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Reading, receiving, revising: A case study on the relationship between peer review and revision in writing-to-learn

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ABSTRACT

Studies examining peer review demonstrate that students can learn from giving feedback to and receiving feedback from their peers, especially when they utilize information gained from the review process to revise. However, much of the research on peer review is situated within the literature regarding how students learn to write. With an increasing use of writing-to-learn in STEM classrooms, it is important to study how students engage in peer review for these types of writing assignments. This study sought to better understand how peer review and revision can support student learning for writing-to-learn specifically, using the lenses of cognitive perspectives of writing and engagement with written corrective feedback. Using a case study approach, we provide a detailed analysis of six students' written artifacts in response to a writing-to-learn assignment that incorporated peer review and revision implemented in an organic chemistry course. Students demonstrated a range in the types of revisions they made and the extent to which the peer review process informed their revisions. Additionally, students exhibited surface, mid-level, and active engagement with the peer review and revision process. Considering the different engagement levels can inform how we frame peer review to students when using it as an instructional practice.

1. Introduction

Feedback is a powerful tool for supporting student achievement that is traditionally given by an instructor or teaching assistant. There are many approaches to feedback across higher education (e.g., formative versus evaluative feedback) with variable results and levels of student satisfaction (Boud & Molloy, 2013; Hattie & Timperley, 2007; Price et al., 2011). In part, the variable outcomes may arise from the view of feedback as transmission of information from instructors to students. Recently, feedback has been reconceptualized as a process whereby students actively use the feedback they receive. In this conceptualization, students can use feedback to identify gaps in their knowledge, then use that information to enhance their learning (Hattie & Timperley, 2007; Price et al., 2011; Shute, 2008). As such, recent research focuses on effective feedback practices and understanding how students view and use the feedback they receive (Boud & Molloy, 2013; Dawson et al., 2021; Sutton, 2012). For example, feedback is typically most effective when students have an active role in the feedback process (such as participating in peer review) and have the opportunity to use the feedback they receive (Carless & Boud, 2018; Henderson et al., 2019).

Peer review has received increasing attention in the literature as an effective feedback practice (Topping, 2009). In addition to the

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benefits associated with receiving feedback, students also benefit from providing feedback. Through providing feedback, students can attain a sense of control over their learning, are involved in a more discursive feedback process, and may be prompted to engage in metacognition about their work (Nicol et al., 2014; Nieminen et al., 2022). This study examines the ties between the artifacts students interact with during peer review and the revisions they make in a writing-to-learn (WTL) context.

2. Literature review

2.1. Peer review in the context of writing

With respect to writing in the classroom, much of the research on peer review is centered around learning-to-write, where peers provide feedback on writing quality rather than content. The literature indicates that students can provide feedback similar in quality to instructors and that students who receive feedback from multiple peers make more meaningful revisions than those who receive feedback from a single instructor (Anson & Anson, 2017; Cho & MacArthur, 2010; Patchan et al., 2009). Additionally, research indicates that students gain more from giving feedback than from receiving feedback (Cho & MacArthur, 2011; Cho & Cho, 2011; Huisman et al., 2018; Lundstrom & Baker, 2009; Nicol & McCallum, 2022; Nicol et al., 2014). Despite the benefits of peer feedback, students have mixed perceptions about its helpfulness (Brammer & Rees, 2007; Huisman et al., 2018; Kaufman & Schunn, 2011; Yu et al., 2020; Zong et al., 2021). In Nicol et al. (2014), where students expressed more positive perceptions of peer review, students viewed receiving feedback as helpful for identifying what they are missing and how their writing might be interpreted differently from intended, whereas they perceive providing feedback to help them think critically and evaluate their own responses.

Less research focuses on the role peer feedback plays in writing pedagogies targeting conceptual learning, i.e. WTL, especially within an undergraduate STEM context (Winstone et al., 2017). In STEM courses, peer feedback can be beneficial for supporting learning via laboratory-style writing, disciplinary writing, and context-based writing assignments (Cox, Poehlmann, Ortega, & Lopez, 2018; Finkenstaedt-Quinn, Watts, Gere, & Shultz, 2023; Russell, 2013). Initial research indicates that students can provide meaningful, constructive, content-focused feedback to their peers that can lead to content-focused revisions (Finkenstaedt-Quinn, Snyder-White, Connor, Gere, & Shultz, 2019; Finkenstaedt-Quinn et al., 2020; Halim et al., 2018; Moon et al., 2018). Additionally, both reading peers' drafts and receiving feedback have been tied to content-focused revisions (Finkenstaedt-Quinn et al., 2021; Watts et al., 2022).

2.2. Theoretical perspectives on writing and feedback processes

This study is guided by cognitive perspectives of writing (i.e. the cognitive process theory of writing and theory of distributed cognition; Flower & Hayes, 1981; Hayes, 1996; Klein et al., 2015, 2012; Zhang & Patel, 2006) and theories of engagement (Fredricks et al., 2004, 2016; Han & Hyland, 2019). The cognitive process theory of writing and theory of distributed cognition capture the internal processes of writing and external influences that guide what students write. Comparatively, the theories of engagement capture the cognitive, behavioral, emotional, and social elements tied to the learning process that can influence how a student interacts with an instructional practice. These lenses provide a framework for gauging students' interactions with aspects of the feedback process, which lends explanatory power to how students approach both peer review and revision.

The cognitive process theory of writing characterizes writing as a cyclical process informed by internal and environmental influences (Hayes, 1996; Klein et al., 2015, 2012). The internal influences consist of the cognitive processes involved in writing, the writer's working and long-term memory, and motivational or affective considerations. The environmental influences consider how the social nature of writing (e.g., the audience and other individuals involved in the writing process) may influence decisions the writer makes throughout the writing process. The theory of distributed cognition complements the cognitive process theory of writing by considering cognition as extending beyond the individual to incorporate external representations of knowledge, such as written artifacts, and knowledge from people with whom the individual interacts. The writing process can thus be supported by interactions with the artifacts or other people. In this way, distributed cognition posits that learning can occur as the writer incorporates knowledge gained from direct and indirect social interactions as they develop their own understanding of a subject. Thus, through consideration of both theories, we can conceptualize how students' thinking may develop as they engage in peer review, and how these developments may be reflected through peer review and revision artifacts.

It is also important to consider students' engagement with the peer review process, which indicates how students utilize the structured peer interactions as they consider their own writing and thus its relative value for students' learning. Applied to written corrective feedback, Han and Hyland (2019) utilize a three dimensional definition of engagement (cognitive, emotional, and behavioral) that is situated within the sociocognitive perspective. The sociocognitive perspective recognizes learning as a socially mediated process where students interact directly or indirectly with their peers. Relative to written corrective feedback, Han and Hyland (2019) define cognitive engagement as students' levels of processing and metacognitive activity as they use and consider feedback. Behavioral engagement is represented by the level of revisions and strategies that students apply during revision. Lastly, emotional engagement is students' affective responses to the feedback (e.g., attitude towards the feedback) and how they manage those responses. Considering students' engagement with peer review can inform our understanding of the utility of peer feedback for supporting learning through WTL.

These theoretical perspectives suggest how, within the context of WTL, as students go through the cognitive process of writing, they draw on their working and long-term memory related to course content. During peer review, students may gain knowledge from external representations of their peers' knowledge by engaging with the structured indirect social interactions afforded by an asynchronous peer review process, in alignment with distributed cognition. In this way, both the written feedback that students receive and their peers' initial drafts may inform students' revisions. In a similar way, the external representations generated throughout the WTL process may serve as artifacts that we, as researchers, can use to identify students' thinking as they encounter points of conflict or agreement with their peers, as theorized by cognitive perspectives of writing (Hayes, 1996; Klein et al., 2015, 2012). Additionally, the written artifacts also inform our understanding of students' level of engagement, as theorized by Han and Hyland's (2019) description of engagement applied to written corrective feedback. Thus, by examining the written artifacts from the WTL process, supported by student survey responses, we can further understand how students negotiate the peer review process.

2.3. Study aims

This study extends the existing literature on the benefits of peer review (i.e. reading peers' drafts, providing feedback, and receiving feedback) within the context of WTL in STEM by examining how the structured peer interactions which occur during peer review influence students' revisions. The prior research focuses on changes in outcomes (e.g., using an external assessment or by scoring students' writing before and after peer feedback) rather than examining the actual written artifacts (e.g., peer feedback and revisions students make) arising from the process (Nicol & McCallum, 2022; Winstone et al., 2017). As such, this research addresses the limitations of the existing research by providing a focused examination of student written artifacts arising from a WTL assignment that incorporated peer review and revision.

To better understand the mechanisms through which students engage in peer review in the WTL context, we sought to investigate how students used the structured peer interactions facilitated by peer review as they revised their explanations and reasoning. This study draws on student artifacts from a WTL assignment implemented in an introductory organic chemistry laboratory II course (i.e., students' initial and revised drafts, peer feedback, drafts read). The following research question guided this study:

How do students demonstrate engagement with the peer review process as revealed by the written artifacts from the WTL process (i.e., the types of revisions, the relationship of revisions to peer review comments received and drafts read, and the nature of peer review comments they gave)?

3. Methods

3.1. Study overview

This study is a descriptive case study of written artifacts from a WTL assignment in an introductory organic chemistry II laboratory course. In alignment with cognitive perspectives of writing where the written artifacts serve as external representations of students' knowledge and their writing processes, the focus of the analysis is on the written artifacts related to the WTL process (i.e., peer feedback and revision) for six students. The artifacts include students' written responses to the assignment (initial and revised drafts),

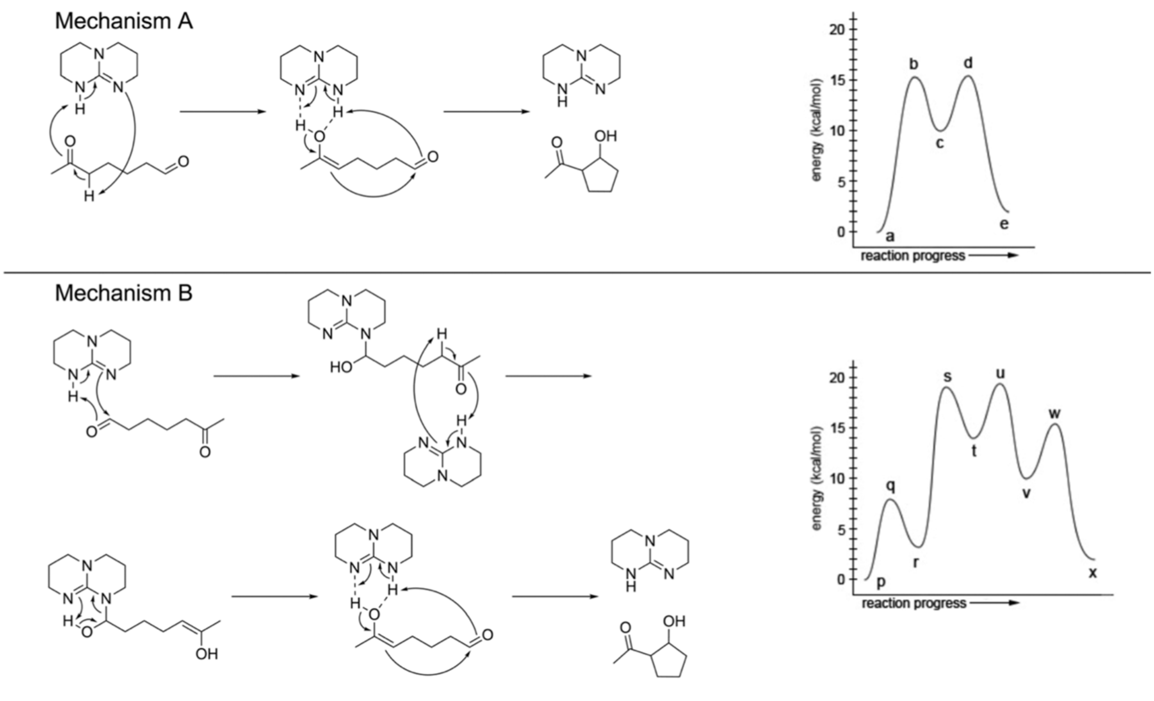

Fig. 1. The two mechanisms, and corresponding RCDs, that were the focus of the WTL assignment. Students were asked to describe each mechanism and RCD, select which mechanism was most likely to occur, and provide a justification thereof.
Figure used with permission from Watts et al, (2022).

the initial drafts they read, the feedback they gave, and the peer feedback they received. Furthermore, student survey responses about the assignment collected from the broader population of students in the course serve as supporting data. By analysing the written artifacts related to the WTL process via a descriptive case study, we gain an in-depth perspective of the relationship between peer review and students' revisions for a writing assignment focused on conceptual learning and disciplinary thinking. This study is considered exempt by the institutional review board. Student consent was obtained to use the data included in this study, and all data had been previously de-identified. Pseudonyms are used throughout and were assigned without knowledge of demographic information.

3.2. Overview of the WTL task

The MWrite Program supports the implementation of WTL into introductory STEM courses at the University of Michigan. The aim of the WTL assignments is to support students' conceptual learning and disciplinary thinking. The assignments consist of students writing an initial draft, undergoing peer review, and revising their writing. Students are given a rhetorical situation to which they respond (i.e., an authentic scenario, audience, role, and genre) and the expectations for what they should include in their response. Students have a week to draft an initial response based on their understanding of the targeted content, and they are allowed to consult any external resources to aid in their writing. After submitting their initial draft, students have half a week to provide feedback on their peers' responses. Peer review occurs online, is asynchronous, and blinded. The peer review is structured such that students read, on average, three of their peers' initial drafts to which they provide feedback. The feedback is guided by rubric criteria that direct students to comment on content related to the learning goals for the assignment. Following peer review, students receive the feedback on their initial drafts and then have half a week to revise. The MWrite WTL assignment design was developed in alignment with evidence-based effective elements of WTL (Anderson et al., 2015; Gere et al., 2019; Klein, 2015) and the benefits of peer feedback (e.g., Cho & MacArthur, 2010; Nicol et al., 2014; Topping, 2009).

This study utilizes student artifacts from the third and final WTL assignment incorporated into an organic chemistry II laboratory course to create the cases subject to analysis. Students in this course are primarily junior and sophomore STEM majors. The full prompt and peer review criteria for the assignment are presented in Appendix A. This assignment placed students in the role of a lab technician working for Doctors without Borders, and students were given the drawn mechanisms and reaction coordinate diagrams (RCDs) for two mechanisms by which a reaction could occur (Fig. 1). The assignment asked students to 1) describe the two mechanisms, 2) relate the mechanisms to the RCDs, and 3) determine which of two mechanisms was more likely to occur. The peer review criteria covered students' mechanistic and RCD descriptions, their choice of the most likely mechanism, and their justification thereof.

3.3. Case selection and building

Case selection was informed by previous research on students' responses to the assignment central to this study (Watts et al., 2022). In their analysis, Watts et al. (2022) identified the mechanism students chose as most likely in their initial and revised drafts, and quantitatively analysed points of agreement and disagreement between students in the peer review process. For this study, six students were selected by examining the prior analysis to identify what peer review and revision interactions were cases of interest (Given, 2008). We sought to identify cases with variations across students' choices of the most likely mechanism from initial to revised draft (e.g., identifying students who did not revise their choice of most likely mechanism versus students who did revise their choice of most likely mechanism). We additionally sought to capture a variety of peer interactions (e.g., identifying students who experienced conflicting versus concordant feedback via the peer reviews they received and drafts they read). To identify the cases for this study, we first selected a random subset of students who had and had not revised their choice of most likely mechanism between the two drafts. For each of those subsets we then examined whether the peer interactions would have presented students with conflicting, concordant, or a mix of feedback regarding their choice of mechanism. We then identified six representative cases which reflected the range of revisions and peer interactions identified across the dataset (Table 1). For example, Laurell was selected as they did not revise their choice of most likely mechanism yet most of their peer interactions were conflicting with their mechanism choice. Comparatively, Seanan was selected as they did revise their choice of most likely mechanism despite most of their peer interactions being in concordance with the mechanism choice in their initial draft.

Each case consisted of a student's initial and revised draft, the peer feedback the student received, and the initial drafts the student read with the feedback they provided, for a total of 8 or 9 documents per case. Two researchers individually read all artifacts associated

Table 1
Overview of students' revisions and peer review interactions across cases.

Pseudonym	Revisions		Agreement		Feedback Given
	Mechanism choice	Other	Peer review	Drafts read	
Laurell	B → B	Clarification, Description	4 disagree	2 disagree, 1 agree	Minor
Joel	B → B	Clarification	1 disagree, 1 agree, 1 neutral	2 disagree, 1 agree	Substantive
Lavie	B → A	Description, Justification	2 disagree, 1 neutral	1 disagree, 2 agree	Substantive
Chandler	A → A	Clarification, Description, Justification	3 agree	2 disagree, 1 agree	Substantive
Sylvain	B → A	Description, Justification	1 disagree, 1 agree, 1 neutral	3 disagree, 0 agree	Substantive
Seanan	A → B	Description, Justification	1 disagree, 2 agree	1 disagree, 2 agree	Substantive

with each case. They wrote memos about the student's justifications for their choice of most likely mechanism, the types of revisions they made (i.e., clarification, description, argument, and justification), the characteristics of the peer feedback they received and gave, and the characteristics of the papers they read (e.g., justification for the most likely mechanism, features of mechanistic descriptions). The memos focused on the features related to the students' revisions. The two researchers then read each other's memos, made comments, and discussed any differences in interpretations. The two researchers then wrote profiles for the six cases, which included an overview of the students' choice of the most likely mechanism from initial to final draft, other pertinent details about students' initial and final drafts, and details about the drafts read, feedback given, and feedback received. The profiles were synthesized into case narratives, providing a cohesive summary of each case. Lastly, a researcher external to the project read all the student artifacts, profiles, and case narratives and made comments identifying any content they felt was missing or differences in interpretation. The three researchers then discussed the profiles and comments to create finalized profiles and case narratives for each case.

During analysis, the researchers noted variation in the types of revisions and the extent to which peer interactions may have informed the revisions. To capture this, each profile was characterized as surface, mid-level, or active engagement in alignment with the framework for engagement with written corrective feedback (Han & Hyland, 2019), where students' completion of their initial drafts, the extent to which they utilized the structured peer interactions when revising, and the apparent effort they placed in crafting constructive feedback for their peers were indicative of cognitive and behavioral engagement. The characterizations were confirmed by the second researcher.

3.4. Student survey

To support the case analysis, we examined students' responses to two questions on a survey administered following students' completion of the WTL assignment. Survey responses additionally served as an indicator of emotional engagement by capturing students' attitudes about peer review. The first question was a Likert scale question (*How helpful were the following resources when responding to this assignment?* - 'peer review comments you received', 'peer review comments you gave', and 'student drafts you read' among others with a scale ranging from 'did not use' to 'very helpful') and the second was a free response question (*Which resource(s) was most helpful and briefly explain how you used it?*). Of the 771 students who completed the course, 110 students responded to the Likert scale question and 103 responded to the free response question. Students' responses to the free response question were categorized by one of the researchers based on whether they identified an aspect of the WTL process (i.e., reading peers' drafts, receiving feedback, general). The responses that identified an aspect of the WTL process were further categorized based on what aspect of the process they identified (i.e., reading peers' drafts, receiving feedback, both, general). A second researcher then independently read through the responses and checked the categorizations; any discrepancies in the analysis were discussed and resolved. The coding scheme is presented in Appendix B. The responses were then thematically analysed (Braun & Clarke, 2006) by one researcher, who discussed the results with the second researcher.

3.5. Trustworthiness

We approached trustworthiness in alignment with the naturalistic approach described by Lincoln and Guba (1985). This included memoing, discussions with fellow researchers, discussion with researcher members in the group not affiliated with the project, and providing a rich description of our results. Additionally, we aim to provide transparency to our research process by describing our analysis processes and providing detailed case narratives (three in the body of the manuscript and the remaining three in Appendix C).

3.6. Limitations

The claims that can be made from this study are bounded by the nature of a case study and the exclusive use of written data. The case study approach allows an in-depth examination of how the structured peer interactions inform revision in the context of a WTL assignment and the differing extent to which students made use of these interactions. In alignment with an interpretivist paradigm, the findings are not generalizable beyond the context of the study but support an understanding of students' experiences within the MWrite Program context. Additionally, by focusing on student artifacts from the writing process, we cannot know why students are making certain decisions. However, the written artifacts are authentic with respect to the classroom setting and were not influenced by the research process. The student survey responses however may have been influenced by social desirability bias (i.e., students may have indicated more positive views of peer review and revision because they viewed it as the expected response).

4. Results – how do students demonstrate engagement with the peer review process as revealed by the written artifacts from the WTL process?

This study seeks to enhance the understanding of the role of peer review in WTL in STEM. The results present three abbreviated profiles from our case analysis, with findings supplemented by our analysis of student survey responses. Together, the findings describe students' writing processes and students' engagement with peer review through the WTL process.

4.1. Relationship between peer review and revision captured in the artifact analysis

Six cases were developed through comparing the writing produced during peer review and students' revisions for each case. In alignment with the cognitive perspectives of writing (i.e., cognitive process theory and distributed cognition), this analysis considered the social environment in which students were writing and how they may have drawn knowledge from their peers' written artifacts. The cognitive perspectives justify using students' written artifacts as external representations of students' knowledge and their internal negotiations during the writing process. We present three of the abbreviated case profiles that arose from the artifact analysis, with the abbreviated profiles for the other cases given in Appendix C. Exemplars of the types of feedback that students gave are presented in Appendix D. Table 1 presents the types of revisions, peer interactions, and constructive quality of the feedback given by each student for each of the cases.

4.1.1. Joel

Joel made very few sentence-level, clarification-focused revisions and did not change their selection of or justification for mechanism B as most likely, despite three disagreements with their selection (from two drafts they read and one reviewer). Of note, Joel's justification for selecting mechanism B indicated a misunderstanding of what is meant by the 'more likely' or 'favorable' mechanism. Specifically, Joel focused on evaluating which mechanism would be more selective for the desired final product, as opposed to evaluating which mechanism the reaction was more likely to follow. None of Joel's reviewers commented on the misunderstanding of the terms 'likely' and 'favorable.' Instead, two of the reviewers agreed with Joel's reasoning based on the energetics of the two mechanisms. One reviewer noted that they changed their mind about which mechanism is more likely from reading Joel's reasoning. This reviewer's comment may have supported Joel's decision not to revise their choice of the more likely mechanism. The reviewer and drafts that disagreed with Joel's selection provided similar reasoning to one another. However, the drafts by the peers that selected mechanism A may have held less weight for Joel, as one provided minimal descriptions of the mechanisms and RCDs while the other provided reasoning that may have been difficult to follow. Joel did make some revisions which reflected comments from two reviewers, though at a surface level. Joel did not make revisions in response to two of the reviewers' other comments, which suggested that Joel clarify their mechanistic descriptions. In the comments Joel gave, they thoroughly provided their reasoning for selecting mechanism B as the most likely.

4.1.2. Lavie

Lavie revised their choice of the most likely mechanism and justification thereof and made description-focused revisions to the rest of their draft (exemplars from Lavie's revisions and related peer interactions are presented in Fig. 2). Lavie revised their choice of the most likely mechanism, and their justification, from mechanism B to mechanism A. In their initial draft, Lavie's justification for mechanism B as the most likely mechanism was grounded in the idea that the reaction was irreversible, which allowed them to base their decision on the activation energy of the first mechanistic step. In their revised draft, Lavie stated that the reaction was reversible and would thus undergo mechanism A. Their justification was based on the smaller number of intermediates and overall lower energy barrier for the mechanism. During the peer review process, two of the drafts Lavie read agreed with Lavie's original choice of

Lavie's abbreviated combined initial and revised draft

The first mechanism (Mechanism A, figure 2) starts off with the electrons around a nitrogen on the TBD reaching out and deprotonating a hydrogen, allowing electrons from its bond to form a double bond with the carbon of the ketone. [...] Then the product e, a stable intramolecular aldol, is formed, completing this mechanism. The TBD catalyst is regenerated in the process.

Mechanism B (figure 4) starts out with a circular transfer of electrons in which the electrons in a nitrogen's double bond attack the carbon of the aldehyde on the starting material, letting the electrons from the C=O bond deprotonate another nitrogen on the TBD which lets electrons form a double bond (N=C). [...] This allows the electrons for the double bond in the ketone to deprotonate a nitrogen, the electrons from the former N-H bond forming a double bond. Intermediate t is formed, and the second molecule of TBD is regenerated. [...] The electrons from the former double bond of the attacked carbon are used to deprotonate a nitrogen, allowing those electrons to form a double bond. This creates stable product x, with TBD regenerated.

Due to the ~~irreversible~~ reversible nature of this reaction, ~~Mechanism B~~ Mechanism A is ~~most~~ more likely to occur than Mechanism B. ~~The energy required to reach transition state q is lower than that required to reach transition state b in Mechanism A. Because of this, most of the starting material will quickly be converted to intermediate r and due to irreversibility, will not be converted back to the starting material. Because most of the starting material will become intermediate r due to the lower energy, the reaction can only proceed in one direction – towards intermediate t of Mechanism B, making this the most likely mechanism.~~ This is due to the presence of less intermediates and lower barrier energies that enable the reaction to proceed with a higher likelihood than in mechanism B. If the reaction was irreversible, Mechanism B would be more likely to occur due to the low initial energy barrier which would cause all the starting material to become intermediate r. However, due to reversibility, intermediate r would be converted back to the starting material and eventually Mechanism A would proceed. Mechanism B is also less likely due to steric hinderance experienced by the molecule when TBD attaches to the molecule, causing protonation and deprotonation to become less likely and increasing the barrier energies. Overall, due to the reversibility of the reacting and the lower energy barriers experienced, Mechanism A is most likely to occur.

Peer interactions related to revisions

Revisions related to one draft read and one reviewer comment:

Draft reviewed 1: [In Mechanism A description] TBD catalyst is also regenerated.
[In Mechanism B description] The second molecule of TBD is also regenerated in this step. [...] This step forms the 5-carbon ring seen in the final product and TBD is regenerated.

Reviewer 1: Again, make sure to be specific when discussing different nitrogens and hydrogens, overall good job.

Revisions related to one draft read and three reviewer comments:

Draft reviewed 2: The pathway I believe is most likely to occur is pathway A. This pathway involves fewer steps and less activation energies to get through. [...] Additionally, the mechanism for pathway B attaches a TBD molecule to the original molecule, creating a bulkier molecular. This could create more steric hindrance to deprotonate and protonate the molecule.

Reviewer 1: I think that mechanism A is more favored because of the less intermediates and how these intermediates are less stable than in mechanism B which result in a pushing forward reaction that may not occur in B, the reaction may stop at the intermediate

Reviewer 2: I do not believe [Mechanism B] is a good choice because mechanism A is kinetically favored when compared to B due to the fact that it requires less activation energy to be carried out.

Reviewer 3: Would the author like to explain why [Mechanism B] is irreversible? What caused this reaction to be irreversible.

Fig. 2. Lavie's revisions and the related peer interactions. Orange strikethrough text and blue underlined text indicates text that Lavie removed and added to their draft, respectively. Green text is from drafts Lavie read related to their revisions and purple text is reviewer feedback related to Lavie's revisions.

mechanism B as most likely. Yet Lavie made revisions in alignment with the comments from the two reviewers and the draft they read advocating for mechanism A as the most likely reaction pathway. Additionally, Lavie's third reviewer suggested they explain why the reaction was irreversible, which may have prompted Lavie to reconsider this key aspect of their justification. The two drafts Lavie read that selected mechanism B as the most likely pathway used chemically incorrect justifications, and Lavie commented that both those peers should re-evaluate their justifications, which may have led Lavie to place less weight on these peer interactions. Lavie also made a few description-focused revisions, which may have come from one of the drafts they read, despite reviewer comments about their mechanistic and energetics descriptions. In general, Lavie provided constructive feedback to all their peers. Unlike Joel, Lavie's revisions were influenced by both the drafts they read and the feedback they received.

4.1.3. Sylvain

Sylvain revised their choice of the most likely mechanism and justification, moving from a focus on sterics and the lower activation energy of the first step of mechanism B towards considering the energy requirements of the mechanisms as a whole and the smaller catalyst requirement of mechanism A. Sylvain only had one peer interaction with an agreement with their selection of mechanism B as the most likely (from a reviewer) and the rest of Sylvain's peers indicated that they selected mechanism A, although one reviewer stated that Sylvain's reasoning was valid. Sylvain's revisions to their choice of the most likely mechanism and justification can be attributable to aspects from all three of the papers they read and one peer reviewer. Notably, Sylvain appears to have changed their thinking about the mechanism choice prior to submitting their peer reviews, as the comments Sylvain gave indicated different reasoning from that exhibited in their initial draft. Additionally, Sylvain provided thorough feedback to each of their peers on all the rubric criteria. Regarding revisions not associated with the mechanism choice, Sylvain appears to have modeled their revised response on the papers they read, which emphasized the mechanistic descriptions with less focus on the RCDs. Sylvain's revisions also aligned with the general feedback they received (i.e., to expand on their mechanistic descriptions and include more descriptions of electron movement).

4.2. Engagement demonstrated in the case profiles

The cases were also viewed through the lens of engagement with written corrective feedback (Han & Hyland, 2019). The types of revisions (i.e., clarification, description, argument, and justification), the relationship between the peer review process and the revisions, and the nature of the feedback each student provided to their peers were considered as indicating cognitive and behavioral engagement. Using this lens, students were inductively grouped into three levels of engagement (i.e., surface, mid-level, or active). Diagrams characterizing the peer interactions and students' choice of the most likely mechanism for the six cases are depicted in Fig. 3.

4.2.1. Surface engagement

Laurell and Joel demonstrated surface-level engagement at the cognitive and behavioral dimensions in the peer review process as indicated by the type (clarification and description) and small number of revisions, only drawing information from the feedback they

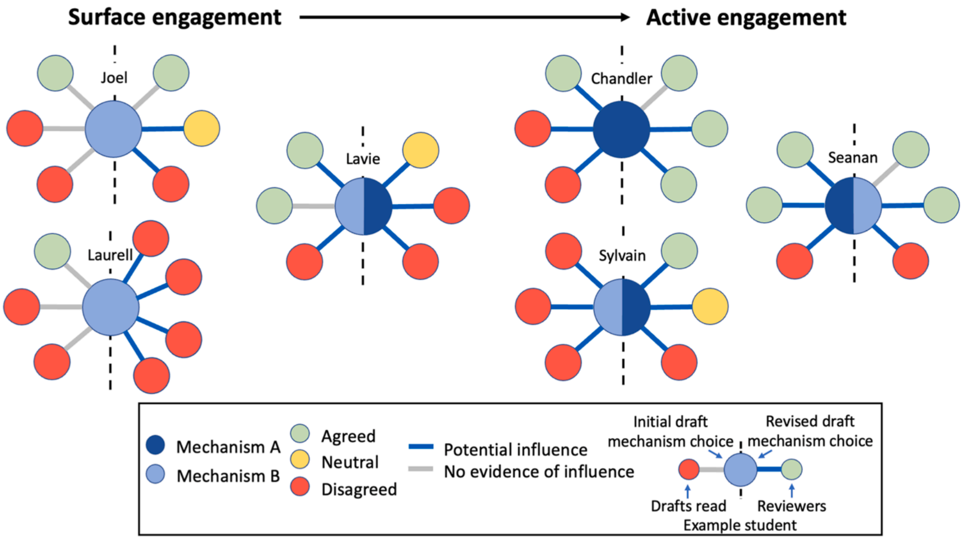

Fig. 3. Case interaction diagrams for the six cases ordered from surface to active interactions. Each student is represented by the middle circle in each diagram. The color of the left half of the circle indicates their initial draft choice and the color of the right half of the circle indicates their revised draft choice. The smaller surrounding circles indicate the peers they interacted with and the colors indicate whether the peer agreed (green) or disagreed (red) with their mechanism choice; neutral agreement (yellow) is where a reviewer said they chose a different mechanism from the student they reviewed, but found their peer's justification valid. Lastly, the lines connecting the peers to each student are colored to indicate evidence of a potential influence on the student's revisions (blue) or lack thereof (gray).

received, and providing minor to substantive feedback to their peers. In Laurell's case, the low level of demonstrated engagement is evidenced by the lack of revisions to their choice of the most likely mechanism and their justification despite six of the seven structured peer interactions that disagreed in reasoning and could have prompted Laurell to revisit their mechanism choice. Additionally, Laurell provided minimal reviewer comments indicating they were also minimally engaged in the act of providing feedback. Joel only made clarification-focused revisions to their draft, informed by the feedback they received; however, this may have been due to the thoroughness of the descriptions in Joel's initial draft. Unlike Laurell, Joel did provide comprehensive feedback to their peers. This indicates Joel may have engaged with the process of providing feedback but was less engaged in the revision portion of the WTL process.

4.2.2. Mid-level engagement

Lavie demonstrated mid-level of engagement with the peer review process. Lavie revised their selection of the most likely mechanism, and their justification thereof, and made a few description-focused revisions to other aspects of their draft. Overall, Lavie received positive comments from peers on their draft, which may have mitigated the impact of suggestions peers gave and internal feedback mechanisms triggered by reading peers' drafts. Lavie's revisions appeared to be primarily informed by the feedback they received rather than the drafts they read, exemplified by Lavie's change from selecting mechanism B as the most likely mechanism to mechanism A following receiving reviews (they stated their choice of and justification for mechanism B in the reviews they provided their peers). Lavie also provided constructive feedback to their peers. Thus while Lavie engaged with peer review (i.e., providing constructive feedback, using feedback they received to inform revisions), they still have potential for further engagement by utilizing the drafts they read to inform their revisions.

4.2.3. Active engagement

Sylvain, Seanan, and Chandler all demonstrated active engagement with the peer review process. Sylvain and Seanan both revised their choice of the most likely mechanism and justification, and their descriptions of the mechanisms. In both cases, the revisions appeared to be informed by both the drafts they read and the reviews they received. Sylvain's change in choice of the most likely mechanism appears to have occurred as they read their peers' drafts, which provides additional evidence that they were actively engaged during that aspect of the review process. Comparatively, despite not revising their choice of the most likely mechanism, Chandler revised their justification thereof. Chandler also extensively revised their mechanistic and RCD descriptions, and made clarity-focused revisions throughout their draft. Similar to Sylvain and Seanan, the changes Chandler made aligned with both feedback they received and the way content was presented in the drafts they read. Lastly, Sylvain, Seanan, and Chandler all provided their peers with substantive feedback, indicating that they were also engaged with this aspect of peer review. That three of the six cases demonstrated active engagement indicates that the structured WTL process can elicit the types of peer interactions that are beneficial to students in a feedback process.

4.3. Relationship between peer review and revision demonstrated in the survey

Analysis of students' survey responses provides additional insight into their emotional engagement with peer review and support the interactions observed in the case analysis. A Likert-scale question asked students to identify how helpful they found various resources for completing the WTL assignment. All of the students who responded to the question (N = 110) reported finding at least one aspect of peer review helpful (i.e., reading peers' drafts, giving feedback to peers, receiving feedback from peers). Of these, 21 students found two of the aspects helpful and 84 students found all three helpful. Overall, students found each aspect of peer review as very helpful or somewhat helpful (Table 2). Students also responded to an open-ended question which asked them to identify which resource was the most helpful and how. Of the 103 students who responded, 54 identified some aspect of the peer review process as the most helpful resource. Of these, three students mentioned the peer review process generally as being helpful, 26 viewed the drafts they read as the most helpful, 17 students viewed receiving feedback as the most helpful, and 8 students identified both the drafts they read and receiving feedback as the most helpful resources. The other students identified interactions with peers and writing fellows or other resources (e.g., course resources) as the most helpful. The responses to both questions demonstrate the value students place on peer review, which indicates positive emotional engagement with the peer review component of the WTL process.

Analysis of students' responses to the open-ended survey question also captured how students perceived the social environment created by the WTL assignments as influencing their writing process, in alignment with the interactions captured in the case analysis. Students described two primary ways in which they perceived reading their peers' drafts and receiving feedback from their peers as informing their revision process. First, students identified that both reading drafts and receiving feedback provided them with additional perspectives to which they could compare their own response. Some students identified that having another perspective let them gauge the quality and correctness of their own responses, whereas other students identified that it provided them with other

Table 2
Student views of the helpfulness of the peer review aspects (N = 110).

Perceived helpfulness	Aspect of peer review		
	Receiving feedback	Giving feedback	Reading drafts
Very helpful	35% (N = 39)	21% (N = 23)	54% (N = 59)
Somewhat helpful	59% (N = 65)	65% (N = 72)	37% (N = 41)
Not very helpful/did not use	6% (N = 6)	14% (N = 15)	9% (N = 10)

approaches for organizing and writing about the content. Second, students described that both elements of peer review (i.e., reading their peers' writing and receiving feedback) helped them identify what content they should focus on. Specifically, students identified that peer review helped them identify mistakes, missing information, and confusing explanations. Additionally, a few students mentioned that the process clarified assignment expectations and a few stated that it helped them better understand the content. Thus, the ways in which students perceived peer review as providing space for gaining knowledge from their peers to inform revisions aligns with the case analysis (e.g., students revised their justifications due to both reading their peers' drafts and receiving feedback).

5. Discussion

Guided by the cognitive process theory of writing and the theory of distributed cognition, examining the six cases provides an in-depth look into the various ways in which peer review informed students' revisions as they went through the WTL process. The case analysis also informs our understanding of students' cognitive and behavioral engagement with the WTL process. The case study is supplemented by analysis of survey responses, which captures students' perceptions of how the constructed social environment (i.e., peer review) informed their revisions and speaks to students' emotional engagement. Importantly, this research demonstrates how the implementation of a peer review process informed by the research literature into an authentic, large-enrollment STEM classroom translates into actual student practice. Additionally, this study serves as an exploratory study that demonstrates a potential progression of engagement with peer review which can inform future, larger scale studies on the ties between peer review and revision for WTL.

Evidence of the written artifacts (i.e., feedback comments and peers' drafts) mediating the revision process, and having a potential influence on students' understanding of the content and reasoning, was present to various extents across the cases. All the cases captured peer interactions where students appeared to make revisions informed by the feedback they received. The potential impact of reviewing peers' initial drafts on students' own revisions can also be seen within four of the six cases, most obviously with Sylvain who revised their mechanism choice during the review stage. This finding further supports the benefits of reading and providing feedback to peers and as a stage for learning (Cho & MacArthur, 2011; Cho & Cho, 2011; Lundstrom & Baker, 2009; Nicol et al., 2014), which has been examined to a lesser extent for WTL (Finkenstaedt-Quinn et al., 2021). However, as revisions due to feedback received were present across all the cases, which was not the case for reading and providing feedback, the study also suggests that students may find it easier to revise from receiving feedback.

The revisions captured in the cases align with students being exposed to new ideas both while reading their peers' writing and when receiving feedback, providing additional evidence demonstrating how students can draw knowledge from one another via peer interactions mediated through writing, in alignment with theoretical perspectives of writing and cognition (Hayes, 1996; Klein et al., 2015, 2012). This aligns with content-focused revisions related to peer feedback seen in other WTL assignments incorporated into STEM courses (Finkenstaedt-Quinn et al., 2019 Halim et al., 2018; Moon et al., 2018). Additionally, the survey analysis provides further evidence of positive student perceptions of peer review, aligning with prior studies on WTL assignments in the organic chemistry lab context (Gupte et al., 2021; Petterson et al., 2022) and technical writing assignments (Nicol et al., 2014; Stewart, 2019). Students' positive perceptions contrast with much of the peer feedback research, which indicates that students perceive received comments as not useful for informing their revisions (Kaufman & Schunn, 2011; McConlogue, 2015; Vu and Dall'Alba, 2007). Our findings are also interesting in light of the study by Cunningham et al. (2022), which indicated that students had more negative perceptions of online peer review compared to in person. As the structure of a writing assignment influences how students respond (Gere et al., 2018, 2019), it is inherent that the same would apply to how peer review is structured. As part of the assignment that is the focus of this study, students were told to make and defend a choice between two mechanisms and then comment on the justification of their peers. This could both expose students to new ideas and support metacognition about their reasoning. Comparatively, in Nicol et al. (2014), students identified that while reviewing provided them with alternate viewpoints, receiving feedback was restrictive as it was limited by what the student had produced and thus did not expose them to new ideas. This indicates that incorporating argumentative reasoning paired with a scaffolded content-focused peer feedback process, such as the WTL assignment described herein, can enrich the feedback process.

The findings of this study also provide insight into students' engagement with the WTL process and peer review more generally. Comparing across the cases indicates that there were differences in students' engagement levels. The cases herein captured two students revising based only on feedback they received, with the other four students using both types of interactions to inform revisions. Additionally, five of the six students provided constructive feedback. Considered in conjunction, this may indicate that there is a progression of engagement with peer review where students first engage with using and providing feedback before starting to consider information gained from reading their peers' work. Furthermore, Laurell, at the surface level of engagement, provided primarily praise-focused feedback which suggests that providing praise is an entry point for students in the feedback process. This aligns with the findings of Patchan and Schunn (2015) that students with lower reviewing ability provided more praise than actionable feedback. However, it is also important to consider that students may find different instructional practices more or less accessible and thus inherently engage with them to different extents. In addition, students' views of the purpose of peer review may also differ from an instructor's, and clarifying the instructional intent could enhance students' use of and benefits resulting from the practice (Stewart, 2019). Thus, this study demonstrates how the WTL process can engage students in authentic writing practices, such as those called for by Martini (2022), while also supporting students' engagement with disciplinary content and scientific practices.

6. Implications for research and practice

This study adds to research on the benefits of peer review generally and for supporting WTL specifically. Additionally, the cases described herein demonstrate how a content-focused feedback process involving multiple peers can inform revision. This work can inform future large-scale analysis of peer review and revision artifacts by guiding the types of interactions that can be sought out. The cases also demonstrate how an assignment design informed by research plays out in actual student artifacts in an undergraduate chemistry classroom. Future research investigating students' thinking and decision making as they go through the WTL process is merited. A longitudinal study focused on how the interactions between peer review and revisions change as a student progresses through a semester can supply information on how students' engagement with peer review develops over time and how it can be supported.

This study illustrates the usefulness of incorporating peer review and revision for content-focused writing assignments, with three of the six students showing active engagement with the processes. However, instructors can guide their students by suggesting they fully consider all sources of information available from their peer interactions (i.e., feedback received and comparing their work to that of their peers). Instructors can also discuss approaches for responding to conflicting information, either with a student's own thinking or between peer artifacts, encountered during peer review. Our findings also indicate that incorporating an argument component into a WTL assignment followed by a structured critique during peer feedback can support students' engagement with peer review as they may be presented arguments contrary to their own. This lends itself to students' critical reflection on their own response and can enhance the benefits of peer review.

Data availability

The authors do not have permission to share data.

Acknowledgments

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Appendix A. Prompt and peer review rubric criteria

Prompt – exploring possible reaction pathways for a catalyzed intramolecular aldol reaction

Ivermectin is a drug used to treat onchocerciasis, a parasitic disease commonly known as river blindness. While the disease is rare in the United States, it is especially prevalent in Ghana, where more than 15% of the population is affected. As a lab technician for Médecins Sans Frontieres (Doctors Without Borders), you have traveled to Ghana to collaborate on a study initiated by biochemists at the University of Ghana who are working to develop a more efficient synthesis of ivermectin. The biochemists you are working with have identified a new strategy to perform **intramolecular aldol reactions** that uses the catalyst triazabicyclodecene (TBD). The TBD-catalyzed aldol reaction could be used in the place of the traditional aldol reaction for an early synthetic step in the synthesis of ivermectin. Using TBD will replace the need of strong acids and bases in this synthetic step, which will limit undesired side reactions. An example of a TBD-catalyzed aldol reaction with a simplified starting material is shown in Fig. 4.

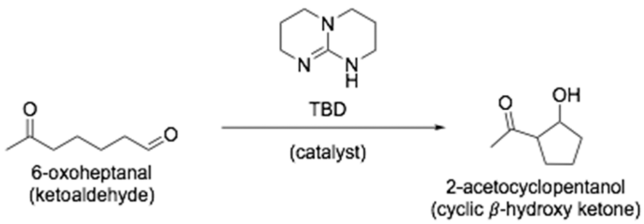
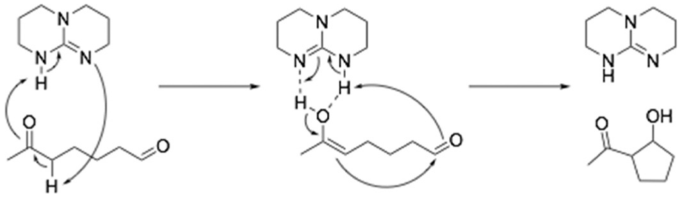
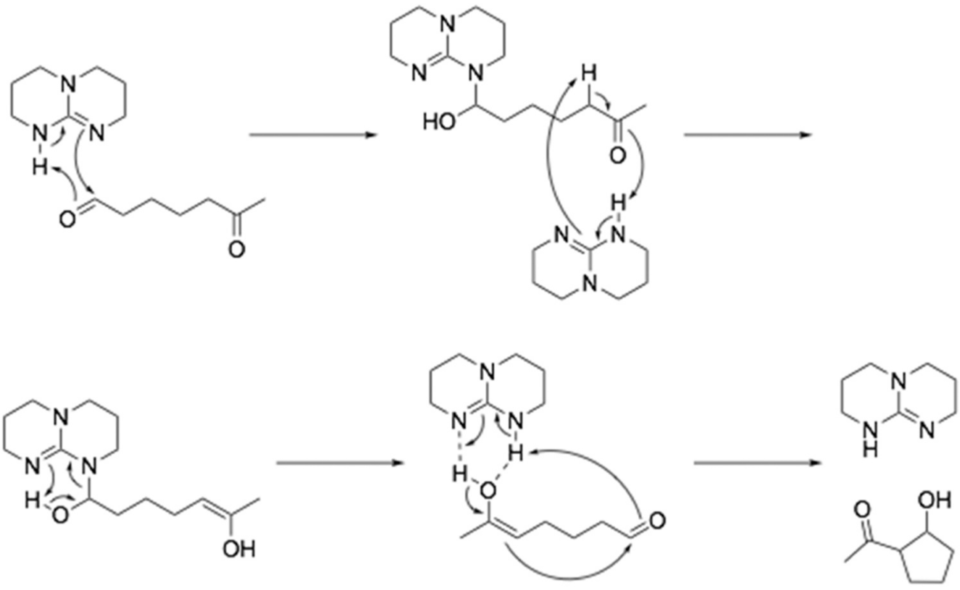


Fig. 4. The intramolecular, TBD-catalyzed aldol reaction of 6-oxoheptanal produces 2-acetocyclopentanol.

The biochemists you are working for have asked you to research the mechanisms for the reaction. This will help them determine the feasibility of applying it to the synthesis of ivermectin. You have identified two potential mechanistic pathways, shown below in **Proposed Mechanism A** and **Proposed Mechanism B**.

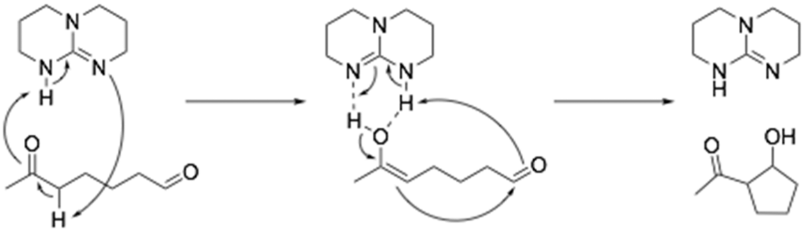


Proposed Mechanism A

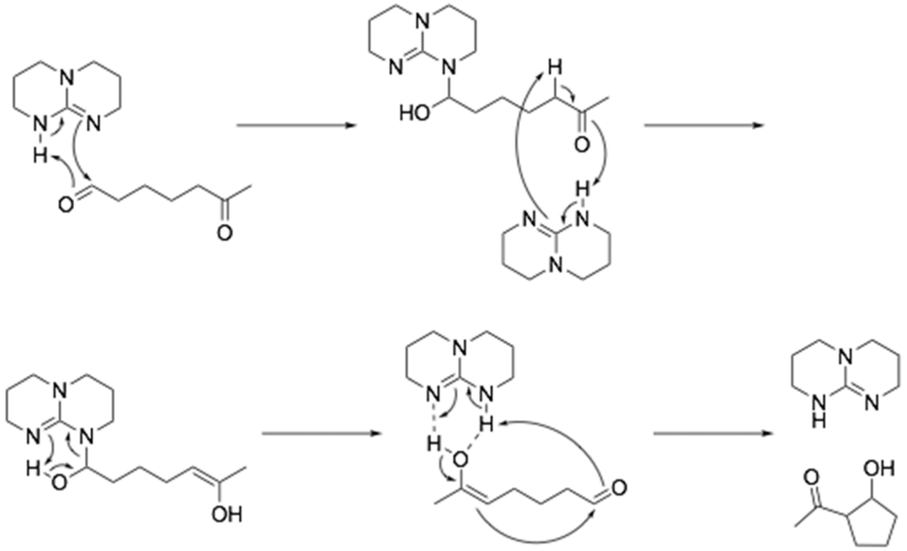


Proposed Mechanism B

For each proposed pathway, you have performed computer simulations to determine their energy profiles. The results of your calculations are shown in Fig. 5, where each reaction coordinate diagram is presented side-by-side.



Proposed Mechanism A



Proposed Mechanism B

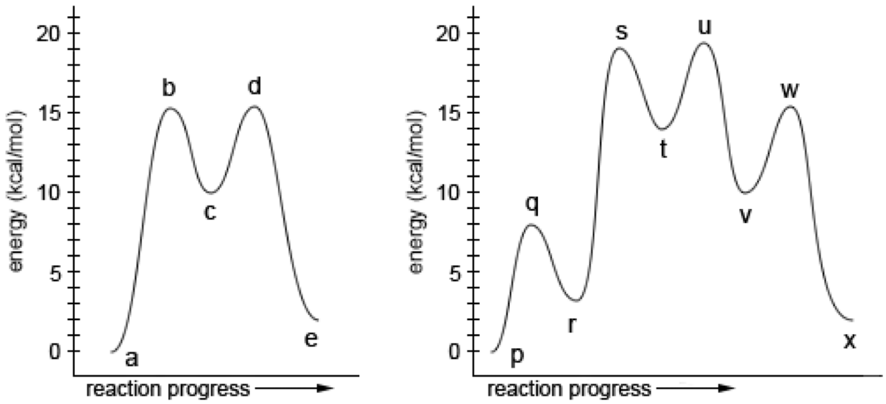


Fig. 5. Reaction coordinate diagrams for Mechanism A (left) and Mechanism B (right). Note that claims about reaction times between Mechanism A and B can't be made since the units on the horizontal axes aren't specified.

At the end of the summer, you will write a brief report to summarize your findings, suggest the most likely pathway, and share your part of the project with the rest of the team. You should provide a detailed explanation of the mechanisms for both reaction pathways. Also, your argument for the most likely pathway should be supported by the mechanisms and the reaction coordinate diagrams. The report is directed toward the biochemists and other concerned parties who will use your recommendations to decide the feasibility of applying this reaction to the more complicated synthesis of ivermectin. Therefore, they may not be experts when it concerns mechanisms or organic-specific terms. Use clear and concise language, striking a balance between organic jargon and oversimplified explanations.

Your report should be approximately between 500 and 700 words (1–2 pages) in length. It should address the following points:

1. Discuss how each mechanism correlates with the corresponding energy diagram.
   a. Summarize the findings.

b. Specifically, explain how the transition states and intermediates of the mechanisms correspond to features on the diagrams.
c. Take care to translate which specific step in the mechanism corresponds to which specific feature of the associated reaction coordinate diagram.

2. Identify which reaction pathway *you think* is most likely to occur. You will be evaluated on the explanation of your choice, *not the choice itself*.
3. When discussing mechanisms, be sure to write about the structural features and electronics of the molecules involved. Include descriptions of how the molecules interact in the mechanism and how they change in structure as a result of their interactions.

You can and should include figures of schemes, structures, mechanisms, or reaction coordinate diagrams, if that supports your response. We suggest that you have the figure(s) in front of you—ready to color-code or mark-up in various ways—and that you use your visible thinking to guide your audience through your explanation. Any images that you include in your response, *including the figures in this prompt or those that you draw in ChemDraw or on paper*, must have the original source cited using either ACS or APA format. Given your audience, your written response should suffice so that the explanations can be understood without the figures. **You will be graded only on your written response.**

Peer Review Rubric and Guidelines:

- Print and read over your peer's essay to quickly get an overview of the piece.
- Read the essay more slowly keeping the rubric in mind.
- Highlight the pieces of texts that let you directly address the rubric prompts in your online responses.
- In your online responses, focus on larger issues (higher order concerns) of content and argument rather than lower order concerns like grammar and spelling.
- Be very specific in your responses, referring to your peer's actual language, mentioning terms and concepts that are either present or missing, and following the directions in the rubric.
- Use respectful language whether you are suggesting improvements to or praising your peer.

1. In what ways does the author discuss the structural features of the molecules and the changes that result from the interactions in Mechanism A? Suggest ways the author could improve their mechanistic description.
2. In what ways does the author discuss the structural features of the molecules and the changes that result from the interactions in Mechanism B? Suggest ways the author could improve their mechanistic description.
3. How does the author relate the mechanistic details to the corresponding energy diagram for each mechanism? Suggest specific ways the author could relate each mechanism to features of its energy diagram.
4. Which mechanistic pathway did the author choose as the most likely? State what choice you think the author made and whether or not you think the author made the correct choice. Provide an explanation for why you think this way.
5. How did the author justify their choice of the most likely mechanistic pathway? Suggest ways the author could use details from their mechanism and energy diagram descriptions to better explain their choice.

Appendix B. Survey coding scheme

Tier 1		
Code	***Definition***	***Exemplar***
WTL process	Described the WTL peer review process, or some aspect thereof, as the most helpful resource	"The peer review process (both reading other drafts and getting feedback) was helpful because it challenged my own initial thinking and gave me an idea of what was expected of my [assignment]."
Other	Did not describe the WTL peer review process, or some aspect thereof, as the most helpful resource	"The textbook was the most helpful. I was learning the things that I had to write about in CHEM 215 so it was easier for me to have access to the textbook and understand the reactions that we were asked to write about."
Tier 2		
Code	***Definition***	***Exemplar***
General	Generally described the WTL peer review process or interacting with peers during that process as helpful	"Seeing other people's thoughts are the most helpful since I realize I am way wrong. Nice getting more than one student."
Comments	Described the comments they received as helpful	"I like the peer reviews best because it gives you more tailored comments to help your individual writing, while also allowing you to see how others approach the topic."
Drafts	Described the drafts they read as helpful	"Student drafts that I read were the most helpful because I was able to strengthen my understanding of the material. Whether the draft was excellent, or needed work, I better understood what the prompt was looking for."
Comments and Drafts	Described both the comments they received and the drafts they read as helpful	"Reading peer review comments and student drafts were helpful. I used them to see if I was missing anything or if I could add details that help strengthen my work."

Appendix C. Profiles

Laurell (surface): Laurell made only minor revisions to their revised draft. Most notably, they did not revise their choice or justification for the most likely mechanism despite the fact that all three reviewers suggested they further justify their choice of mechanism B. Furthermore, Laurell experienced only one agreement across the peer review process, from a draft they read. Of note is that both drafts Laurell read that selected the other mechanism may have appeared less credible because the peers interchanged the terms for intermediates and transition states, which Laurell did not do, indicating a possible misunderstanding with regard to Laurell's peers' content knowledge. Laurell did make a small revision to their comparison of the activation energies of the mechanisms, which may have originated from a reviewer comment. Furthermore, Laurell made very few sentence-level revisions to their mechanism and RCD descriptions, which may have come from the reviewer comments, all of whom asked for more explanation of features related to the RCDs. In addition to making few revisions, the feedback Laurell provided on the drafts they reviewed was relatively short and primarily praise.

Chandler (active): Chandler made revisions both in their reasoning for their selection of mechanism A as most likely and within their mechanistic and RCD descriptions. While Chandler kept their justification for mechanism A from their initial draft, they added additional reasoning to further support their choice in their revised draft. From the peer review process, four of the six peer interactions supported Chandler's choice of mechanism A (with two disagreements coming from drafts they read). The revisions Chandler made to their justification appear to be due to feedback from one peer and the draft they read, which also selected mechanism A. Furthermore, two of the reviewers suggested Chandler expand their discussion of the reaction coordinate diagrams, intermediates, and transition states, along with incorporating more organic chemistry vocabulary, all of which Chandler incorporated into their revisions. The three papers Chandler read also included some discussion of stability, energy, or transition states, which were also reflected in Chandler's revisions to their mechanistic descriptions. Overall, Chandler provided substantive feedback to the drafts that they read, combining praise with comments about what their peers could revise.

Seanan (active): Seanan made major revisions to their draft, revising both their choice of the most likely mechanism and expanding on their descriptions of the two mechanisms. Seanan switched from mechanism A to mechanism B in their revised draft, moving from comparing the relative number of steps and energies of the intermediates and transition states between the two mechanisms to comparing the activation energy and steric hindrance for the first step of the mechanisms. The change in Seanan's choice of mechanism is notable, as they only interacted with two peers who selected mechanism B (one draft that they read and one reviewer). The change in Seanan's mechanism choice appears primarily attributable to the comments they received, in particular from the peer who selected mechanism B (as Seanan incorporated that peer's justification into their revised draft). Seanan's change in their choice of the most likely mechanism may also be attributable to two reviewers who correctly identified a chemically incorrect justification in Seanan's draft, one reviewer who suggested they incorporate more discussion of intra/intermolecular stabilization, and one of the drafts they read that discussed the activation energy of the first mechanistic step. Furthermore, Seanan may have placed less weight on two of the peer interactions, which would have supported their decision of mechanism A, as one draft did not provide a thorough justification and one reviewer did not provide much feedback. Seanan also made major revisions to their mechanistic descriptions that align with both the drafts that they read and the reviews that they received. Seanan provided some praise to their peers as well as detailed, substantive feedback.

Appendix D. Examples of peer feedback given

Student	*Peer review question*	*Exemplar feedback*
Laurell (gave minor feedback)	*1*	"Very descriptive of bonds, at times could use more scientific words to describe functional groups, such as carbonyl group rather than C═O" "Good use of diagrams, and good way of identifying carbons." "Does not discuss mechanism"
	4	"Proposed mechanism [A], because there are fewer steps, could be valid" "Chose mechanism A, good reasoning" "Chose pathway B, and I agree as the first step has a lower activation energy"
	5	"Refers to energy diagram well." "A doesn't have the lowest activation energy on the first step. Could discuss the implications of that" "Argument is based on steric hindrance. Refers to the energy diagram as well"
Chandler (gave substantive feedback)	*1*	"The author does a good job of explaining what parts of the energy diagram the mechanism relates to. I would recommend going into more depth on the mechanisms steps and how the molecule changes throughout the reaction (why higher energy at certain points)." "You did a good job of explaining the mechanism in relation to the energy diagram. It might be helpful to add a figure of the mechanism for reference." "Your description of the mechanism and energy diagram were really good. My only advice would be to number the C's on the mechanism A figure so that the described mechanism is easier to follow."
	4	"The author chose mechanism B. I thought that by looking at the rate determining step, that A would be more likely." "The mechanistic pathway the author chose was Mechanism A. I think the author made the correct choice because I believe less energy is required in order for mechanism A to occur."

(*continued on next page*)

(*continued*)

Student	Peer review question	Exemplar feedback
		"The mechanistic pathway the author chose as the most likely was mechanism B. I thought it was mechanism A based on the lower activation energy of the rate determining step, but I think the author made a good point in the explanation."
	5	"They said that mechanism B requires less activation energy to get from starting materials to products. I would specifically point out what steps have lower activation energy."
		"The author justified their choice by discussing how mechanism A had greater kinetic stability than mechanism B. They discuss the number of transition states and activation energy needed. I think you could mention specific cases from the diagrams as well as numerical values from the graph to help support your argument. Overall good job!"
		"They justified their choice by explaining it in terms of the difference in number of steps and activation energy between the two mechanisms. I think overall the description was good and does not need to be added to."

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