented their data or analysis.

Interestingly, six students discussed feedback from their peers that they chose not to follow. Mahvesh received conflicting reviews about the understandability of their language and chose not to revise, whereas Tamsyn disagreed with the feedback they received as they felt that their response was already sufficient. Three of the students chose not to follow some of the suggestions from their peers since they felt the suggested revisions would negatively impact their response; these suggestions involved removing or changing portions of their response that students felt were important for interpreting their analyses or argument. For example, Claire did not follow the specific suggestion they received, though they still revised their draft in response to it:

“For my analysis of a quantitative and categorical variable, someone said that my plot was confusing and I should get rid of the outliers, however, I ignored this because I believe that outliers are important to have and acknowledge. Instead, to try to make my analysis clearer I added numerical values to explain what I meant by ‘nearly all’ and ‘most.’”

This shows that Claire recognized the importance of outliers to their response, but still took the feedback into consideration and made a productive revision.

Six students also considered the intended audience when revising. They primarily described revising their response to make it more understandable for an audience with limited statistical knowledge. Mohsin demonstrated the importance of considering the intended audience when writing when they said:

“From the peer review of Q1 and the office hour, I add more information about the center and shape of the graph and list more data, such as Q1, Q3, and IQR. I think suggestions are really helpful because missing information can negatively impact the audience to understand the whole picture of price.”

Comparatively, Phillip received a suggestion to add calculations to their memo but felt that the audience given in the assignment would not benefit from the addition and so chose to not revise. Interestingly, despite the lack of emphasis on the audience in the peer review rubric and from comments by the writing fellows, students seemed to place an importance on this aspect of the assignment.

Students also reflected on how they benefited from engaging in the peer review process, where both affect and reflection are important components of the revision process. Five students explicitly expressed positive experiences with the peer review process. Dave’s description of the benefits captured the positive affect similarly expressed by their peers:

“After reading my peer reviews I was definitely able to make some meaningful changes. . . . Overall, reading my reviews and reviewing others’ memorandums helped me make my memorandum a lot more specific and professional, as I could take advice and inspiration from my peers.”

All of the five students described finding the suggestions and feedback they received from their peers to be helpful for revising their drafts. Two of the students, Dave and Yael, additionally mentioned that reading their peers’ draft was beneficial. Furthermore, six students explicitly engaged in metacognitive reflection on how the peer review process impacted their response to the assignment. Three of these focused

on how they were able to improve their argument due to feedback they received from their peers. Anne said:

“The second part of my recommendations showed me that although I understood outliers, I did not understand the analytical importance of including them in my thought process and reasoning. After going back to where I was told I ignored the outliers, I was actually able to use them to create a more nuanced argument about the data I provided.”

As described above, Mohsin reflected on how they added content when they revised as they realized its importance for the audience to be able to understand their memo. Two students, Phillip and Marcie, demonstrated metacognition arising from reading their peers' drafts: Phillip described better understanding the assignment, and Marcie discussed adding reasoning to their draft due to seeing peers arguing counter to one of the analyses they had performed.

Discussion

Our results indicate that students thoughtfully engaged with peer review and revision during the WTL process situated in a STEM context. Students' revision reflections contained nuanced descriptions of the revisions they made and why, providing useful insight into students' revision process. As seen across the three cases, students described both specific revisions they made and what elements of the process informed the specific revisions. Our analysis furthers research on WTL by providing insight into how students use the information garnered from the peer review process to inform their revisions; it also aligns with the aims of WTL, which focuses on content rather than the ability to write (Gere et al., 2019).

Our findings also expand on the existing literature on benefits of peer review for writing by demonstrating the types of higher-order revisions students made when focusing on their argument and related concepts. Students described revising the arguments they presented in their responses, their statistical analyses and explanations thereof, and their responses in general to enhance clarity. Most of the students described revising their argument and reasoning in their revision reflections, which was a primary aim of the assignment as the ability to translate statistical findings within a data set to applicable recommendations for a client is an important aspect of the statistics discipline. This aligns with WTL research generally, which indicates that WTL can support students to engage in higher-order thinking and application of content that is known to be difficult for them (Gere et al., 2019; Nevid et al., 2017). It is promising that students identified revising their arguments and reasoning primarily due to receiving feedback from their peers and indicates that peer review can also support this skill in STEM disciplinary contexts.

Our findings indicate that students recognized that both aspects of peer review informed their revisions and that they viewed the experience in a positive light. The ubiquity of student revisions due to feedback, in conjunction with the complexity of the types of revisions they made (e.g., on the argumentation and analysis levels) indicates that students were constructively engaging with feedback from their peers. This contrasts with other studies focused on student revisions due to receiving feedback, which indicated that not all students use feedback to revise (Leijen and Leontjeva, 2012; Lu et al., 2023). Students also described how reading and providing feedback led them to engage in metacognitive reflection on their own writing. This aligns with prior peer review literature which indicates that students benefit from both receiving feedback and being the reviewer (Cho and Cho, 2011; Cho and MacArthur, 2011; Lundstrom and Baker, 2009; Zhang et al., 2017). However, our finding that students themselves recognized the benefits from both aspects of peer review is less common (Nicol et al., 2014). Thus, our findings may indicate that tasks such as the revision reflections support students to recognize the benefits of both aspects of the peer review process more fully when they revise.

Limitations and Implications

Our findings are bounded by the course and self-selected set of students from which we gathered data, which limits the claims we can make from this study. Additionally, students' responses to the revision reflection may have been shaped by the students' knowledge that they had agreed to participate in this study or by the prescribed nature of the reflections (i.e., students may have attempted to demonstrate that they engaged in the processes expected by the instructor). While the revision reflections were prescriptive, in this context it may further support the structure of the assignment as a whole: if directing students to comment on their revisions led students to consider and utilize information from the peer review process as they revised when they might not have otherwise, then the revision reflections played a useful role. In alignment with an interpretivist paradigm, we recognize that our analysis of students' reflections was informed by our positionality (i.e., our varying degrees of familiarity with the WTL process and the statistical concepts covered). However, our methodology, through which we engaged in reflexivity and discussion as a research team, allowed for an in-depth exploratory analysis that can inform future analyses.

This study provides an initial exploration of what students wrote about in revision reflections associated with a WTL assignment that incorporated peer review and revision. A key next step is to compare students' revisions when they do and do not write revision reflections in order to identify whether incorporating revision reflections enhances their engagement with and utilization of the peer review process. Furthermore, we found that some students engaged in explicit metacognitive reflection

in their revision reflections. It is important to understand how metacognitive reflection was elicited by the revision reflections as opposed to arising naturally through the act of participating in the peer review process. Related, it is worth examining how modifications to the assignment or learning environment could support increased metacognitive reflection from students, as it is an important part of learning.

While we found that students only expressed positive views of peer review, prior research indicates that students have mixed perceptions (Huisman et al., 2018; Kaufman and Schunn, 2011; Nicol et al., 2014; Strijbos et al., 2010). This indicates research focused on how the assignment or feedback structure shapes students' affective experiences is needed. Furthermore, the alignment between feedback from writing fellows and peers seen here indicates a potential avenue for addressing students' negative perceptions of the peers' abilities (i.e., alignment between the two sets of feedback could reinforce peers' feedback and serve as an indicator of peers' abilities to provide meaningful feedback). Interestingly, students attributed some revisions to consideration of the rhetorical audience, even though it was not emphasized in the assignment or by the writing fellows. This finding aligns with prior MWrite research and indicates the importance of connecting the audience with the learning goals of the assignment (i.e., linking what we want students to be writing about to the depth of detail we want them to provide). Overall, students' revision reflections were a useful tool for capturing their thoughts and revision process, and our examination indicates the merit of using revision reflections to support students' engagement and reflection with peer review and revision.

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References

- Adler-Kassner, L., Clark, I., Roberston, L., Taczak, K., & Yancey, K. B. (2016). Chapter 1: Assembling knowledge: The role of threshold concepts in facilitating transfer.
- Anderson, P., Anson, C. M., Gonyea, R. M., & Paine, C. (2015). The contributions of writing to learning and development: Results from a large-scale multi-institutional study. *Research in the Teaching of English*, 50(2), 199–235. <https://doi.org/https://doi.org/10.1002/tea.3660310910>

- Anson, I. G., & Anson, C. M. (2017). Assessing peer and instructor response to writing: A corpus analysis from an expert survey. *Assessing Writing*, 33, 12–24. <https://doi.org/https://doi.org/10.1016/j.asw.2017.03.001>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Chang, C. Y. (2016). Two decades of research in L2 peer review. *Journal of Writing Research*, 8(1), 81–117. <https://doi.org/10.17239/jowr-2016.08.01.03>
- Cho, Y. H., & Cho, K. (2011). Peer reviewers learn from giving comments. *Instructional Science*, 39(5), 629–643. <https://doi.org/10.1007/s11251-010-9146-1>
- Cho, K., & MacArthur, C. (2010). Student revision with peer and expert reviewing. *Learning and Instruction*, 20(4), 328–338. <https://doi.org/https://doi.org/10.1016/j.learninstruc.2009.08.006>
- Cho, K., & MacArthur, C. (2011). Learning by reviewing. *Journal of Educational Psychology*, 103(1), 73–84. <https://doi.org/10.1037/a0021950>
- Cho, K., Schunn, C. D., & Charney, D. (2006). Commenting on writing: Typology and perceived helpfulness of comments from novice peer reviewers and subject matter experts. *Written Communication*, 23(3), 260–294.
- Finkenstaedt-Quinn, S. A., Halim, A. S., Kasner, G., Wilhelm, C. A., Moon, A., Gere, A. R., & Shultz, G. V. (2020). Capturing student conceptions of thermodynamics and kinetics using writing. *Chemistry Education Research and Practice*, 21(3), 922–939. <https://doi.org/10.1039/C9RP00292H>
- Finkenstaedt-Quinn, S. A., Polakowski, N., Gunderson, B., Shultz, G. V., & Gere, A. R. (2021). Utilizing peer review and revision to support the development of conceptual knowledge through writing. *Written Communication*, 38(3), 351–379. <https://doi.org/https://doi.org/10.1177/07410883211006038>
- Finkenstaedt-Quinn, S. A., Snyder-White, E. P., Connor, M. C., Gere, A. R., & Shultz, G. V. (2019). Characterizing peer review comments and revision from a writing-to-learn assignment focused on Lewis structures. *Journal of Chemical Education*, 96(2), 227–237. <https://doi.org/10.1021/acs.jchemed.8b00711>
- Finkenstaedt-Quinn, S. A., Watts, F. M., Gere, A. R., & Shultz, G. V. (2023). A portrait of MWrite as a research program: A review of research on writing-to-learn in STEM through the MWrite Program. *International Journal for the Scholarship of Teaching and Learning*, 17(1), Article 18. <https://doi.org/10.20429/ijstol.2023.17118>
- Finkenstaedt-Quinn, S. A., Watts, F. M., & Shultz, G. V. (2024). Reading, receiving, revising: A case study on the relationship between peer review and revision in writing-to-learn. *Assessing Writing*, 59. <https://doi.org/https://doi.org/10.1016/j.asw.2024.100808>
- Flower, L., Hayes, J. R., Carey, L., Schriver, K., & Stratman, J. (1986). Detection, diagnosis, and the strategies of revision. *College Composition and Communication*, 37(1), 16–55. <https://doi.org/10.2307/357381>

- Gere, A. R., Limlamai, N., Wilson, E., Saylor, K. M., & Pugh, R. (2019). Writing and conceptual learning in science: An analysis of assignments. *Written Communication*, 36(1), 99–135. <https://doi.org/10.1177/0741088318804820>
- Gupte, T., Watts, F. M., Schmidt-McCormack, J. A., Zaimi, I., Gere, A. R., & Shultz, G. V. (2021). Students' meaningful learning experiences from participating in organic chemistry writing-to-learn activities. *Chemistry Education Research and Practice*, 22, 396–414. <https://doi.org/10.1039/D0RP00266F>
- Halim, A. S., Finkenstaedt-Quinn, S. A., Olsen, L. J., Gere, A. R., & Shultz, G. V. (2018). Identifying and remediating student misconceptions in introductory biology via writing-to-learn assignments and peer review. *CBE - Life Sciences Education*, 17(2), Article 28. <https://doi.org/10.1187/cbe.17-10-0212>
- Hayes, J. R., Flower, L., Schriver, K. A., Stratman, J., & Carey, L. (1987). Cognitive processes in revision. *Advances in Applied Psycholinguistics*, 2, 176–240.
- Huisman, B., Saab, N., van den Broek, P., & van Driel, J. (2019). The impact of formative peer feedback on higher education students' academic writing: A meta-analysis. *Assessment & Evaluation in Higher Education*, 44(6), 863–880. <https://doi.org/10.1080/02602938.2018.1545896>
- Huisman, B., Saab, N., van Driel, J., & van den Broek, P. (2018). Peer feedback on academic writing: Undergraduate students' peer feedback role, peer feedback perceptions and essay performance. *Assessment & Evaluation in Higher Education*, 43(6), 955–968. <https://doi.org/10.1080/02602938.2018.1424318>
- Kaufman, J. H., & Schunn, C. D. (2011). Students' perceptions about peer assessment for writing: Their origin and impact on revision work. *Instructional Science*, 39(3), 387–406. <https://doi.org/10.1007/s11251-010-9133-6>
- Klein, P. D. (2015). Mediators and moderators in individual and collaborative writing to learn. *Journal of Writing Research*, 7(1), 201–214. <https://doi.org/10.17239/jowr-2015.07.01.08>
- Leijen, D. A. J., & Leontjeva, A. (2012). Linguistic and review features of peer feedback and their effect on implementation of changes in academic writing: A corpus based investigation. *Journal of Writing Research*, 4(2), 177–202. <https://doi.org/10.17239/jowr-2012.04.02.4>
- Lu, Q., Yao, Y., & Zhu, X. (2023). The relationship between peer feedback features and revision sources mediated by feedback acceptance: The effect on undergraduate students' writing performance. *Assessing Writing*, 56. <https://doi.org/https://doi.org/10.1016/j.asw.2023.100725>
- Lundstrom, K., & Baker, W. (2009). To give is better than to receive: The benefits of peer review to the reviewer's own writing. *Journal of Second Language Writing*, 18(1), 30–43. <https://doi.org/https://doi.org/10.1016/j.jslw.2008.06.002>
- Moon, A., Zotos, E., Finkenstaedt-Quinn, S. A., Gere, A. R., & Shultz, G. V. (2018). Investigation of the role of writing-to-learn in promoting student understanding of

- light-matter interactions. *Chemistry Education Research and Practice*, 19(3), 807–818. <https://doi.org/10.1039/C8RP00090E>
- Moore, J. L., & Felten, P. (2019). Understanding writing transfer as a threshold concept across the disciplines. In J. A. Timmermans & R. Land (Eds.), *Threshold concepts on the edge* (pp. 341–352). Brill. https://doi.org/https://doi.org/10.1163/9789004419971_024
- National Research Council. (2012). *Discipline-Based education research: Understanding and improving learning in undergraduate science and engineering*. The National Academies Press. <https://doi.org/10.17226/13362>
- Nevid, J. S., Ambrose, M. A., & Pyun, Y. S. (2017). Effects of higher and lower level writing-to-learn assignments on higher and lower level examination questions. *Teaching of Psychology*, 44(4), 324–329. <https://doi.org/10.1177/0098628317727645>
- Nicol, D., & McCallum, S. (2022). Making internal feedback explicit: Exploiting the multiple comparisons that occur during peer review. *Assessment & Evaluation in Higher Education*, 47(3), 424–443. <https://doi.org/10.1080/02602938.2021.1924620>
- Nicol, D., Thomson, A., & Breslin, C. (2014). Rethinking feedback practices in higher education: A peer review perspective. *Assessment & Evaluation in Higher Education*, 39(1), 102–122. <https://doi.org/10.1080/02602938.2013.795518>
- Patchan, M. M., Charney, D., & Schunn, C. D. (2009). A validation study of students' end comments: Comparing comments by students, a writing instructor, and a content instructor. *Journal of Writing Research*, 1(2), 124–152. http://www.jowr.org/abstracts/vol1_2/Patchan_et_al_2009_1_2_abstract.html
- Petterson, M. N., Finkenshaedt-Quinn, S. A., Gere, A. R., & Shultz, G. V. (2022). The role of authentic contexts and social elements in supporting organic chemistry students' interactions with writing-to-learn assignments. *Chemistry Education Research and Practice*, 23, 189–205. <https://doi.org/https://doi.org/10.1039/D1RP00181G>
- Reynolds, J. A., Thaiss, C., Katkin, W., & Thompson, R. J. (2012). Writing-to-learn in undergraduate science education: A community-based, conceptually driven approach. *CBE - Life Sciences Education*, 11(1), 17–25. <https://doi.org/10.1187/cbe.11-08-0064>
- Schmidt-McCormack, J. A., Judge, J. A., Spahr, K., Yang, E., Pugh, R., Karlin, A., Sattar, A., Thompson, B. C., Gere, A. R., & Shultz, G. V. (2019). Analysis of the role of a writing-to-learn assignment in student understanding of organic acid-base concepts. *Chemistry Education Research and Practice*, 20(2), 383–398. <https://doi.org/10.1039/C8RP00260F>
- Scott, T. (2005). Creating the subject of portfolios: Reflective writing and the conveyance of institutional prerogatives. *Written Communication*, 22(1), 3–35. <https://doi.org/10.1177/0741088304271831>
- Strijbos, J.-W., Narciss, S., & Dünnebie, K. (2010). Peer feedback content and sender's competence level in academic writing revision tasks: Are they critical for feedback

- perceptions and efficiency? *Learning and Instruction*, 20(4), 291–303. <https://doi.org/https://doi.org/10.1016/j.learninstruc.2009.08.008>
- Watts, F. M., Finkenstaedt-Quinn, S. A., & Shultz, G. V. (2024). Examining the role of assignment design and peer review on student responses and revisions to an organic chemistry writing-to-learn assignment. *Chemistry Education Research and Practice*, 25, 721–741. <https://doi.org/10.1039/D4RP00024B>
- Watts, F. M., Park, G. Y., Petterson, M. N., & Shultz, G. V. (2022). Considering alternative reaction mechanisms: Students' use of multiple representations to reason about mechanisms for a writing-to-learn assignment. *Chemistry Education Research and Practice*, 23, 486–507. <https://doi.org/10.1039/D1RP00301A>
- Wu, Y., & Schunn, C. D. (2020). The effects of providing and receiving peer feedback on writing performance and learning of secondary school students. *American Educational Research Journal*, 58(3), 1–35. <https://doi.org/10.3102/0002831220945266>
- Zhang, F., Schunn, C. D., & Baikadi, A. (2017). Charting the routes to revision: An interplay of writing goals, peer comments, and self-reflections from peer reviews. *Instructional Science*, 45(5), 679–707. <https://doi.org/10.1007/s11251-017-9420-6>

Appendix

Table 2.
Coding of revision reflections.

Parent Code	Child Code	Definition	Exemplar
Type of change	Added missing content	Student describes adding content descriptions or analyses.	"Finally, a recommendation was that I should give a couple more characteristics throughout my memorandum, so I tried including a couple I knew would relate to my conclusion." - Axie
	Fixed incorrect content	Student describes fixing incorrect content or analyses.	"Comments on the axis of the grouped bar chart pointed out my mistake." - Lois
	Explanation	Student describes adding or revising explanations (descriptive, lower-order).	"Doing peer reviews helped me see how others summarized their data. This helped me reword my statistical summaries." - Mahvesh
	Reasoning/argument	Student describes making changes to their reasoning and/or final argument/summary (causal, higher-order).	"My peers suggested [I] include some ratio or percentage . . . which can support my argument." - Sequoia
	Clarity	Student describes making clarity-related revisions.	"I . . . saw where I had trouble explaining my points in a concise but compelling manner." - Claire
	Grammar/structure	Student describes making grammatical or structural (e.g., adding an intro, making text more concise) changes.	"I can learn from their sentence structure that analyzes the data." - Stephen
Source of revision	Peer feedback	Student mentions how feedback they received from their peer(s) influenced their revisions or revision process.	"My peers had suggested a change to take out a lot of heavy worded sentences and to provide more application to the hotels throughout the memorandum." - Tamsyn
	Reading and providing feedback	Student mentions how reading their peers' drafts and/or giving feedback influenced their revisions or revision process.	"I also think that giving out revisions was important because it gave me more ideas as to what to put in my paper." - Andy
	Writing fellows/office hours	Student mentions writing fellows or attending office hours influencing their revisions or revision process.	"Based on the feedback from my peers and writing fellow . . ." - Nalo

Parent Code	Child Code	Definition	Exemplar
Evaluation	Did not make a suggested change	Student states that they did not make a change suggested to them.	"For the side-by-side box plot, I don't make any changes though it was mentioned in the comment." - Maia
	Reflection/metacognition	Student reflects on their own writing/analysis from going through the peer review or revision processes (e.g., gains new perspective).	"I never thought of my analysis in this perspective." - Alexis
	Mentions revisions for audience	Student discusses making revisions with the prompt audience in mind.	"Also, I add explanations of Q3 and IQR for audiences with minimum statistical knowledge." - Mohsin
	Affective comment	Student makes a positive or negative affective comment about the peer review process.	"The peer reviews definitely helped me get started in the right direction." - Emily