

THE EFFECTIVENESS OF STRUCTURED TEACHING AND MODELING OF PEER
EDITING ON THE SCIENTIFIC WRITING OF HIGH SCHOOL
ENVIRONMENTAL SCIENCE STUDENTS

by

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of

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DEDICATION

To my husband and daughters, your support means the world to me. Jared, thank you for being my ultimate peer editor and reading the many versions of this paper. Thank you for cooking dinner and doing dishes each night while I checked discussion boards and completed assignments. I could not have done this without you. Adelynn and Ella, I hope seeing your mom work so hard inspires you to be lifelong learners.

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ABSTRACT

The Next Generation Science Standards have shifted the focus of science instruction from rote memorization of facts to students engaging in science by discovering information, constructing explanations, engaging in arguments from evidence, and communicating ideas. One way for students to express their scientific knowledge and ideas is through writing. However, many high school students struggle with writing, and many science teachers lack the confidence and time to implement writing instruction into their curriculum. Peer review is an instructional strategy that can effectively support students as they develop their writing skills in science classrooms. This research examined the impact of structured teaching and modeling of peer editing on the scientific writing of 38 high school students in Advanced Placement Environmental Science. Treatment consisted of two peer editing lessons where students established feedback criteria, scored models with rubrics, and provided constructive feedback. Each lesson was followed by a peer editing exercise that allowed students to apply the knowledge gained. After peer editing, students read through peer feedback and made corrections to their writing. End of unit writing assessments were used to determine the impact of peer editing on student writing, and pretreatment and posttreatment surveys were used to gauge students' familiarity with peer editing and their confidence to help their peers. In addition, a teacher journal was used to document observations during peer editing lessons, and student interviews provided insight into the perceived benefits and challenges of peer editing sessions. The results demonstrated that students felt more confident in their peer editing skills and believed the lessons improved their writing. In peer editing exercises, students asked more questions and were more engaged with their peers and the grading rubric. Although writing assessment scores did not significantly improve, both teacher and students found peer editing instruction useful.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

I teach science at Yorkville High School in Yorkville, Illinois. Yorkville is a suburb west of Chicago with a population of approximately 25,000 (United States Census Bureau, 2023). We are a K-12 district with seven elementary buildings, one middle school, and one high school. Yorkville prides itself on its small town feel with all the schools in the district containing the same mascot, the Foxes. However, Yorkville is in one of the fastest growing counties in Illinois, Kendall County. Our school enrollment has grown from 1,667 students in 2015 to 2,139 students in 2024 (Illinois State Board of Education, n.d.). This quick growth has led to shifting academic needs and larger class sizes.

The students in my science classes have traditionally struggled with writing assignments, like laboratory analysis and free response questions (FRQs). Although writing is taught in English classes, students find it difficult to translate the skills learned in English to our science classroom. In addition, writing in science is more straightforward and concise than the writing taught in English classrooms. As a result, I spend time explicitly teaching scientific writing to students. However, I find that there is a growing gap in writing skills among my students, and it is difficult to provide timely individualized feedback due to my growing class sizes.

My Advanced Placement (AP) Environmental Science course poses a unique challenge due to the amount of content that must be taught in addition to scientific writing skills. AP Environmental Science is a junior and senior level elective course at Yorkville High School. In this class my teaching goals are to increase students' knowledge and skills in environmental

science and to have students evaluate their understanding through self-assessment. In addition, I must prepare students for their AP exam in May. Unlike other schools where the AP exam is optional and an additional cost, Yorkville High School builds the cost of the exam into the course fee and requires students to take the AP exam to receive weighted credit in the course. As a result, all students enrolled in the AP course take the AP exam in May, and students are invested in performing well. The AP Environmental Science exam consists of a multiple-choice section and a FRQ section. Students must complete three FRQs in 70 minutes. The global average on each of the three FRQs is low, ranging from 4.34 to 5.35 out of 10 points in 2025 (College Board, 2025a). My classes have traditionally scored higher than the global average. In 2025, my students' average scores on the three FRQs ranged from 5.5 to 6.2 points. Despite their success on this portion of the AP exam, scientific writing is a challenge for many of my students, making it a skill we work on continuously throughout the school year. I am always trying to find ways to improve my instruction and methods used to teach scientific writing. If there is a way to make the scientific writing process smoother for my students, I want to find it and use it.

One instructional strategy I use is to provide students with opportunities to practice writing FRQs in each unit. To be successful on the FRQ section of the AP test, students need to understand the task verbs and the response expectations for each task verb. For example, the word explain requires students to analyze information about how or why something is occurring. The word identify can be a one- or two-word answer without providing an explanation. Task verb expectations are learned at the beginning of the year, and these skills are reviewed each unit through practice FRQs. Most units consist of two practice FRQ assignments. These assignments are completed outside of class. Students self-grade these FRQs in class using grading rubrics. I

also give students the option to switch their FRQ with a peer and peer-grade each other's FRQs, but few students choose this option. At the end of each unit, students take a summative test that consists of 40 multiple-choice questions and one FRQ to mimic their AP exam. To get students ready for the pacing of the AP exam, the summative test is timed similarly to their AP exam. I grade both the multiple-choice questions and the FRQ for accuracy. The practice FRQ assignments during the unit should prepare students for the summative FRQ at the end of the unit. This practice used to suffice in preparing students for their unit exams, but in recent years I have noticed a widening disparity in the scientific writing skills of incoming students.

Prior to taking AP Environmental Science, students either take Biology or Biology Honors during their freshman year and Chemistry or Chemistry Honors during their sophomore year. Juniors and seniors have many science course options, and AP Environmental Science is one of their options. Students usually choose AP Environmental Science because they are interested in the course material, they have friends who have recommended the course, or they are interested in taking a weighted science credit. AP Environmental Science is a steppingstone to other AP science classes, like AP Biology and AP Chemistry. My class frequently consists of first-time AP students who have never taken an honors level science course. For example, in 2024 I taught two AP Environmental Science classes that contained 60 students in total, and 33 of those students were taking an AP class for the first time. In 2025 I taught two sections containing 38 students, and 16 students were first-time AP students. These students often struggle with writing and need support.

Lack of articulation in science skills between our high school science classes also contributes to students struggling with scientific writing. Our chemistry course team decreased

the number of lab activities and writing assignments during the Covid-19 pandemic due to the social distancing and remote learning that took place. In recent years, the chemistry teachers have been hesitant to place these pieces back into the course citing that students lack the skill level and maturity to complete laboratory activities. Although students complete writing tasks in biology during their freshman year, a year off with little skill development means students are often not ready for the writing tasks in AP Environmental Science. On the other hand, students who take Chemistry Honors have a great deal of laboratory experience and frequently write claim, evidence, and reasoning statements as a part of laboratory assignments. Chemistry Honors students also complete FRQs on every summative test. Therefore, the discrepancy of skills gained during students' sophomore year science class poses an additional challenge because the scientific writing skills of my students vary greatly.

In addition, as our community grows, class sizes have also grown. Science classes used to be capped at 24 students. However, in recent years my classes have contained over 30 students. Larger class sizes combined with the increasing academic needs of my students make providing timely quality feedback on formative writing assignments, like practice FRQs, a challenge. This is why I allow students to self-grade their practice FRQs with an option to peer-grade. However, I am unsure if all students benefit from this self-grading process.

During the self-grading process, many students quickly grade their FRQs using a grading rubric, score the assignment out of 10 points, and turn it in for completion points. Although students are always given the option to trade their paper and peer-grade, very few students choose to grade their FRQs this way. Most students do not correct their answers or reflect on how to improve their answers to earn a point. Personally, I have experienced the power of peer

editing in my graduate studies at Montana State University in the Master of Science in Science Education program. Peer editing is a frequent assignment in our coursework. I often gain new ideas while reading peers' papers and receive valuable feedback to improve my writing during these peer editing assignments. I believe my high school students can gain the same benefit from peer editing. If I explicitly teach my students the importance of peer editing and directly instruct them how to peer edit, then I believe it will improve their scientific writing. Making peer editing mandatory allows students to read someone else's work and see alternative ways of answering the same question giving students examples of how to improve their own writing. Also, guiding students through reflection after peer editing and allowing students an opportunity to make corrections to their writing will reinforce how to correct mistakes and hopefully prevent them in the future. Peer-grading also allows students to provide timely feedback in a way that is impossible for one teacher with over 30 students, and strategically pairing students might also help meet the needs of a wide range of writing skills among students.

Focus Question

My focus question was, How does structured teaching and modeling of peer editing impact scientific writing of Advanced Placement Environmental Science students in a high school science classroom?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Peer assessment, also known as peer review or peer editing, is an effective strategy in writing instruction in which students assess the quality of a product of another equal status student (Topping, 2009). Teaching students how to edit and revise their writings in collaboration with other students can help them develop the writing skills needed for the postsecondary level (Graham & Perin, 2007). Teachers cannot assume students know how to peer edit. This skill must be explicitly taught (Graham & Perin, 2007; Sanchez et al., 2017; Topping, 2009; Wu & Schunn, 2020). Furthermore, when taught effectively, peer review can improve student writing on current and future assignments (Wu & Schunn, 2020).

The Need for Writing Instruction

Over the last decade, science education has shifted away from rote memorization to understanding the process of science by doing science. The Next Generation Science Standards (NGSS) focus on students becoming scientists and understanding the scientific process as a way of knowing by discovering information, constructing explanations, engaging in arguments from evidence, and obtaining, evaluating, and communicating ideas. These science and engineering practices stress the importance of not only oral argumentation but also writing in science education. Students should build on their writing skills through each grade level, so that by 12th grade, students are able to write text to communicate their own ideas and use words, tables, and graphs to communicate their understanding (National Research Council, 2012).

Despite this new emphasis on writing, only 27% of 12th grade students ($N=28,100$) are at or above proficiency on the latest National Assessment of Educational Progress (NAEP) writing assessment (National Center for Education Statistics, 2012). In this assessment students are scored on their development and organization of ideas when given specific prompts. Additionally, in the latest NAEP science assessment, 22% of 12th grade students ($N=26,400$) scored at or above proficiency (National Center for Education Statistics, 2019). The NAEP science assessment measures students' content knowledge and performance in four science practices: identifying scientific principles, using scientific principles, using scientific inquiry and using technological design. Although this assessment contains both multiple choice and constructed response questions, the data is not displayed to distinguish between the two types of student responses (National Assessment of Educational Progress, 2019). Both assessments demonstrate that high school students struggle with communicating in written text. This data combined with the emphasis of communication in NGSS highlights the importance of focusing on writing instruction in science classrooms (Drew et al., 2017).

Writing Instruction in Science Classrooms

Although science teachers find writing important, very little emphasis is placed on teaching students how to write within science classrooms. Many content area teachers do not feel confident in their ability to teach writing or are unaware of the most effective ways to teach it. Others look at writing instruction as an additional item added to their plate and therefore not an important piece to teaching content material. When surveyed, 59% of science teachers in sixth through 12th grade across the United States ($N=284$) said they use writing to help reinforce scientific inquiry, but very few teachers engage students in peer feedback and revising their

writing. More than 30% of science teachers have never explicitly taught students how to revise their writing (Drew et al., 2017).

In a meta-analysis of 123 studies on writing instruction in fourth through 12th grade, Graham and Perin (2007) found that instructional strategies improve the quality of writing for students. The most effective strategy is teaching students how to plan, revise, and edit their writing. Students who struggle with writing benefit the most from this instructional practice. The second most effective strategy is teaching students how to summarize after reading. Students who successfully summarize reading material can pull out the most important concepts in a concise and accurate manner, improving their writing. The third most effective strategy is allowing students to collaborate with each other in the writing process through peer revising and editing. Graham and Perin found that when students work collaboratively to plan, draft, and/or revise writing there is a strong and positive impact on writing quality. In addition to these instructional practices, the researchers emphasized that students must have clear specific goals when writing, and they should be given the opportunity to analyze and imitate product models. Overall, it is highly advantageous to explicitly teach students collaborative writing strategies that involve editing and revising.

The Benefits of Peer Review

One clear way to address student writing skill deficits is through peer assessment. Peer editing can identify misconceptions early, which allows students and teachers to address deficits sooner. This feedback allows students to identify strengths and weaknesses, isolate areas for remediation, and foster metacognitive skills. The benefits occur for both the assessor and assessed because peer editing encourages self-reflection for both students, increasing

metacognition. Metacognition allows students to identify mistakes, learn from them, and apply that knowledge in a future assignment. Feedback can identify and correct errors, add new information, and verify existing information. In addition, peers can give more frequent and plentiful feedback compared to teachers since there are more students than teachers in the classroom (Topping, 2009).

In a meta-analysis of 33 studies dealing with self- and peer-assessment in third through 12th grade, Sanchez et al. (2017) found that students who self- and peer-grade show higher levels of academic performance on subsequent tests because they have developed a clearer understanding of the material. Actively engaging students in the grading process allows them to self-reflect and improve on future assignments. However, this process does not come naturally for students. In their analysis, all studies provided rubrics to students, and many studies provided students with guidance on how to conduct self- and peer-grading. Teachers must train their students to self- and peer-grade to see the benefits. The researchers recommend that future studies focus on the amount and type of guidance given to students.

Teacher Concerns of Peer Editing

Despite the benefits of peer editing, there are some common concerns expressed by teachers. One concern is that peer comments will not align with teacher comments, and as a result, students will miss errors that need to be fixed or make unnecessary changes to their assignment. However, Falchikov and Goldfinch (2000) conducted a meta-analysis that reviewed 48 quantitative peer assessment investigations and found that, on average, peer feedback aligns with teacher feedback. The alignment of feedback is higher when academic products are assessed, and the assignment is well designed with clearly understood criteria. Sanchez et al.

(2017) also found a strong correlation between student and teacher feedback, noting that peer assigned grades were similar to teacher assigned grades. These results may be due to the structure and guidance given by teachers who provided students with rubrics to assist in their editing. However, other factors, like the type of grade awarded for the assignment, could also play a role. For example, using a peer assessment as a summative final grade could inflate the grade given by the peer. The authors suggest more research is needed to determine what causes the alignment of peer and teacher feedback.

Another common concern of peer editing is time. For example, Weaver (2023) says effective peer editing requires additional instruction, and the investment of time in training students is costly and could cause teachers to cut other writing assignments in the classroom. Weaver does describe some benefits to peer editing, like teachers gaining insight into student understanding during peer editing discussions. Teachers can use this insight to drive future lessons and meet the needs of their students. On the other hand, Sanchez et al. (2017) say the upfront investment of teaching students how to peer edit is no different than any other new curriculum initiative. Therefore, involving students in the assessment process by implementing peer editing is a worthwhile investment in time.

Strategies for Teaching Peer Editing

Teachers need to explicitly teach writing skills and peer editing skills for students to improve their writing. With good organization, clear goals, and practice, students can give effective feedback (Graham & Perin, 2007; Topping, 2009). Wu and Schunn (2020) found that secondary students not only improved writing through peer editing but also applied what they learned to a future assignment. Teachers in this investigation taught high school students how to

peer edit by reviewing unhelpful and helpful comments in a class discussion. Students were paired and given a sample essay to review. As a class, students discussed the comments made in their pairings, and the teacher emphasized high level comments, such as providing a deeper explanation or supporting an idea with evidence. After this activity, students wrote an essay and then performed peer editing using a rubric. During the peer edit, students were asked to provide comments in focus areas determined by the researchers. After the peer edit, students revised their papers and then completed a second writing task one week later using the same rubric as the first writing assignment. The study found that through purposeful instruction of peer editing, students improved their scores on both the revised essay and on the second writing assignment. In other words, peer editing not only helped students improve their writing, but students were able to apply information learned to a future assignment.

Reflection after peer feedback is also crucial. According to Wichmann et al. (2017), peer editing is only useful when sense-making support is provided to students after peer editing and during the paper revision process. Students often have trouble with feedback uptake, meaning they do not know how to make sense of peer feedback and use it to improve their writing.

Allowing students to reflect on peer feedback is crucial to feedback uptake. After receiving peer feedback, students in this investigation used a table to make sense of each comment and to determine how the comment would help them improve their essay. Overall, the researchers found that giving students the opportunity to reflect on peer feedback allowed them to evaluate the feedback, make appropriate changes, and score higher on writing assignments.

The Need for Peer Review

The NGSS have forced a shift in science education away from students memorizing and repeating a list of facts to students exploring phenomena through scientific investigation and acting more like scientists. The standards require students to construct explanations and engage in arguments from evidence. In addition, students must be able to obtain, evaluate, and communicate these ideas. Writing is an important means of this communication and as the research shows, an area where students typically struggle. As a result, instructors must bridge the gap by implementing best practices in writing instruction to help students succeed (Drew et al., 2017).

Peer review is an instructional strategy that can effectively support students as they develop their writing skills in science classrooms. When teachers provide meaningful instruction of peer editing where students evaluate the effectiveness of comments and assess end-product models, students can give feedback similar to their teacher. In addition, peer reviewing allows for more eyes on any one student's writing and offers a dual metacognitive benefit where both the peer reviewer and student being reviewed reflect on their writing to make improvements. Consequently, structured teaching and modeling of peer editing combined with instructing students how to reflect on peers' comments can benefit both teacher and student by improving student writing in science classrooms (Topping, 2009; Wichmann et al., 2017).

CHAPTER THREE

METHODOLOGY

The goal of this research was to determine how structured teaching and modeling of peer editing impacted the scientific writing of students. Treatment consisted of two peer editing lessons where students were explicitly instructed how to give constructive feedback aligned with Advanced Placement (AP) exam rubrics. In addition, students evaluated models of graded student responses. Each lesson was followed by a peer editing exercise where students applied the knowledge gained in the lessons. A mixed methods approach was used to determine the effectiveness of the peer editing lessons and exercises on the scientific writing of students. Qualitative and quantitative data were triangulated to increase the credibility of findings.

Demographics

The study took place at Yorkville High School in Yorkville, Illinois. Yorkville High school is a public school in the western suburbs of Chicago about 55 miles outside of the city. The school runs on a modified block schedule where each class meets three times a week. Two class periods run 88 minutes, and the last class of the week is 47 minutes. At the time of the study, the school enrollment was 2,139 students and composed of 63.3% White, 21% Hispanic, 8.2% Black, 2.6% Asian, and 4.7% two or more ethnicities. The student to teacher ratio was 21:1, and 23.6% of students received free or reduced lunch (“Yorkville High School,” n.d.).

The participants in this investigation were juniors and seniors in AP Environmental Science at Yorkville High School. The majority of students who take AP Environmental Science are college bound and interested in science. There were 38 participants in the study across two

classes ($N=38$). My second period class consisted of 17 students with 47% male and 53% female ($n=17$). My sixth period class contained 21 students with 62% male and 38% female ($n=21$). During their sophomore year, 59% of students in second period class took Chemistry and 41% took Chemistry Honors. In sixth period, 71% of students took Chemistry their sophomore year while 29% took Chemistry Honors. In my second period, 44% of the students were taking an AP class for the first time. In my sixth period, 38% of the class were first-time AP students. Due to the mix of sophomore science course levels and prior AP coursework, each class contained students with a range of writing abilities. The diversity of each class reflected the overall school population demographics (Table 1). Research took place over two units. Both classes received treatment, but in alternating units. While one class received treatment, the other class served as nontreatment. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A).

Table 1. Demographics of Yorkville High School, second period AP Environmental Science, ($n=17$), sixth period AP Environmental Science, ($n=21$).

Ethnicity	Yorkville High School	Second period AP Environmental Science	Sixth period AP Environmental Science
White	63.3%	76%	71%
Hispanic	21%	12%	14%
Black	8.2%	0%	5%
Asian	2.6%	6%	5%
Two or more ethnicities	4.7%	6%	5%

Treatment

Peer editing treatment began at the start of the second semester. Second period received treatment first while sixth period received no treatment. Treatment for second period occurred in

Unit 5: Land and Water Use and consisted of two lessons designed to get students reviewing constructive feedback and using the College Board rubrics to learn AP grading expectations. Each lesson was followed by students peer reviewing a practice free response question (FRQ). In the first lesson students reviewed constructive and nonconstructive feedback on a writing assignment (Appendix B). The goal of this lesson was to develop criteria for constructive feedback. In small groups, students were asked to evaluate a student FRQ sample posted by the College Board that was graded in two different ways. One grader gave very specific and helpful feedback while the other did not. Students first evaluated the comments with partners, attempted to correct the wrong answers, and then shared their ideas in a whole class discussion. During the whole class discussion, students came to a consensus on the difference between constructive and nonconstructive feedback (Figure 1).

Peer Editing: Constructive vs. Nonconstructive Feedback			
Constructive			Nonconstructive
To build and improve	Purpose		To criticize and tear down
Builds confidence and morale	Impact		Lowers confidence and morale
Respectful, supportive, considerate	Tone		Harsh, negative, or personal
Detailed and precise	Specific		Vague and unhelpful
Leads to improvement	Actionable		Does not lead to improvement

Figure 1. Lesson one criteria for constructive and nonconstructive feedback.

Following the lesson, students peer edited a practice FRQ that was assigned for homework the class period before (Appendix C). Students chose their peer editor and were encouraged to sit next to each other. During peer editing, students used a grading rubric to identify correct and incorrect answers. For incorrect responses, students were told to give at least

two constructive comments to help their peers improve their FRQ. A grading sheet was developed to help peer editors keep track of points and comments during peer editing (Figure 2).

Unit 5 FRQ #1 Scoring Sheet

Give at least two constructive comments on this sheet of paper.

Question	Score (circle)	Constructive Comment
(a) (i)	1 0	
(a) (ii)	1 0	
(a) (iii)	1 0	
(a) (iv)	1 0	
(b) (i)	1 0	
(b) (ii)	1 0	
(b) (iii)	1 0	
(b) (iv)	1 0	
(c) (i)	1 0	
(c) (ii)	1 0	

Total score: _____/10

Figure 2. Sample scoring sheet used during peer editing.

After peer editing, students returned papers to their peers. Each student looked over the peer comments. Students were asked to use peer feedback to make corrections to their FRQ in a new pen color. A different color was used, so corrections could easily be distinguished from original answers. The assignment was collected, and completion points were awarded.

In the second lesson, students graded three FRQ samples from the College Board in small groups (Appendix D). Students used a College Board scoring rubric to determine how many points each sample earned and provided at least two constructive comments to help the student earn more points. Students shared constructive comments with the class, and in a whole group discussion, students evaluated the usefulness of the comments. The goal of this lesson was to

assess end-product models from an AP exam, review the criteria for constructive and nonconstructive comments, and become more familiar with rubrics used for scoring FRQs on the AP exam. After the lesson, students peer edited a practice FRQ that was assigned for homework the period before (Appendix E). Students chose their peer editor and were encouraged to sit next to each other. During peer editing, students used a grading rubric to identify correct and incorrect answers. For incorrect responses, students were told to give at least two constructive comments to help their peers improve their FRQ. A grading sheet was developed to help peer editors keep track of points and comments during peer editing. After peer editing, students returned papers to their peers. Each student looked over the peer comments and made corrections to their FRQ in a new pen color. A different color was used, so corrections could easily be distinguished from original answers. The assignment was collected, and completion points were awarded.

The nontreatment group completed both practice FRQs, but students self-graded their responses and did not participate in the two peer editing lessons. At the end of Unit 5: Land and Water Use, a summative assessment was given to both treatment and nontreatment groups. It contained multiple choice questions and one FRQ. I assessed the accuracy of each student's FRQ response out of 10 points. During Unit 6: Energy Resources and Consumption, the treatment and nontreatment groups were switched. Second period served as the nontreatment group while sixth period received treatment. The same methodology was used with sixth period for this unit.

Data Collection and Analysis Strategies

To determine the effectiveness of structured teaching and modeling of peer editing on the scientific writing of students, a variety of data collection instruments were used. Both qualitative and quantitative data were developed to triangulate the results of this study. Quantitative

measures included surveys and summative free response writing test data. Student voice was captured in surveys, student interviews, and a teacher journal. Both quantitative and qualitative measures were evaluated to determine the usefulness of peer editing instruction and modeling.

Pretreatment Peer Review Survey

The Pretreatment Peer Review Survey was filled out prior to the first peer editing lesson (Appendix F). The survey was a mix of qualitative and quantitative questions and asked students about their experiences with peer review, like student confidence to give valuable feedback and student ability to take feedback from a peer to improve their own work. The quantitative questions contained a four-point Likert scale of strongly disagree (1), disagree (2), agree (3), and strongly agree (4). To elicit student voice and qualitative data, students were asked to elaborate on why they chose answers on two of the Likert questions. The survey was conducted using Google Forms. Prior to taking the survey, students were reminded that it was voluntary and would not help or harm their grade. The data from the Pretreatment Peer Review Survey was imported into Excel, and the frequency of responses was calculated. To visualize the data, stacked bar graphs were made. The qualitative data from the survey was analyzed for themes and patterns.

Posttreatment Peer Review Survey

The Posttreatment Peer Review Survey was given after the second peer editing lesson (Appendix G). The survey was a mix of qualitative and quantitative questions. It contained the same questions as the Pretreatment Peer Review Survey with an additional four questions that pertained to the usefulness of the strategies used during treatment and the overall effectiveness of peer editing instruction. Like the pretreatment survey, the quantitative questions contained a

four-point Likert scale of strongly disagree (1), disagree (2), agree (3), and strongly agree (4). To elicit student voice and qualitative data, students were asked to elaborate on why they chose answers on six of the Likert questions. The Posttreatment Peer Review Survey was given using Google Forms. Prior to taking the survey, students were reminded that it was voluntary and would not help or harm their grade. The data from the Posttreatment Peer Review Survey was imported into Excel, and the frequency of responses was calculated. To visualize the data, stacked bar graphs were made. The qualitative data from the survey was analyzed for themes and patterns.

Teacher Journal

Throughout the study I kept a handwritten Teacher Journal (Appendix H). I recorded student comments during the two peer editing lessons, including whether students found the activities useful. I also documented the engagement level of students in the lessons, whether students were helping each other, if there were any directions students struggled with, and what the classroom environment felt like. I also wrote down student comments and questions while they peer edited each other's practice FRQs. Lastly, I made notes of student comments and questions while students used peer comments to edit and improve on their own assignments. The Teacher Journal was analyzed for themes and patterns. The journal helped me track successes and challenges during the study and triangulate the quantitative data collected in the study.

Free Response Writing Test

To assess the effectiveness of peer editing on the scientific writing of students, I used Free Response Writing Test scores from Unit 5: Land and Water Use and Unit 6: Energy Resources and Consumption (Appendix I). These summative assessments were given at the end

of each unit and were part of a larger test that also contained multiple choice questions. Since my research was only concerned with the scientific writing of students, the multiple-choice questions were excluded from the study. The test was given on paper, and students wrote their responses on an answer sheet. I graded each Free Response Writing Test out of 10 points. The Free Response Writing Test scores were compared between treatment and nontreatment groups for each unit. The score for each student was entered into Excel, and the mean, median, and mode were calculated. To test for a difference in scores between treatment and nontreatment groups, the Wilcoxon rank-sum test was used. To visualize this information a Box and Whiskers plot was used.

Student Interviews

Five students were interviewed in each class after the second peer editing lesson took place. All students were asked the same eight questions in the Student Interview (Appendix J). Students were told that participating in the interview was voluntary and would not help or harm their grade. Students volunteered to be interviewed, and students were chosen to get a variety of skill levels. Students were told the purpose of the interview and how the information gained would be used. I interviewed each student one on one where they were working. Students were working in small groups or individually on a different activity, so students not being interviewed were busy and not bothered while I was interviewing their classmates. I transcribed student responses to the interview questions, and thematic analysis was used to find common themes. All four data sources, Peer Review Survey, Teacher Journal, Free Response Writing Test, and Student Interviews, were triangulated to increase the trustworthiness of results (Table 2).

Table 2. Data triangulation matrix.

Research Question	Data Source 1	Data Source 2	Data Source 3	Data Source 4
How does direct instruction and modeling of peer editing impact scientific writing of Advanced Placement Environmental Science students in a high school science classroom?	Treatment and nontreatment Free Response Writing Test scores	Peer Review Surveys pre and post peer editing instruction	Student Interviews post peer editing instruction	Teacher Journal

DATA ANALYSIS: CLAIMS AND EVIDENCE

The purpose of this study was to determine if purposeful, meaningful instruction of peer editing would impact the scientific writing of high school students. Instruction consisted of two lessons where students evaluated models of graded student responses and learned how to give constructive and nonconstructive feedback aligned with Advanced Placement rubrics. Each lesson was followed by peer editing opportunities. The focus question to be answered was, how does structured teaching and modeling of peer editing impact scientific writing of Advanced Placement Environmental Science students in a high school science classroom?. The outcomes of this study were mixed. Students increased confidence in peer editing after treatment, and most students valued the peer editing lessons and thought peer editing improved their writing. However, the results of the Free Response Writing Test scores remained unaffected, and no difference was found between the treatment and nontreatment groups.

Effectiveness of Peer Editing Lessons

The results of the Posttreatment Peer Review Survey indicated that 69% of respondents strongly agreed and 25% agreed that instruction on peer editing was useful ($N=36$). Instructing students how to peer edit gave them ideas for what to say to their peers. Students surveyed said the lessons on peer review added clarity to their comments with one student commenting, “Now I can articulate my thoughts for improvement much more clear because of the lesson.” Several students also thought peer review would be a skill that would benefit them in the future. As a result, they found the instruction on peer review useful. One student mentioned, “I think it will help in the long run.” Of those surveyed, two students (6%) disagreed that the instruction on peer

review was useful (Figure 3). These students noted that they knew how to peer edit but still found the lessons a good refresher and useful. Of the students who disagreed, one student said, “I already know how to peer review so that wasn't really needed, but going over constructive vs. non-constructive feedback was useful.”

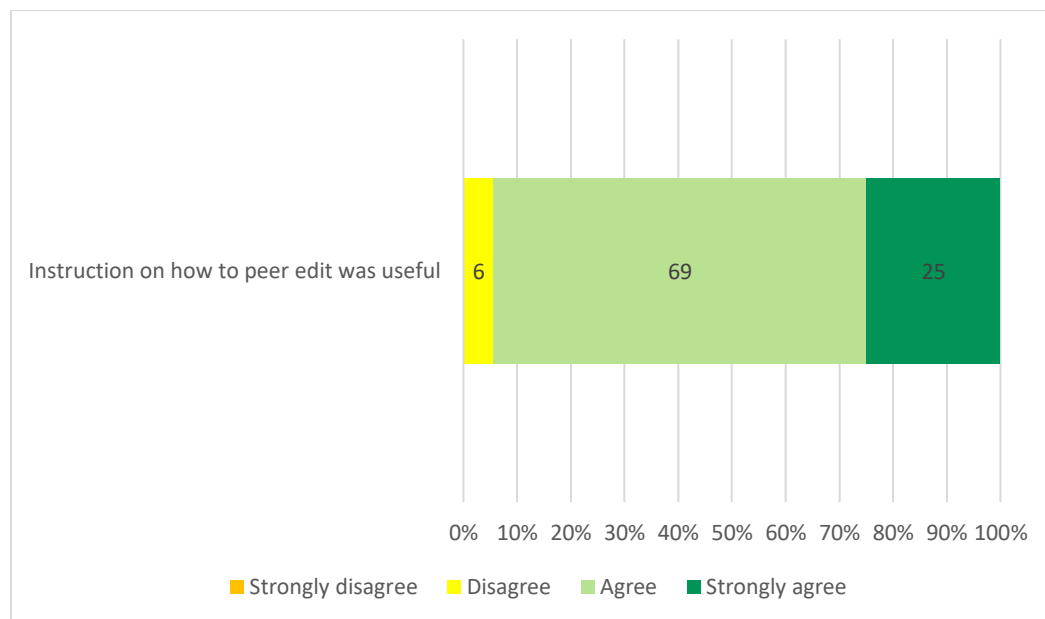


Figure 3. Percent distribution in the Posttreatment Peer Review Survey, instruction on how to peer edit was useful (Question 10), ($N=36$).

Of those surveyed in the Posttreatment Peer Review Survey, 100% agreed or strongly agreed that the first lesson on learning constructive and nonconstructive feedback was useful ($N=36$). One student said, “It gave examples of both positive and negative feedback; not just saying don't do this but how to rephrase it to make it more constructive.” The second lesson where students graded student samples from the College Board had more mixed reviews. Most students either strongly agreed or agreed that the lesson was useful (91%), but three students (9%) did not find the lesson useful (Figure 4). These students were frustrated with the amount of time spent on the lesson. Each lesson lasted approximately 40 minutes. In the second lesson,

three different student responses were reviewed and graded, giving constructive feedback on each. One student noted, “We had never been truly taught before, so that was helpful, but at the same time it is a fairly simple concept that I do not believe needed quite as much time as it got.” The same sentiment was noted in the Teacher Journal. The two 40-minute peer editing lessons required a large portion of class time. In addition, the process of peer editing required more time than self-grading. Self-grading took less than 10 minutes while peer-grading required up to 20 minutes. Teacher workload was also not reduced during this study. There was no change in the teacher grading time of end of unit Free Response Writing Test scores, and since practice Free Response Questions were previously self-graded, peer editing did not decrease teacher workload of entering these grades into the computer.

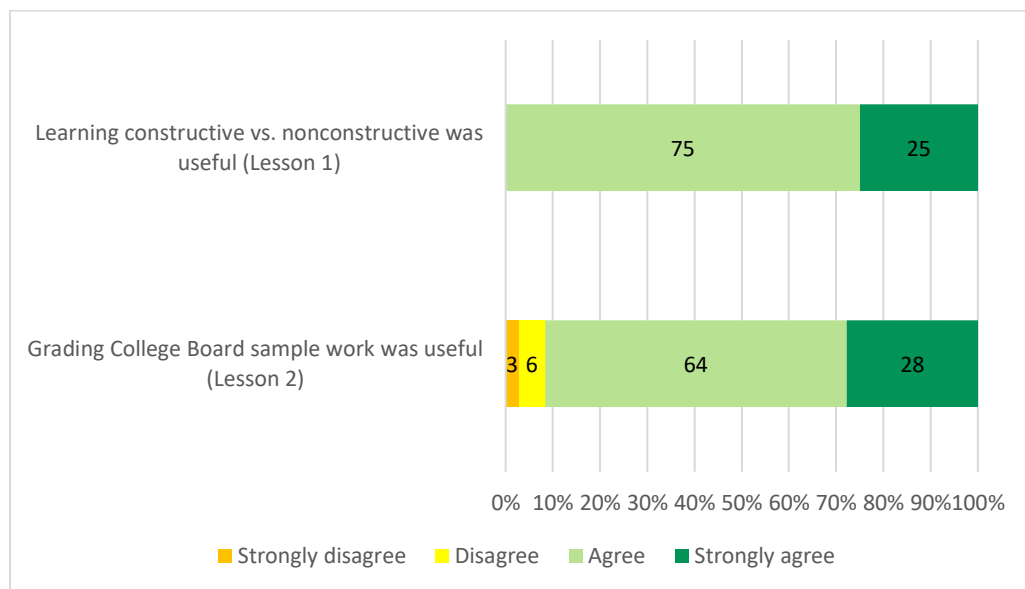


Figure 4. Percent distribution in the Posttreatment Peer Review Survey, learning constructive and nonconstructive was useful (Question 8), grading student sample work was useful (Question 9), ($N=36$).

Student Attitudes on Peer Editing

Students also gained confidence in peer editing after they experienced the two peer editing lessons. Prior to treatment, students took the Pretreatment Peer Review Survey, which found that 84% of students strongly agreed or agreed they could give helpful feedback to their peers that would improve their peer's writing ($N=37$). Of the 16% who disagreed with this same statement, several students cited feeling bad giving too harsh criticism while others noted that they were unsure of the feedback to provide because they did not know what their teacher was expecting. After the two peer editing lessons, students took the Posttreatment Peer Review Survey. The number of students who felt they could give valuable feedback increased from 84% pretreatment to 94% posttreatment with 22% strongly agreeing and only 6% disagreeing ($N=36$). Many students said they understood the writing expectations, which meant they could provide useful feedback. One student responded, "I am familiar with what is required for good scoring and can provide relevant feedback on how to achieve it." When asked to rate their confidence in giving constructive feedback to peers, before treatment 16% of students lacked confidence. One respondent said, "I don't do great at FRQs so I think my feedback will not be effective." After the peer editing lessons, the number of students who lacked confidence dropped to 8% with the majority of students (92%) agreeing or strongly agreeing that they could confidently give their peers constructive feedback (Figure 5). One student noted, "Before this lesson I didn't really know what to say in the comments when peer editing, but after Mrs. Jones taught us, I am much more confident about it."

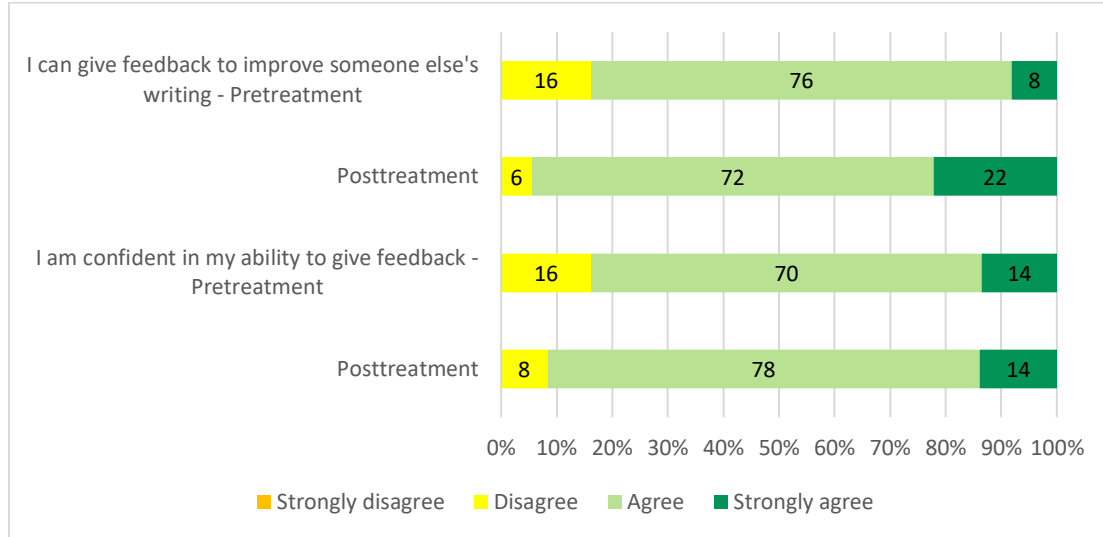


Figure 5. Percent distribution in the Pretreatment Peer Review Survey ($N=37$) and Posttreatment Peer Review Survey ($N=36$), I can give feedback to improve someone else's writing (Question 4), I am confident in my ability to give feedback (Question 5).

In addition, 69% of students surveyed agreed and 22% strongly agreed that feedback from their peers helped them to improve their work. Students felt their peers were able to help them fix mistakes with one student noting, “When I get another person’s eyes on my work, they are able to spot mistakes I hadn't noticed.” Other students surveyed appreciated the new ideas and point of view a peer offered. One respondent said, “I can gain new and different perspectives that I may not have considered before.” In Student Interviews, several other students noted that gaining insight into how others think was an additional benefit of peer editing. One student described peer editing as “mutually beneficial,” and another mentioned she was able to “get ideas from other people’s work.” Overall, the majority of students felt feedback from peers allowed them to improve their writing (Figure 6).

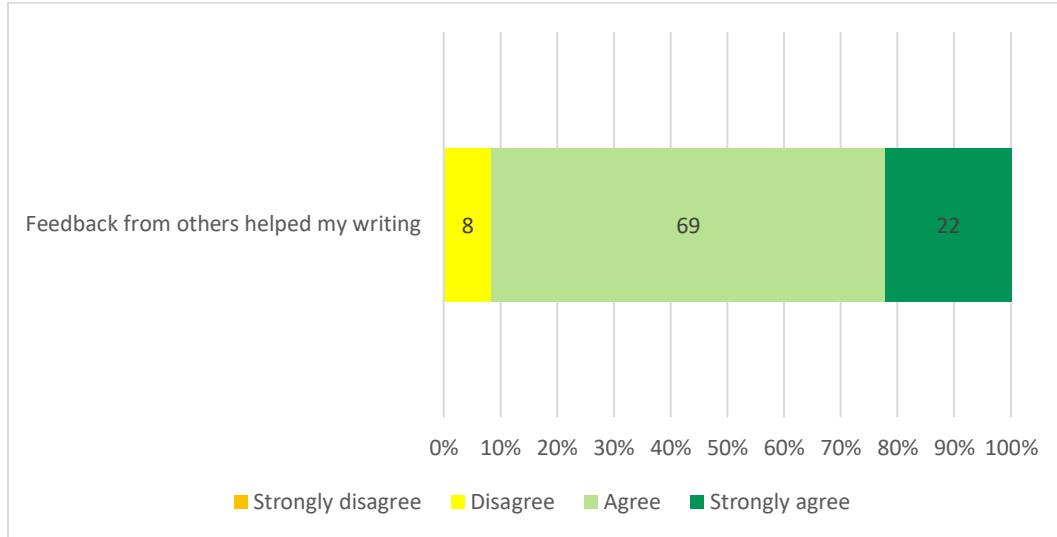


Figure 6. Percent distribution in the Posttreatment Peer Review Survey, feedback from others helped my writing (Question 7), ($N=36$).

In the Teacher Journal, an added benefit noted during peer editing was the collaboration that occurred between peers. After lessons, students peer edited a practice free response question. During these peer editing sessions, students were engaged with each other. They asked clarifying questions on responses they did not understand and explained constructive comments they gave their peers. This level of engagement was not noted during self-grading sessions. Students were very quiet during self-grading, asked very few questions, and did not analyze the grading rubric in the same way that the peer graders did.

Student Prior and Current Experience with Peer Review

In the Pretreatment Peer Review Survey, 65% of respondents agreed they had used peer editing in other classes and 70% of students agreed they had been taught how to peer review with many citing experiences in English class ($N=37$). No students mentioned using peer editing in a previous science class. There were mixed comments on the level of teaching that had taken

place. Some students mentioned explicit instruction while others mentioned using rubrics to grade their peers' essays. For example, one student said, "A teacher has explained how the peer review needs to be done with simple and clear directions," indicating some level of instruction had taken place. While another student discussed, "I have learned to peer review mostly in my English classes where I have to check another peer's work as they do mine. This checking is to make sure everything that is on the rubric is in their essay before submitting." Among the 30% of students who disagreed that they had been taught how to peer edit, many cited they were asked to peer review with minimal instruction. One respondent noted, "A teacher has never really taught me how to peer review, they just give us a paper on what to look for and expect us to know what to do. I think it's basically them thinking that a previous teacher already taught us."

After treatment, the number of students who said peer review was used in other classes dropped from 65% to 58% ($N=36$). Students looked at this question differently the second time around. Comments revolved around peer editing only being used in English and now our science course. Some students mentioned using peer review at younger grades, but not as frequently now in high school. Initially some students may not have understood the concept of peer review. Prior to taking the survey, there was no discussion on peer review, its definition, and what it meant for our class. In the Pretreatment Peer Review Survey some students commented they peer review in math and other classes when they take group tests. Working collaboratively with peers is not peer review, so this was a misconception. After our peer editing lessons, students had a much firmer grasp on the concept of peer editing. For example, in the Posttreatment Peer Review Survey one student said, "It taught me, after years of teachers just giving us papers and saying peer review this, how to actually complete a peer review instead of being confused and putting whatever on

the paper to complete the assignment.” After treatment, some students decided that fewer classes use peer review and the percentage of students who agreed with this question dropped.

As expected, the number of students who agreed they had been taught how to peer edit increased from 70% pretreatment to 94% posttreatment. Two students disagreed with this statement (6%) posttreatment. Several students were absent during the peer editing lessons, and identifying information was not collected during surveys. One student who disagreed posttreatment said, “No one has really taught us, English has said to just do it with little direction.” The second student responded, “I kinda figured it out on my own and then over time teachers will just give me a rubric to grade off of, so I just went along with it.” Consequently, it cannot be determined if these two students missed the lessons or just felt the lessons were not valuable to them (Figure 7).

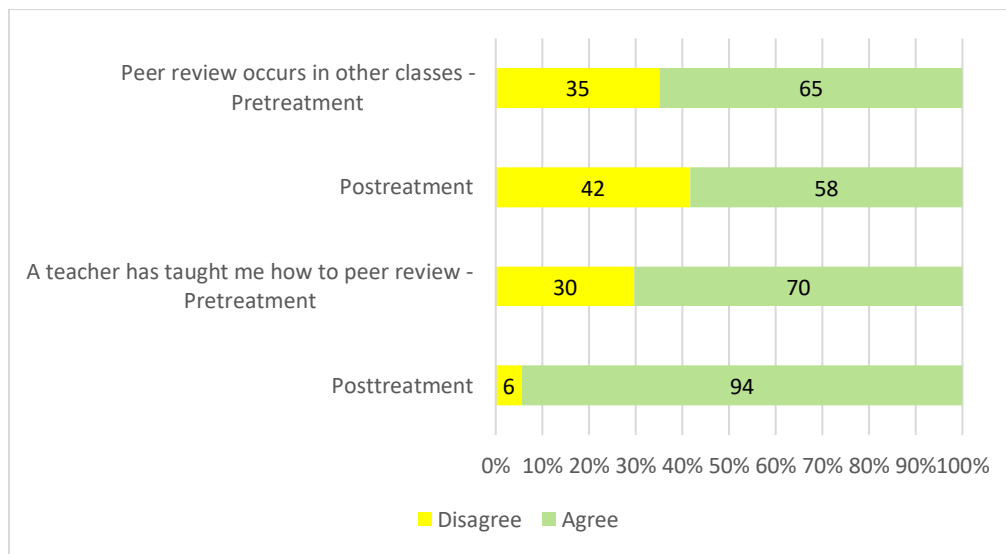


Figure 7. Percent distribution in the Pretreatment Peer Review Survey ($N=37$) and Posttreatment Peer Review Survey ($N=36$), Peer review occurs in other classes (Question 1), A teacher has taught me how to peer review (Question 2).

Free Response Writing Test Results

Although students reported positive experiences with peer editing in surveys, no measurable difference was detected in the Free Response Writing Test scores. The Wilcoxon rank-sum test yielded a p value of .14 ($N=38$), which is greater than .05 and indicated no statistical difference between the treatment and nontreatment groups on the Unit 5 Free Response Writing Test scores (Appendix K). Although the scores between treatment and nontreatment groups were not statistically different, the treatment group had a higher mean and median. Out of 10 points, the treatment group had a mean score of 5.18 ($n=17$) compared to the nontreatment group's mean score of 3.90 points ($n=21$). The median score of the treatment group was also higher with a score of 5 compared to the nontreatment median score of 3. In addition, the treatment group showed a smaller interquartile range indicating less dispersion and more consistency in treatment test scores (Figure 8).

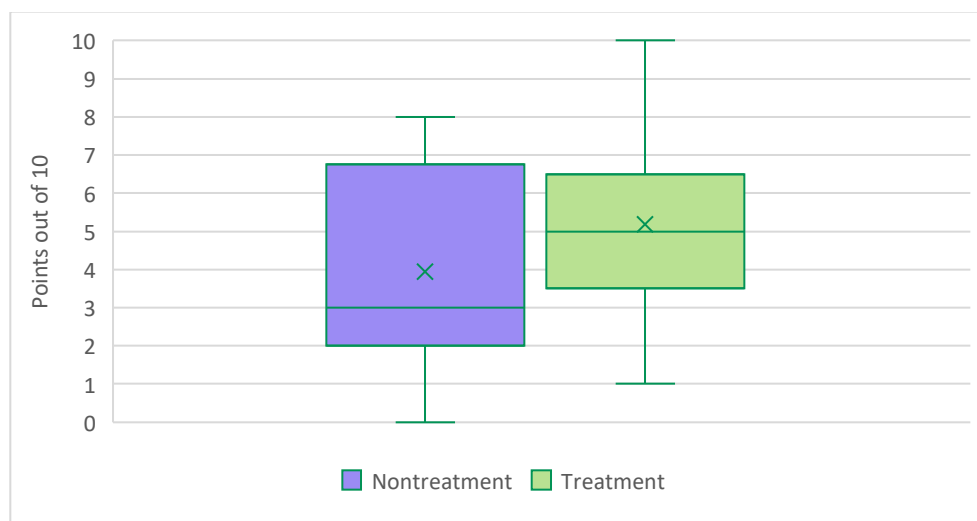


Figure 8. Box and Whiskers plot of Unit 5 Free Response Writing Test scores for nontreatment ($n=21$) and treatment ($n=17$) groups.

In Unit 6 the treatment and nontreatment groups were switched. Like Unit 5, the Wilcoxon rank-sum test yielded a p value greater than .05 ($p=.78$, $N=38$) and indicated no statistical difference in the Unit 6 Free Response Writing Test scores between the treatment and nontreatment groups (Appendix L). Unlike results in Unit 5, the treatment group did not have a higher mean than the nontreatment group. Out of 10 points, the treatment group had a mean score of 6.62 ($n=21$) compared to the nontreatment group which had a higher mean score of 6.82 ($n=17$). Although the mean score was not higher, the difference between treatment and nontreatment groups in Unit 6, 0.20 points, was drastically smaller than Unit 5, 1.28 points. In addition, both groups had a median score of 7 in Unit 6. The interquartile range also showed less variability for the nontreatment, but overall, both groups showed less dispersion and more consistent scores on the Unit 6 test compared to the Unit 5 test (Figure 9).

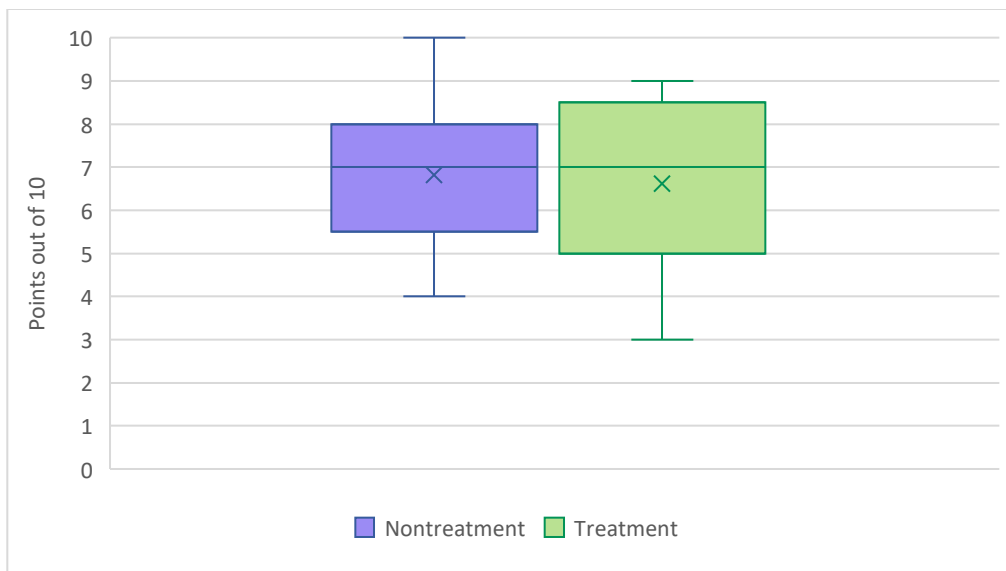


Figure 9. Box and Whiskers plot of Unit 6 Free Response Writing Test scores for nontreatment ($n=17$) and treatment ($n=21$) groups.

Student Advice for Teachers

One of the questions in the Student Interview asked students to give advice to another teacher implementing peer review in their classroom. Ten students were interviewed after treatment concluded. Eight out of 10 students interviewed said teachers should provide some level of instruction of peer editing, since many students do not know how to do it effectively. One student mentioned, “Teachers need to at least give examples of how to peer edit correctly. They can’t just say give constructive feedback. Students need to see what that means because it’s different in each class.” Two other students, who were interviewed, valued peer editing in person. These students suggested teachers complete peer editing exercises in class instead of outside of class as homework. One student mentioned that sitting next to his peer made it easier to explain the edits face to face.

CHAPTER FOUR

VALUE: REASONING AND REFLECTION

Claims from the Study

The goal of this study was to determine if explicit instruction of peer editing helped students to become better writers. Although the results of this study indicated that peer review had no significant impact on the Free Response Writing Test scores of Advanced Placement (AP) Environmental Science students, students still appreciated the direct instruction on how to peer edit, and they gained confidence in peer editing one another's work, which led them to believe they developed into better writers. I appreciated the level of student engagement that occurred during peer editing exercises with students asking more questions and diving deeper into their understanding of AP grading rubrics. If given more peer editing opportunities, I believe students would become better writers and teacher workload could decrease. In addition, I believe peer editing could close the gap between high and low achieving students.

Usefulness of Peer Editing Instruction

The majority of students valued receiving instruction on how to peer edit, with 69% of respondents strongly agreeing and 25% agreeing that lessons on peer editing were useful. Students acknowledged that feedback in each class looks different. Therefore, teachers should provide some instruction on what that feedback looks like. For example, the feedback on a paper in English may look different than feedback provided on a free response question in science. As a result, teachers should provide specific examples and review writing expectations for their class before a peer edit exercise occurs.

In addition, students gained confidence in peer editing after peer editing instruction. Prior to peer editing instruction, 84% of students were confident in their ability to give feedback to peers. After peer editing instruction, this number increased to 92%. Prior to treatment, 84% of students either strongly agreed or agreed they could give peers feedback to improve their writing. After peer editing lessons, this number rose to 94% with 22% of students strongly agreeing. Students appreciated that the peer editing lessons provided examples of constructive course-specific feedback. In addition, they learned the expectations of AP graders on the AP exam. As a result, students had examples of what to say to help their peers and their confidence to peer edit increased.

Students also believed that peer editing helped them to become better writers. Of those surveyed, 69% of students agreed and 22% strongly agreed that feedback from their peers helped them to improve their work. Students described how peer editing benefited them in two ways. They received useful feedback from their peers, and while peer editing, they got ideas for how to answer questions in different ways. This benefit was mentioned in the research of Topping (2009), who discussed that peer editing encourages self-reflection and metacognition. As students read other students' work, they gained ideas for how to improve their own work. In addition, another important piece to peer review is giving students time to reflect after peer editing occurs. Students should be given class time to review peer comments, make edits and ask clarifying questions. Wichmann et al. (2017) referred to this as feedback uptake, and it was something I consciously built into each of the peer editing exercises. I believe allowing time for reflection and giving students time in class to make corrections to their writing based off peer

feedback, made them feel more confident as writers because they were able to understand and fix their mistakes.

Higher Student Engagement

Although the peer review lessons were a time investment, two 40-minute lessons, and peer-grading took more class time than self-grading, 20 minutes compared to less than 10 minutes, I believe the time invested in peer editing is worthwhile because students engage more deeply with the text and rubrics compared to self-grading. During all four peer editing exercises, I noted more student questions and more student discussion compared to the group who self-graded. The peer-grading group seemed more invested in understanding the grading rubric and understanding their peers' responses to accurately award points. Students who self-graded had less pressure to accurately grade because they were grading themselves, and since this practice was for completion points, students knew I also would not be looking at it deeply to catch mistakes. Peer-grading added an extra layer of accountability that caused students to engage more deeply with the rubric and their peers.

The findings also suggested that peer review is an underutilized strategy in science courses. Although 65% of students said they have used peer review before in other classes, none mentioned using it in a previous science class. As a result, peer review is an instructional strategy that could be used more frequently in science courses. When supported with proper instruction, peer review could be a skill used to develop the writing of science students. Perhaps teachers are nervous about the time investment, but the student collaboration and deepening of knowledge that occurred while peer editing made the time well spent.

Potential to Decrease Teacher Workload

In addition, I predict students will become better writers if given more peer editing opportunities and as a result, teacher workload could decrease. In this study, students peer edited for one unit the second semester of the school year. As a result, I did not feel or see a reduction in teacher workload during this study. Peer grading and the initial lessons are time consuming, but after students understand expectations, the process would be more automated. I think it is best for students to start the school year with self-grading practice to understand the writing prompts before attempting to give peers advice on how to fix mistakes. After the first quarter of the school year practicing self-grading, I would introduce peer editing with the lessons in this study and conduct peer editing the rest of the school year. As noted previously, peer review added an extra layer of accountability and allowed students to engage more deeply with rubrics. Using peer review for most of the school year would allow students to evaluate peer responses and have a better understanding of rubric requirements, which will hopefully help them become better writers and score higher on end of unit assessments. With growing class sizes, this would ultimately save me time grading and providing feedback on end of unit assessments, decreasing teacher workload.

Potential to Close the Gap between High and Low Achieving Students

Finally, I believe peer editing helped close the gap in scores between my two class periods. I tracked test scores between these two classes all school year, and my sixth period consistently scored lower than my second period on all assessments. My sixth period class had a higher number of students who took Chemistry their sophomore year, 71%, compared to 59% in my second period. Compared with students in Chemistry Honors, students in Chemistry had

fewer opportunities to practice writing skills. As a result, the lower assessment scores in sixth period could be explained by the fact that many students had not practiced these skills during their sophomore year. However, after sixth period received peer editing treatment, I noticed the gap in scores between these two classes decreased.

My sixth period class was the nontreatment group in Unit 5 and the treatment group in Unit 6. In Unit 5, as expected, the treatment group had a mean score that was 1.28 points higher than the nontreatment group. In Unit 6, my sixth period received treatment and had a lower mean score of 6.62 compared to the nontreatment group which had a higher mean score of 6.82. Although my sixth period did not score higher than second period during their peer editing treatment, the mean score was only 0.20 lower and was the smallest difference in mean writing scores between the two classes all school year. This data suggests peer editing might have reduced the disparity in scores between the two class periods. By exposing students to examples of peers' work, AP rubrics, and peer feedback, peer editing may have helped struggling writers to develop their skills and move closer to the performance level of high-achieving peers.

Value of the Study and Consideration for Future Research

Overall, peer editing is worthwhile. The time spent teaching students how to peer review effectively was well worth the investment. Instructing students how to peer edit increased their confidence to give their peers meaningful feedback. During peer editing exercises, students were highly engaged with the grading rubrics and asked clarifying questions to ensure their understanding. As a result, they learned the writing expectations at a deeper level, which made them feel like better writers. Dedicating time to teaching students how to effectively peer edit also demonstrated the importance I place on it as an educator. I believe this creates greater

student engagement, leading students to take the peer editing process seriously and invest time in evaluating their peers' work and providing constructive feedback. This study also reinforced the need to teach students academic soft skills, like collaboration and using feedback to improve work. I often hear teachers complaining that students cannot work in teams or struggle to learn from their mistakes and as a result, fail tests. Over the last few years, I have realized that I need to explicitly teach these skills because they do not come naturally to most students. As a result, I will share my peer review lessons with my colleagues in hopes they will also implement peer review in their classrooms as a way for students to improve confidence in their writing skills.

In addition, peer editing mimics what real scientists do. The Next Generation Science Standards (NGSS) focus on students becoming scientists and understanding the scientific process as a way of knowing. Engaging in argument from evidence is one of the science and engineering practices where students critique claims of other students and evaluate the evidence that supports the claims (National Research Council, 2012). Peer review is an important piece to understanding the nature of science because it allows scientists to build durability in scientific claims. Giving students opportunities to model what scientists do is essential because it helps students deepen their knowledge in the scientific process and helps them to become well informed citizens.

Although I did not see significant growth in student test scores, I believe peer editing for longer could show greater growth. My plan is to start peer editing sooner next school year. The level of engagement students displayed while peer-grading made this whole process worthwhile to me. As students have deeper conversations about grading rubrics, they are likely to improve their writing skills. More work should be done to determine if using peer review for longer

periods of time in a high school science classroom can improve students' writing. In addition, a future study could focus on peer review's impact on teacher workload. With growing class sizes, can peer review help students become better writers and decrease the grading requirements of teachers? Attention should also be paid to students who struggle with writing. In my study, I observed the class period that typically struggles with writing performed better in the unit we used peer editing. This raises the question of whether peer editing can help shrink the gap between high and low achieving students. A long-term study on peer editing would be beneficial to address this issue. In addition, students mentioned that peer editing occurs outside of class as homework for some classes. I wonder if this method is as effective as having students peer edit side by side in class. A future study could examine whether peer editing is more effective for high school students in person during class or online outside of class.

Impact of Action Research on the Author

I am a naturally reflective teacher, always making changes between lessons and tweaking curricula from year to year. Action Research allowed me to become more systematic in my already reflective nature. I also learned to think of data in a different way. I learned to consider multiple sources of data and find ways to triangulate data, so I have multiple pieces of evidence to support or refute a teaching strategy. Understanding data in this way allowed me to effectively analyze results to see if student learning was meaningfully impacted.

I plan to share this systematic way of measuring a tool or strategy's effectiveness with the new teachers I mentor in my district. I truly believe that teachers must remain engaged to stay in the field of education. It is easy to get stuck in a loop of negativity blaming students, parents, and the school for the problems we see in the classroom. When teachers instead wear the hat of

problem solver, it allows them to change their practice in the classroom and try to solve some of the problems they are seeing. This mindset will allow teachers to remain engaged in the profession and lessen the chances of burning out. Teachers who reflect and make changes to their instructional practice feel a sense of empowerment and stay more intellectually engaged in the profession of teaching (Mertler, 2025).

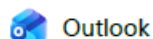
REFERENCES CITED

- College Board. (2025a). *2025 chief reader report - AP Environmental Science: Set 1*. <https://apcentral.collegeboard.org/media/pdf/ap25-cr-report-environmental-science-set-1.pdf>
- College Board. (2025b). *AP Environmental Science Exam questions*. AP Environmental Science Exam Questions. <https://apcentral.collegeboard.org/courses/ap-environmental-science/exam/past-exam-questions>
- Drew, S. V., Olinghouse, N. G., Faggella-Luby, M., & Welsh, M. E. (2017). Framework for disciplinary writing in science grades 6–12: A national survey. *Journal of Educational Psychology*, 109(7), 935–955. <https://doi.org/10.1037/edu0000186>
- Falchikov, N., & Goldfinch, J. (2000). Student Peer Assessment in higher education: A meta-analysis comparing peer and teacher marks. *Review of Educational Research*, 70(3), 287–322. <https://doi.org/10.3102/00346543070003287>
- Graham, S., & Perin, D. (2007). A meta-analysis of writing instruction for adolescent students. *Journal of Educational Psychology*, 99(3), 445–476. <https://doi.org/10.1037/0022-0663.99.3.445>
- Illinois State Board of Education. (n.d.). *Yorkville high school*. Illinois Report Card. Retrieved March 20, 2025, from <https://www.illinoisreportcard.com/school.aspx?source=profile&Schoolid=240471150260001>
- Mertler, C. A. (2025). *Action research: Improving schools and empowering educators*. Sage Publications, Inc.
- National Assessment of Educational Progress. (2019). *Science Framework*. National Assessment Governing Board, U.S. Department of Education, Washington, D.C. <https://www.nagb.gov/content/dam/nagb/en/documents/publications/frameworks/science/2019-science-framework.pdf>
- National Center for Education Statistics. (2012). *The Nation's Report Card: Writing 2011 (NCES 2012–470)*. Institute of Education Sciences, U.S. Department of Education, Washington, D.C. <https://nces.ed.gov/nationsreportcard/pdf/main2011/2012470.pdf>
- National Center for Education Statistics. (2019). *The Nation's Report Card: Science 2019*. Institute of Education Sciences, U.S. Department of Education, Washington, D.C. <https://www.nationsreportcard.gov/highlights/science/2019/>
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

- Sanchez, C. E., Atkinson, K. M., Koenka, A. C., Moshontz, H., & Cooper, H. (2017). Self-grading and peer-grading for formative and summative assessments in 3rd through 12th grade classrooms: A meta-analysis. *Journal of Educational Psychology*, 109(8), 1049–1066. <https://doi.org/10.1037/edu0000190>
- Topping, K. J. (2009). Peer assessment. *Theory Into Practice*, 48(1), 20–27. <https://doi.org/10.1080/00405840802577569>
- United States Census Bureau. (2023, July 1). U.S. Census Bureau quickfacts: Yorkville City, Illinois. <https://www.census.gov/quickfacts/fact/table/yorkvillecityillinois/PST045223>
- Weaver, C. (2023). A troubled practice: Three models of peer review and the problems underlying them. In Jackson, P. & Weaver, C. (Eds.), *Rethinking peer review: Critical reflections on a pedagogical practice* (pp. 59-72). The WAC Clearinghouse; University Press of Colorado. <https://doi.org/10.37514/PER-B.2023.1961>
- Wichmann, A., Funk, A., & Rummel, N. (2017). Leveraging the potential of peer feedback in an academic writing activity through sense-making support. *European Journal of Psychology of Education*, 33(1), 165–184. <https://doi.org/10.1007/s10212-017-0348-7>
- 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), 492–526. <https://doi.org/10.3102/0002831220945266>
- Yorkville High School. (n.d.). Illinois Report Card. Retrieved October 25, 2025, from <https://www.illinoisreportcard.com/school.aspx?source=profile&Schoolid=240471150260001>

APPENDICES

APPENDIX A: EXEMPTION INSTITUTIONAL REVIEW
BOARD



IRB Protocol #2025-2374-EXEMPT APPROVED

From NoReply@TOPAZTI.net <NoReply@TOPAZTI.net>

Date Mon 12/8/2025 2:59 PM

To Gotz, Robyn <robyn.gotz@montana.edu>; Jones, Jennifer <jennifer.jones36@student.montana.edu>; Szott, Brenna <brenna.szott@montana.edu>

****External Sender****

Hello Jones, Jennifer,

Your protocol was reviewed by the IRB and has been approved.

PI: Jones, Jennifer

Approval Date: 12/8/2025

Title: The Effectiveness of Structured Teaching and Modeling of Peer Editing on The Scientific Writing of High School Students

Protocol #: 2025-2374-EXEMPT

Review Type: Exemption

Expiration Date: 12/8/2030

Work described under this protocol may now commence. The PI is responsible for ensuring that the protocol accurately describes research practices being conducted.

- > Review Category designation determined by the IRB can be found in the final section of your protocol.
- > Any changes must be submitted via Amendment prior to implementation.
- > Per the Common Rule, research only requires Interim (annual) Review by the IRB if 1) it was reviewed via Full Committee or 2) is regulated by the FDA.
- > All research is subject to post approval monitoring.
- > All protocol types must be renewed 5 years after approval.
- > Inform the IRB once your research is complete so that the protocol may be inactivated.

Please contact your IRB Program Manager with any questions or if you are in need of assistance. Thank you for your diligence in the care of human subjects research participants.

Institutional Review Board for the Protection of Human Subjects | Office of Research Compliance |
Montana State University

Figure A1. Email of Institutional Review Board approval

APPENDIX B: LESSON ONE: CONSTRUCTIVE AND
NONCONSTRUCTIVE FEEDBACK

Lesson One: Constructive and Nonconstructive Feedback

Purpose: Evaluate the comments on a free response question (FRQ) graded in two different ways and discuss criteria for constructive and nonconstructive feedback on writing assignments.

Lesson:

1. Place students in partners or groups of three. Display the sample directions (Figure B1).

Peer Editing: Constructive vs. Nonconstructive Feedback

1. Read the FRQ prompt
2. Look at FRQ response with **Grader A**
3. **Correct** incorrect points based on the feedback given
4. If you see **+1**, underline WHY received point



5. Look at FRQ response with **Grader B**
6. **Correct** incorrect points based on the feedback given
7. If you see **+1**, underline WHY received point

Figure B1. Sample directions to display for students.

2. Pass out the Free Response Question prompt below and have students read through the prompt (Figures B2-B3).

ENVIRONMENTAL SCIENCE

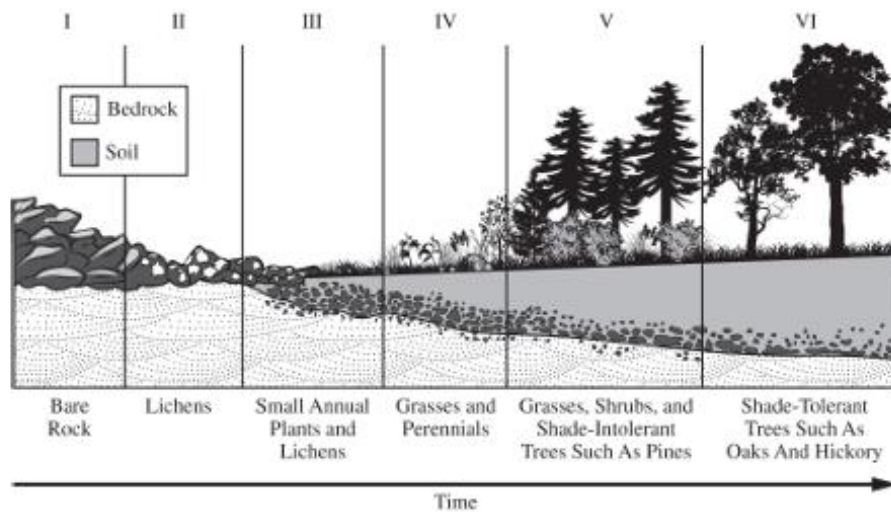
SECTION II

Time—1 hour and 10 minutes

3 Questions

Directions: Answer all three questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers in the Free Response booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. **You will only earn credit for what you write in the separate Free Response booklet.**

1. The following diagram shows how an area changed over time. The dominant vegetation in each stage is labeled in the diagram. Each roman numeral represents a stage in the ecological process.

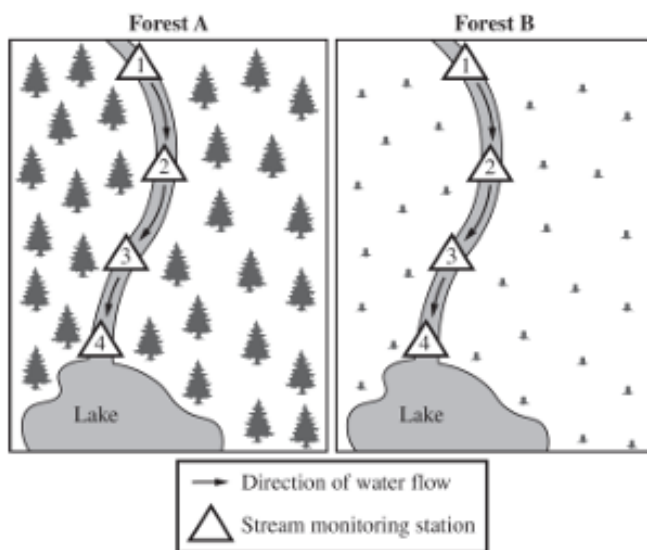


- Identify the ecological change over time illustrated in the diagram.
- Identify the stage in which pioneer species first appear.
- Describe how soil forms from stage II to stage III.
- Identify a cultural ecosystem service that may be provided by a mature forest.

Figure B2. Lesson one free response question prompt, page one.

AP® Environmental Science 2024 Free-Response Questions

Researchers are interested in investigating the effect of the removal of trees on the water quality of nearby waterways. To conduct their experiment, the researchers locate two identical forest watersheds, both with a river running through them. Forest A is an intact forest and forest B is a clear-cut forest. Four stream monitoring stations are set up in each forest study area. Each station monitors a variety of water quality indicators, including water temperature, at various locations along the river. The experimental setup is shown in the following diagrams. The arrows shown in the rivers represent the direction of water flow. The triangles in the river show the location of the stream monitoring stations.



- (e) **Identify** a testable hypothesis being investigated by the researchers.
- (f) **Identify** the independent variable in the experiment.
- (g) **Describe** the purpose of forest A in the experiment.
- (h) **Explain** why the water temperature might change because of clear-cutting trees in forest B.

After the experiment was completed, land developers constructed a golf course in the clear-cut area of forest B. To prepare the land, developers removed any remaining stumps and newly grown trees and began planting and fertilizing new grass. The researchers are interested in the effect the golf course may have on the water quality of the river. To monitor the river in forest B, the researchers repeated the experiment once the golf course had been constructed.

- (i) **Explain** why an indicator of water quality other than temperature could be altered by the golf course in forest B.
- (j) **Explain** how the aquatic organisms living in the lake illustrated in the diagram of forest B are likely to be affected by the new golf course.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

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Figure B3. Lesson one free response question prompt, page two.

3. Pass out the graded student sample response A (Figures B4-B5).

A (5/10) 1B 1 of 2

Important: Completely fill in the circle that corresponds to the question you are answering on this page.

Question 1 Question 2 Question 3

Begin your response to each question at the top of a new page. Do not skip lines.

d) we can see how biodiversity is increasing and ~~not~~ productivity increases. productivity does ↑

e) Pioneer species first appear in stage II +1

f) Lichens break down the rocks and provide nutrients to the soil when they die. The soil in stage III is composed of rock debris and lichen remains that have been decomposed +1

g) ~~A native forest could be a place for campers to travel, a location for a park.~~
A native forest could be a place for campers to travel or a location for a park +1

h) The testable hypothesis being investigated is whether the removal of trees affects the water quality of nearby water ways Format wrong

i) The independent variable is whether the forest is intact or clear-cut +1

j) Forest A serves as a control group Describe

k) Since there are no trees to provide shade in forest B,

Page 2

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

Figure B4. Lesson one graded student sample response A, page one.

A

1B 2 of 2

- **Important:** Completely fill in the circle that corresponds to the question you are answering on this page.

Question 1

Question 2

Question 3



Begin your response to each question at the top of a new page. Do not skip lines.

h could.) the waterway will be exposed to more sunlight, +1
raising the water temperature

i) Runoff from the grass on the golf course could contain
salt, increasing the salinity of the waterway when they
come into contact

j) The aquatic organisms are not likely used to the
increased salinity of the water coming from the river, so
many organisms could die due to the sudden change
in environmental conditions

Page 3

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

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Figure B5. Lesson one graded student sample response A, page two.

4. Students will correct incorrect responses using the feedback provided on the FRQ.
5. For responses that received +1, students must underline why the student earned the point.
6. Repeat this process with student sample response B (Figures B6-B7).

B 5/10 1B 1 of 2

Important: Completely fill in the circle that corresponds to the question you are answering on this page.

Question 1 Question 2 Question 3

● ○ ○

Begin your response to each question at the top of a new page. Do not skip lines.

a) we can see how biodiversity is increasing and net productivity increases Think vocab. term
What's the process called?

b) Pioneer species first appear in stage II +1

c) Lichens break down the rocks and provide nutrients to the soil when they die. The soil in stage III is composed of rock debris and lichen remains that have been decomposed +1

d) ~~A native forest could be a place for campers to travel, a location for a park.~~
A native forest could be a place for campers to travel or a location for a park +1

e) The testable hypothesis being investigated is whether the removal of trees affects the water quality of nearby water ways MUST use words like ↑ or ↓
If... then... because

f) The independent variable is whether the forest is intact or clear-cut +1

g) Forest A serves as a control group ISO... MUST Describe

h) Since there are no trees to provide shade in forest B,

Page 2

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

Figure B6. Lesson one graded student sample response B, page one.

B

1B 2 of 2

● **Important:** Completely fill in the circle that corresponds to the question you are answering on this page.

Question 1

Question 2

Question 3

●

✗

○

Begin your response to each question at the top of a new page. Do not skip lines.

h cond.) the waterway will be exposed to more sunlight, +1
raising the water temperature *Great explanation*

i) Runoff from the grass on the golf course could contain
salt, increasing the salinity of the waterway when they
come into contact *Good start, but wrong water parameter*
Think impact of fertilizer

j) The aquatic organisms are not likely used to the
increased ~~salinity~~ of the water coming from the river, so
many organisms could die due to the sudden change
in environmental conditions

wrong parameter
Think eutrophication

Page 3

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

● Q5398511

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● ●

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Figure B7. Lesson one graded student sample response B, page two.

7. Give students the following discussion prompt:
 - a. Which FRQ grader was easier to correct? Grader A or Grader B? WHY?
 - b. What is constructive vs. nonconstructive feedback?
8. Give students time to discuss in small groups and then share with the whole group.
9. Create a criteria list of constructive and nonconstructive feedback (Figure B5).

Peer Editing: Constructive vs. Nonconstructive Feedback		
Constructive		Nonconstructive
To build and improve	Purpose	To criticize and tear down
Builds confidence and morale	Impact	Lowers confidence and morale
Respectful, supportive, considerate	Tone	Harsh, negative, or personal
Detailed and precise	Specific	Vague and unhelpful
Leads to improvement	Actionable	Does not lead to improvement

Figure B8. Sample criteria list of constructive and nonconstructive feedback.

Activity adapted from the College Board (2025b) released exam FRQs.

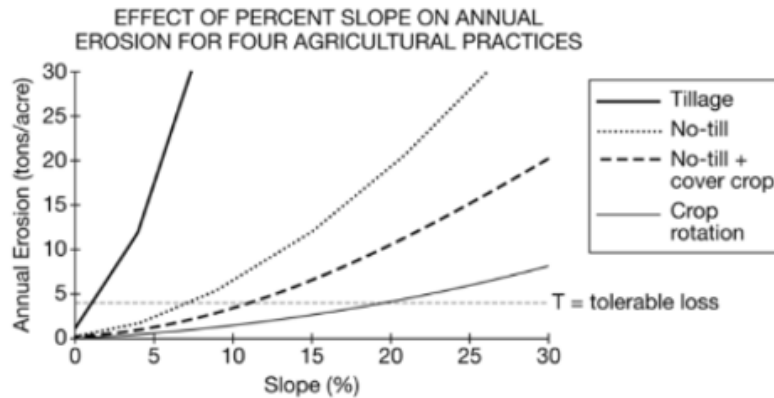
APPENDIX C: PRACTICE FRQ PEER EDIT AFTER LESSON

ONE

Unit 5 FRQ #1 Practice - Feeding the World

All FRQs must be handwritten on a separate sheet of paper!

Refer to the figure or diagram to answer the question. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.



Soil erosion is one of the most serious soil-degrading processes. Each year tons of soil erode from cropland, pastures, forests, and other places. The amount of erosion varies dramatically among various land-use types.

The figure above shows the effects of different agricultural practices and slopes on annual erosion rates.

(a) Refer to the graph above for the following.

- (i) **Identify** the scientific question that resulted in the data presented in the graph.
- (ii) **Identify** the agricultural practice that could be used on a 15% slope without leading to a higher than tolerable loss of soil.
- (iii) **Describe** the effect of adding a cover crop compared to using the no-till method.
- (iv) **Identify** one natural mechanism of soil erosion.

- (b) Sediment from erosion can enter streams and affect water quality. One way sediment can enter a stream is from nearby road construction. Two methods to reduce sediment run-off in streams are to either put down straw bales or plant grass. The hypothesis to be tested is that straw bales reduce more sediment run-off than planted grass does. To test the hypothesis, two plots near a road under construction are measured. On one plot (A), straw bales are used to cover the soil, while a second plot (B) is planted with grass. The sediment discharge from each plot is measured after rainfall.

- (i) **Identify** the dependent variable stated in the hypothesis.
- (ii) **Describe** one way to add a control to improve the design of the study.
- (iii) **Identify** one variable that was not discussed that could affect the results of the study.

Sediments reaching streams affect water clarity, which is tested by determining turbidity. Turbidity can be determined by measuring the depth at which a submerged object can no longer be seen from the surface.

Sample Group	Turbidity
Straw bale plots (plot A)	12 cm
Planted grass plots (plot B)	28 cm

- (iv) Based on the data in the table above, **make a claim** about the stated hypothesis.

- (c) Several fish species lay their eggs in the gravel in the streams under investigation in the study.

- (i) **Describe** the type of survivorship curve expected for these fish species.
- (ii) **Explain** why the input of sediment to a stream can negatively affect reproduction of fish that lay their eggs in the gravel of the streambed.

Figure C1. Unit 5 practice free response question number one.

Activity adapted from the College Board (2025b) released exam FRQs.

Unit 6 FRQ #1 Practice - Energy Resources

All FRQs must be handwritten on a separate sheet of paper!

1. Many college students have a mini fridge in their dorm room. A standard mini fridge costs roughly \$100, uses about 100 watts of electricity each hour, and can be expected to last for 5 years. The refrigerator is plugged into an electrical socket 24 hours a day, but is usually running only about 12 hours a day. Assume that electricity costs \$0.10/kWh. **YOU MUST SHOW WORK AND UNITS TO RECEIVE POINTS!**

- a. **Calculate** the lifetime monetary cost of owning and operating the refrigerator.
- b. Assume that the electricity used to power the refrigerator comes from a coal-burning power plant. One metric ton of coal contains 29.3 GJ (8,140 kWh) of energy. Because of the inefficiency of electricity generation and transmission, only one-third of the energy in coal reaches the refrigerator. **Calculate** how many tons of coal are used to power the refrigerator during its lifetime.
- c. Assume that 15 percent of the mass of the coal burned in the power plant ends up as coal ash, a potentially toxic mixture that contains mercury and arsenic. **Calculate** how many tons of coal ash are produced as a result of the refrigerator's electricity use over its lifetime.
- d. What externalities does your answer from part (a) not include?
- i. **Describe** one social cost associated with using this appliance.
- ii. **Describe** TWO environmental costs associated with using this appliance.
- e. **Describe** one way a college student could reduce the electricity use associated with having a mini fridge in his or her dorm room.

Activity adapted from the College Board (2025b) released exam FRQs.

APPENDIX D: LESSON TWO: SAMPLE FRQS FROM THE
COLLEGE BOARD

Lesson Two: Sample FRQs from the College Board

Purpose: Review the criteria for constructive and nonconstructive comments, give constructive comments to sample FRQs from the College Board, and become more familiar with rubrics used for scoring FRQs on the AP exam.

Lesson:

1. Place students in partners or groups of three. Project the directions for the activity (Figure D1).

FRQ Grading

1. Skim the FRQ Question.
2. Read the student response.
 - **Highlight** the point earned and
 - **justify with the number/letter** on the grading rubric.
3. Work with your team to determine if a point should be earned. **Write at least TWO constructive** comments.
4. Write the total score on top.
5. We will discuss what score the AP Readers gave.



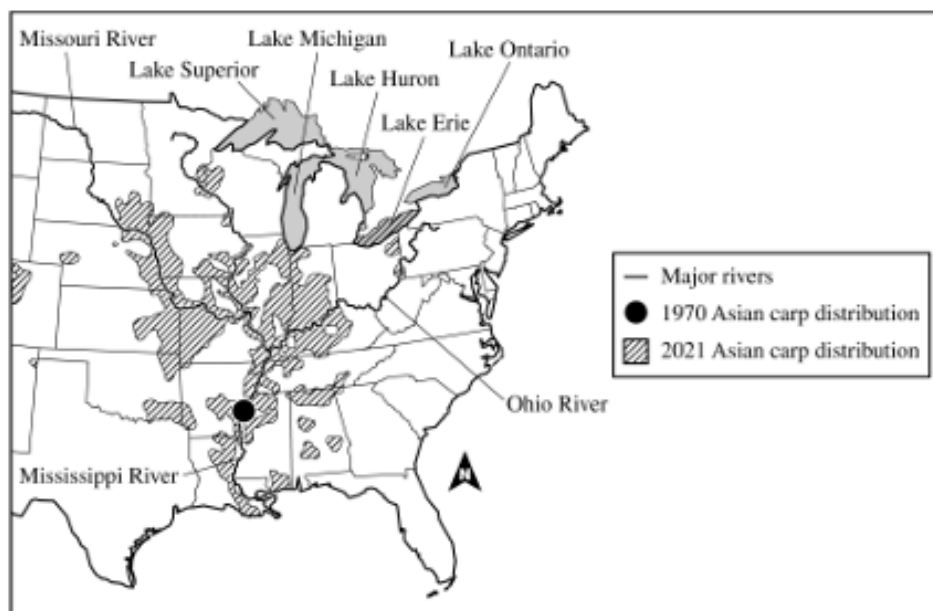
Figure D1. Lesson two free response questions grading directions for students.

2. Pass out the Free Response Question prompt and have students read through the prompt (Figures D2-D3).

AP® Environmental Science 2023 Free-Response Questions

2. Asian carp were first introduced in the southern United States in the 1970s by fish farmers wanting to control algal growth in fish ponds. Asian carp can eat up to 40% of their body weight in algae each day, and a female carp can produce up to 1 million eggs every year.

Distribution of the Asian Carp in the United States



- (a) Based on the information given, **identify** a body of water invaded by Asian carp that is labeled on the map.
- (b) Based on the information shown in the map, **describe** the change in the distribution of Asian carp since their introduction in the 1970s.

The Great Lakes are a group of five major freshwater inland lakes that all share the same watershed.

- (c) **Describe** one impact the introduction of Asian carp could have on the ecosystem services provided by the Great Lakes region.
- (d) **Propose** a realistic solution to help reduce the spread of the Asian carp from their current distribution.
- (e) **Justify** the solution proposed in part (d) by providing an additional advantage.

The following is an example of a simple food chain in the Great Lakes.

Algae → Zooplankton → Macroinvertebrates → Yellow perch → Rainbow trout

- (f) **Identify** the primary consumer in the Great Lakes food chain.
- (g) **Describe** what the arrows in the aquatic food chain represent.

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Figure D2. Advanced Placement Environmental Science free response prompt about Asian Carp, page one.

AP® Environmental Science 2023 Free-Response Questions

(h) **Describe** one possible effect of the introduction of the Asian carp on the Great Lakes food chain.

The blue pike, a fish that was endemic to the Great Lakes, was commercially fished from the late 1800s until their population crashed in 1958. In 1970, the species was declared to be extinct.

(i) **Describe** one way that overfishing of blue pike illustrates the tragedy of the commons.

(j) One potential solution to reduce overfishing is to use aquaculture. **Describe** one disadvantage of this solution.

Begin your response to this question at the top of a new page in the separate Free Response booklet and fill in the appropriate circle at the top of each page to indicate the question number.

Figure D3. Advanced Placement Environmental Science free response prompt about Asian Carp, page two.

3. Pass out student sample response 1A (Figure D4).

1A 1 of 1

Important: Completely fill in the circle that corresponds to the question you are answering on this page.

Question 1 Question 2 Question 3

● ○ ○

Begin your response to each question at the top of a new page. Do not skip lines.

1(a) 9 species

(b) As the age increased, the average number of species increased.

(c) Spontaneously restored piles ~~increase~~ have an increase in animal species over time because animals feed off of ~~the~~ plants, so when the plant species increase, so do animal species, whereas since technically restored piles don't have as many plant species, they won't have as many animal species either.

(d) A plant would have been small as it wouldn't have had time to grow into a bigger plant in the 1-5 year time span.

(e) the return of plant life would have taken longer since the cold temperatures and harsh climate of the tundra would have only allowed ^{few} sparse plants to grow, and only in the summer, since in winter the ground ^{too} would be frozen for plants to grow.

(f) what is the most efficient ^{and effective} ~~material~~ material when trying to limit runoff.

(g) mL of water collected.

(h) the water collected from all three trays would have decreased because the higher percentage of sand would allow for more water infiltration into the soil since the particles are bigger.

(i) increased levels of lead and mercury from the mine drainage could ~~bioscience~~ biomagnify in organisms in the ecosystem, resulting in ~~lead~~ being in all trophic levels, causing health problems such as brain damage in organisms.

(j) establishing stretches of permeable surfaces like green spaces between water sources and mines would allow the water to infiltrate into the soil.

Page 2

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

06/05/12

Figure D4. Advanced Placement Environmental Science sample student responses 1A.

4. Using the scoring rubric, students will determine the score awarded for the student sample (Figures D5-D9). Students will use highlighters to identify where the point was earned and justify the point with the number and letter on the grading rubric. Students must find at least two areas to leave constructive comments to help the sample student earn more points.

2023



AP[®] Environmental Science

Sample Student Responses and Scoring Commentary Set 2

Inside:

Free-Response Question 1

- ☒ Scoring Guidelines
- ☒ Student Samples
- ☒ Scoring Commentary

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Figure D5. Advanced Placement Environmental Science scoring rubric, page one.

Question 2: Analyze an Environmental Problem and Propose a Solution **10 points**

- (a) Based on the information given, **identify** a body of water invaded by Asian carp that is labeled on the map. **1 point**

Accept one of the following:

- 1 • Mississippi River
- 2 • Lake Erie
- 3 • Missouri River
- 4 • Ohio River

- (b) Based on the information shown in the map, **describe** the change in the distribution of Asian carp since their introduction in the 1970s. **1 point**

Accept one of the following:

- 1 • They are more widely distributed/found in most of the watershed/in a larger area than they were in the 1970s.
- 2 • They have moved up/down the Mississippi river.
- 3 • They have moved up the Missouri River/Ohio River.
- 4 • They have moved northwest and northeast up the rivers.

- (c) **Describe** one impact the introduction of Asian carp could have on the ecosystem services provided by the Great Lakes region. **1 point**

Accept one of the following:

- 1 • Improved drinking water quality as carp consume algae.
- 2 • Decreased recreational opportunities (boating/swimming) from the increased population of carp in the water interfering with activities.
- 3 • Decreased fishing due to carp outcompeting native fish species.
- 4 • Decreased drinking water quality as carp displace filter feeders like native mussels in the food chain/web.
- 5 • Decreased algae population resulting in decreased photosynthesis and increased greenhouse gases/global warming/climate change.
- 6 • Decreased algae population resulting in decreased photosynthesis and decreased oxygen production.

Figure D6. Advanced Placement Environmental Science scoring rubric, page two.

- (d) **Propose** a realistic solution to help reduce the spread of the Asian carp from their current distribution. **1 point**

Accept one of the following:

- 1 • Offer incentives for fishers to catch and kill carp.
- 2 • Encourage consumption of carp.
- 3 • Build fencing/netting between waterways.
- 4 • Use shock treatment (dispersal barrier system).
- 5 • Create/Use an Asian-carp specific poison/deterrent (carpicide, CO₂, microparticles).
- 6 • Implement high-frequency sound deterrent system.
- 7 • Prohibit transfer of bait or ballast water from one body of water to another.

- (e) **Justify** the solution proposed in part (d) by providing an additional advantage. **1 point**

Accept one of the following:

Solution proposed in part (d)	Justification of solution with additional benefit
1 Build fencing/netting between waterways.	• A Create jobs in the Great Lakes fishing industry. • B Little to no harm to native animal/plant populations in watershed. • C Reduce negative impacts carp have on the feeding relationships in the Mississippi/Great Lakes watershed. • D Maintain revenue for existing fishing industry/tourism of Great Lakes.
2 Create/Use an Asian-carp specific poison/deterrent (carpicide, CO ₂ , microparticles).	
3 Implement high-frequency sound deterrent system.	
4 Use shock treatment (dispersal barrier system).	
5 Encourage consumption of carp.	• A Increase revenue in the Great Lakes fishing industry/sale of carp. • B Reduce negative impacts carp have on the feeding relationships in the Mississippi/Great Lakes watershed. • C Provide new food source (domestically/internationally)/combat hunger issues worldwide. • D Allow the return of native species resulting from less competition from the Asian carp.

Figure D7. Advanced Placement Environmental Science scoring rubric, page three.

AP® Environmental Science 2023 Scoring Guidelines

Offer incentives for fishers to catch and kill carp.	• A Create jobs in the Great Lakes fishing industry. • B Increase revenue from the sale of Asian carp. • C Reduce negative impacts carp have on the feeding relationships in the Mississippi/Great Lakes watershed. • D Provide new food source (domestically/internationally)/combat hunger issues worldwide. • E Allow the return of native species resulting from less competition from the Asian carp.
Prohibit transfer of bait or ballast water from one body of water to another.	• A No harm to native animal/plant populations in watershed. • B Reduce negative impacts carp have on the feeding relationships in the Mississippi/Great Lakes watershed. • C Maintain revenue for existing fishing industry/tourism of Great Lakes.

(f) Identify the primary consumer in the Great Lakes food chain. 1 • Zooplankton	1 point
(g) Describe what the arrows in the aquatic food chain represent. Accept one of the following: 1 • The flow of energy/energy flow. 2 • The flow of matter/matter flow.	1 point
(h) Describe one possible effect of the introduction of the Asian carp on the Great Lakes food chain. Accept one of the following: 1 • There will be fewer zooplankton/macrobenthos/yellow perch/rainbow trout. 2 • There will be less food for other species at the same trophic level on the food chain. 3 • There will be less food for species that don't eat carp and are higher on the food chain.	1 point

Figure D8. Advanced Placement Environmental Science scoring rubric, page four.

AP® Environmental Science 2023 Scoring Guidelines

(i)	Describe one way that overfishing of blue pike illustrates the tragedy of the commons.	1 point
Accept one of the following:		
1 • The blue pike are a shared resource that were depleted/went extinct due to unregulated access. 2 • The blue pike are a common resource that were depleted by fishers, maximizing profits/catching as many as possible.		
(j)	One potential solution to reduce overfishing is to use aquaculture. Describe one disadvantage of this solution.	1 point
Accept one of the following:		
1 • Aquaculture contaminates water with excess organic waste/antibiotics. 2 • Fish that escape from facilities compete or breed with wild fish. 3 • Fish in aquaculture facilities can spread diseases to wild fish. 4 • The high density of fish in aquaculture facilities can lead to increased disease. 5 • Loss of jobs in the fishing industry. 6 • Excess pressure on fisheries/wild stocks used to create food pellets. 7 • Decrease in genetic diversity of farm raised fish. 8 • Habitat degradation from conversion of ecosystems to fish farms. 9 • Overuse of antibiotics in farmed fish (create antibiotic resistant bacteria that can be harmful to humans).		
Total for question 2		10 points

Figure D9. Advanced Placement Environmental Science scoring rubric, page five.

5. After students have written a total score out of 10 at the top of the paper, the teacher will review the score awarded by the College Board with the whole class.
6. Repeat this process with student sample responses 2A (Figures D10-D11) and 3A (Figures D12-D13).

Activity adapted from the College Board (2025b) released exam FRQs.

Important: Completely fill in the circle that corresponds to the question you are answering on this page.

Question 1 Question 2 Question 3

● ○ ○

Begin your response to each question at the top of a new page. Do not skip lines.

(a) The average number of species found in technically restored piles 16-25 years after restoration started was 8.

(b) As more years passed, the number of plant species found in spontaneous restoration piles increased. The increase was steady, and about 2-4 new species were found every 5 years.

(c) This hypothesis is correct, after 35 years the average number of species in spontaneous piles was about double the number in technical piles. Technical restoration piles had an average of 8 species while spontaneous piles had 16-17 species.

(d) A plant found in a spontaneous restoration pile from years 1-5 would have been easily adaptable ~~and~~ since it was so early on in the process.

(e) The return of plant life would've taken longer in the Tundra because plants can't grow as easily in those conditions. Plants wouldn't have much nutrients, sunlight, or ~~and~~ warm weather, making it hard for them to grow.

(f) ~~Does wheatgrass or small wood chips help limit runoff?~~ Does wheatgrass or small wood chips help limit runoff?

(g) The dependent variable is ~~what mixture is inside of the different trays.~~ what mixture is inside of the different trays.

Page 2

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

● ● ● ● ● ●

05365/02 ●

Figure D10. Advanced Placement Environmental Science sample student responses 1B, page one.

1B 2 of 2

● **Important:** Completely fill in the circle that corresponds to the question you are answering on this page.

Question 1 Question 2 Question 3

● ○ ○

Begin your response to each question at the top of a new page. Do not skip lines.

(h) If ^{more} sand was used, more water would be able to pass through and be collected. This is because sand is more permeable and has smaller particles than soil or clay.

(i) One ecological impact that could result from runoff is eutrophication in nearby waterways. Excess nutrients may be carried into the water, causing eutrophication which causes algae blooms.

(j) One strategy would be to add more vegetation in between the mines and waterways. This vegetation would soak up a lot of the runoff before it reaches the waterways.

Page 3

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

● Q5365/03 ● ● ● ● ● ● ● ●

Figure D11. Advanced Placement Environmental Science sample student responses 1B, page two.

Figure D12. Advanced Placement Environmental Science sample student responses 1C, page one.

● **Important:** Completely fill in the circle that corresponds to the question you are answering on this page.

Question 1 Question 2 Question 3

● ○ ○

Begin your response to each question at the top of a new page. Do not skip lines.

i) one ecological impact would be that the nearby waterways would be negatively impacted and polluted to be worse quality ~~the~~ affecting humans and animals, that use that water's healths.

j) one strategy would be ~~the~~ to monitor and regulate the mining companies from adding the mine waste to those waterways.

Page 3

Use a pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

● Q5065/03 ● ● ● ● ● ● ● ●

Figure D13. Advanced Placement Environmental Science sample student responses 1C, page two.

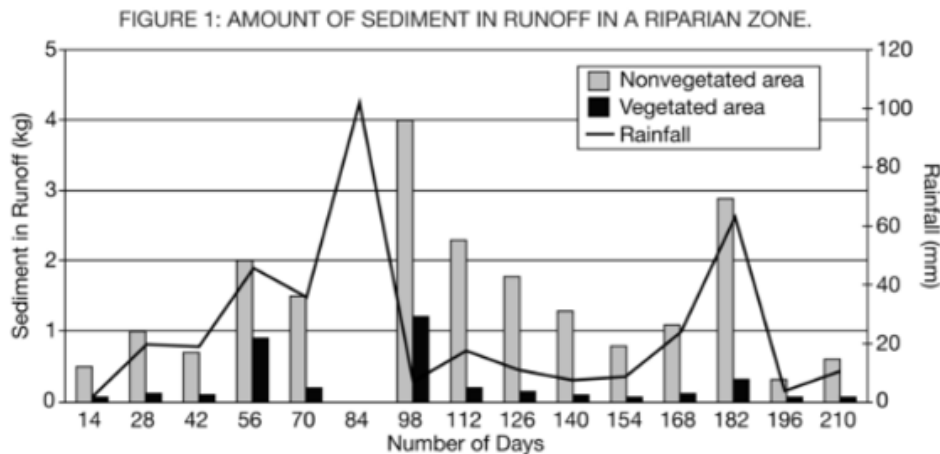
APPENDIX E: PRACTICE FRQ PEER EDIT AFTER LESSON

TWO

Unit 5 FRQ #2 Practice

All FRQs must be handwritten on a separate sheet of paper!

1. Mineral resources are extracted from the earth by mining ore and separating it from the residual rock.
 - (a) Identify one type of mining that is used to extract natural resources from the earth.
 - (b) Figure 1 below shows the amount of sediment in runoff in undisturbed (vegetated) areas and in areas where mining has disturbed the vegetation (nonvegetated area) in the riparian zone of a stream in Brazil.



- (i) Identify the day of the study when the largest amount of sediment was present in runoff.
 - (ii) Describe the relationship between the amount of rainfall and the amount of sediment in runoff.
 - (iii) Based on the data in the graph, explain how mining practices affected the water quality in nearby streams.
- (c) The extraction of mineral resources has a variety of environmental impacts and can also affect human health.
 - (i) Describe one effect mining can have on human health.
 - (ii) Make a claim that proposes a solution to reduce the environmental impacts of mining, other than a ban on mining.
 - (iii) Use data and evidence from the graph to support a potential solution to reduce the impacts of mining on stream quality.
- (d) Scientists are interested in investigating the possibility that plants can be used to remove heavy metals from contaminated soil. They divide a sample of soil with heavy metal contamination into five different pots and plant five different species of grass they believe will take up metals into their roots and leaves. They also plant the same grasses in five pots with uncontaminated soil. After allowing the grasses to grow for a month, they cut the grass and measure the concentration of metals in milligrams per kilogram.
 - (i) Identify the dependent variable for the investigation.
 - (ii) Identify one modification that could be made to the investigation that will alter the results.
 - (iii) After determining the species of grass that removes the most metal, it is planted in the area that was logged. In addition to removing metals from the soil, describe one advantage to the stream of planting grass in this area.

Figure E1. Unit 5 practice free response question number two.

Unit 6 FRQ #2 Practice

All FRQs must be handwritten on a separate sheet of paper!

Battery electric vehicles (BEVs) often have been proposed as an environmentally sound alternative to the internal-combustion engine (ICE) vehicles for transportation. In response to state initiatives, several car manufacturers now include electric vehicles among their available models. In spite of these state initiatives, the penetration of electric vehicles into the transportation sector of the United States, as well as other countries, remains modest.

- Identify and describe** one environmental benefit to using electric vehicles in place of gasoline-powered engines for transportation. +1 point
- Assume that the fuel efficiency of the ICE vehicle is 25 miles per gallon (mpg) and that gasoline costs \$3.75 per gallon (gal). **Calculate** the cost of gasoline per mile. +2 points
- The charger supplies energy to the BEV battery at an average rate of 4.0 kilowatts (kW) and fully charges the BEV battery in 7.0 hours. The car will run for 100 miles on a full charge. The cost of electricity is \$0.11 per kilowatt-hour (kWh).
 - Calculate** the cost of the electricity to fully charge the battery. Assume that the battery is not charged to begin with. +2 points
 - Calculate** the cost of electricity per mile to drive the BEV. +1 point

Fremont Examiner

Microalgae for Fuel Production: Can Green Goo Solve Our Energy and Climate Problems?

Scientists and investors are promoting the potential of some of the smallest, oiliest critters on Earth as a solution to our energy problems. Although the humble organisms look like green goo, some species of microalgae are over 50 percent oil. Scientists say microalgae are the most efficient organisms at converting sunlight to energy. In fact, they beat other oil crops for production per acre, hands down.

Gallons of Oil per Acre per Year	
Corn	20
Soybeans	50
Safflower	83
Sunflower	102
Rapeseed	115
Oil palm	640
Microalgae	10,000

Seventy percent of this oil can be recovered by pressing the algae; over 90 percent can be recovered by solvent extraction. The resulting oil can be used for heating, for electricity generation, or for making other fuels, like biodiesel. After the oil is removed, the remaining material can be used as animal feed or soil amendment. The Germans are even looking into using it for construction material. "In this way, we sequester that carbon indefinitely," said Dr. Klaus Mueller. Some scientists are bubbling emissions from coal-burning power plants through algae-filled tanks to remove CO₂.

Proponents claim that microalgae can be used to capture nutrients from animal feedlot waste lagoons and sewage treatment plants. Because they grow only in the top inch of water, the algae might even be grown in rooftop pools someday. But are microalgae really all they're cracked up to be? Like other monoculture crops, they may be susceptible to widespread damage from disease.

- Calculate** the number of acres required to produce 1,000 gallons of oil in one year from +2 points
 - microalgae
 - soybeans
- Describe** one environmental advantage that biodiesel production from microalgae offers over biodiesel production from the other crops listed in the table. +1 point
- Explain** why burning biodiesel fuel has a different impact on atmospheric CO₂ concentrations than does burning fossil fuels. +1 point

Figure E2. Unit 6 practice free response question number two.

Activity adapted from the College Board (2025b) released exam FRQs.

APPENDIX F: PRETREATMENT PEER REVIEW SURVEY

1/21/26, 8:14 PM

Peer Review Survey

Peer Review Survey

Taking part in this survey is voluntary and participation or nonparticipation will not affect your grade or standing in class in any way.

Choose the best choice and when appropriate explain your choice.

** Indicates required question*

1. Peer review is used in other classes. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

2. A teacher has taught me how to peer review. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

3. Explain your choice to the previous statement. *

4. The only feedback that is valuable comes from the teacher of my class. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

5. I can give other students helpful feedback that will improve their writing. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

Figure F1. Pretreatment peer review survey, page one.

1/21/26, 8:14 PM

Peer Review Survey

6. I am confident in my ability to offer constructive feedback to my peers. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

7. Explain your choice to the previous statement. *

8. I can take feedback from others and apply it to my work to make it better. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

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Google Forms

Figure F2. Pretreatment peer review survey, page two.

APPENDIX G: POSTTREATMENT PEER REVIEW SURVEY

1/21/26, 8:15 PM

Peer Review Survey

Peer Review Survey

Taking part in this survey is voluntary and participation or nonparticipation will not affect your grade or standing in class in any way.

Choose the best choice and when appropriate explain your choice.

** Indicates required question*

1. Peer review is used in other classes. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

2. A teacher has taught me how to peer review. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

3. Explain your choice to the previous statement. *

4. The only feedback that is valuable comes from the teacher of my class. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

5. I can give other students helpful feedback that will improve their writing. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

Figure G1. Posttreatment peer review survey, page one.

1/21/26, 8:15 PM

Peer Review Survey

6. I am confident in my ability to offer constructive feedback to my peers. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

7. Explain your choice to the previous statement. *

8. I can take feedback from others and apply it to my work to make it better. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

9. Feedback from other students on my FRQ writing helps me to improve the quality of my work. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

10. Explain your choice to the previous statement. *

11. Learning the difference between constructive and nonconstructive comments was useful. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

Figure G2. Posttreatment peer review survey, page two.

1/21/26, 8:15 PM

Peer Review Survey

12. The activity where we graded student sample work from College Board and learned scoring expectations was useful. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

13. The instruction on how to peer edit was useful. *

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Agree
☐ Strongly agree

14. Explain your choice to the previous statement. *

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Figure G3. Posttreatment peer review survey, page three.

APPENDIX H: TEACHER JOURNAL

Teacher Journal

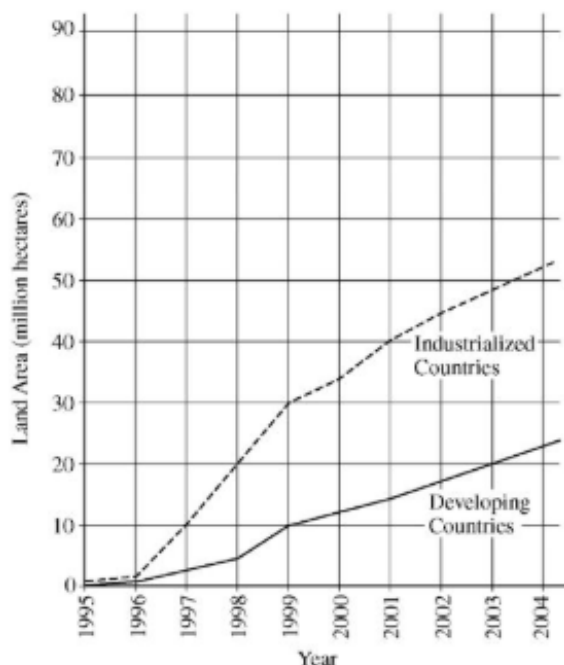
I plan to record:

1. Student comments during the peer editing instructional activities (modeling good and poor comments, grading student sample work from the College Board).
 - Are students finding the activities useful?
 - Are students engaged? Helping each other?
 - Are they struggling with the directions?
 - What does the classroom environment feel like?
2. Student comments and questions while peer editing.
3. Student comments and questions while using peer comments to edit and improve on their own assignments.

APPENDIX I: FREE RESPONSE WRITING TEST

Unit 5 Free Response Question. Use the back of your answer sheet to write the FRQ below. Take a minute to think, plan and outline. Pay attention to how many points each section is worth. Write clearly, include any necessary facts and vocabulary — DO NOT OVER OR UNDER WRITE. Label your answers with their letter, write legibly and organize!

The major issues in modern agriculture include the use of genetically modified (GM) crops and the implementation of sustainable agricultural practices. The following graph shows the increase in the use of GM crops in both developing and industrialized countries from 1995 to 2004.

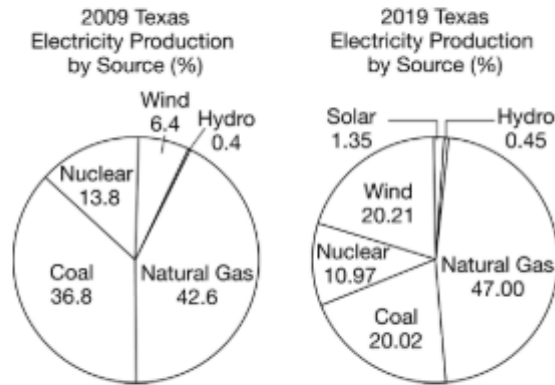


- (a) Reply to the following questions based on the data in the graph above. 4 points
- Calculate** the increase in the area of land used for growing GM crops in developing countries from 1999 to 2003. Express your answer as a percentage of the 1999 value.
 - Calculate** the annual rate of increase in land area used for growing GM crops in industrialized countries from 1997 to 1999.
 - Using the rate you calculated in part (ii), **calculate** the area of land that would have been expected to be used for GM crops in industrialized countries in 2004.
 - Identify** one likely cause for the difference between the projected land area for GM crops in industrialized countries in 2004 and the actual land area for GM crops in industrialized countries in 2004.
- (b) **Describe** one environmental advantage of using GM crops. 1 point
- (c) **Describe** one environmental disadvantage of using GM crops. 1 point
- (d) A healthy soil ecosystem is of primary importance in sustainable agriculture. **Describe** TWO viable agricultural practices that farmers can use to maintain or improve soil quality. 2 points
- (e) Consuming locally grown produce is often a way for people to be more environmentally friendly.
- Make a claim** that proposes an environmental advantage of consuming locally grown produce. 1 point
 - Justify** the claim made in (e)(i) by explaining an additional benefit of eating local, other than helping the environment. 1 point

Figure I1. Unit 5 free response test question.

Unit 6 Free Response Question. Use your answer sheet to write the FRQ below. Take a minute to think, plan and outline. Pay attention to how many points each section is worth. Write clearly, include any necessary facts and vocabulary — DO NOT OVER OR UNDER WRITE. Label your answers with their letter, write legibly and organize!

- (a) The graphs show the percentage of electricity production by source in 2009 and 2019 for the state of Texas



- (i) Based on the graphs, **describe** the trend in electricity production from coal between 2009 and 2019. *1 point*
- (ii) The Texas state government decided to offer subsidies in 2020 for energy production by solar power in the form of a consumer tax credit. **Explain** how these government subsidies would affect the energy production by coal by 2030 in Texas. *1 point*
- (b) An important contributor to global climate change is the release of CO_2 from the rapidly increasing number of coal-burning power plants in China. Assume that the coal burned at these plants to provide the power to manufacture a single iPhone releases 40 kg of CO_2 and that it costs \$0.75 to capture 1 kg of CO_2 and keep it from entering the atmosphere.
- (i) **Calculate** the cost, in dollars, to capture the total amount of CO_2 released from manufacturing one iPhone. *2 points*
- (c) Strategies for the use of solar energy in building designs include passive solar design that also incorporates active solar energy technologies.
- (i) **Describe** passive solar home design and active solar energy use. *1 point*
- (ii) **Identify** two examples of passive solar home design technique. *2 points*

KEEP GOING - more on the next page.

Figure I2. Unit 6 free response test question, page one.

- (d) Hogs are best raised between 14°C and 21°C. A farmer is concerned that higher temperatures at the farm might reduce hog growth rates. The state agricultural school provided the farmer with information about how temperature plays an important role in hog growth and their nutritional needs. Daily summer high temperatures at the hog farm range from 20°C to 35°C. The farmer conducts an investigation in which hogs are kept at four different temperatures. Each group contains 10 hogs, and each hog is offered the same type of feed and allowed to eat as much as it wants over seven days. The amount each hog consumes is recorded on a daily basis, and the average for each group is calculated.

Temperature (°C)	Average Daily Feed Intake (grams/day)
18	2,700
22	2,650
25	2,550
28	2,300

- (i) **Identify** the control group for the investigation. *1 point*
- (ii) **Identify** the hypothesis of the investigation. *1 point*
- (iii) The farmer lives in a climate in which the temperature drops below freezing (0°C) in the winter, and the farmer plans to keep the hogs outside. **Explain** how this would likely impact the feed requirements of the hogs. *1 point*

Figure I3. Unit 6 free response test question, page two.

Questions adapted from the College Board (2025b) released exam FRQs.

APPENDIX J: STUDENT INTERVIEWS

Interview Questions

Taking part in this interview is voluntary and participation or nonparticipation will not affect your grade or standing in class in any way.

1. What part of peer review did you find the most difficult?
2. Do you find peer review valuable? Why or why not?
3. Are you able to be honest with your peers about ways that they can improve? Why or why not?
4. Do you find it easy to take feedback from your peers and apply it to your work? Why or why not?
5. Did peer feedback help you to become a better writer in APES? Why or why not?
6. What did you learn from the process of peer editing? Give specific examples.
7. If another teacher were to implement peer editing, what would be your advice?
8. Is there anything else you would like me to know?

APPENDIX K: UNIT 5 WILCOXON RANK-SUM TEST
RESULTS

Unit 5 FRQ Scores Wilcoxon rank sum												
Treatment	Nontreatment		Score	Rank	Rank Sum							
6	7	Treatment	6	27	n2 Treatment	382						
1	8	Treatment	1	4	n1 Nontreatment	359						
9	3	Treatment	9	37								
5	2	Treatment	5	22	n2 Treatment Count	17						
3	3	Treatment	3	13	n1 Nontreatment Count	21						
7	3	Treatment	7	31.5								
4	3	Treatment	4	18	μ_w	409.5						
6	5	Treatment	6	27	σ_w	34.06						
1	8	Treatment	1	4	z	-1.4826						
7	4	Treatment	7	31.5	p value	0.06909	0.13819					
10	1	Treatment	10	38			2 tail					
6	7	Treatment	6	27	alpha	0.05						
5	0	Treatment	5	22	Reject?							
6	8	Treatment	6	27								
4	3	Treatment	4	18								
3	5	Treatment	3	13								
5	2	Treatment	5	22								
	0	Nontreatment	7	31.5								
	6	Nontreatment	8	35								
	2	Nontreatment	3	13								
	2	Nontreatment	2	7.5								
		Nontreatment	3	13								
		Nontreatment	3	13								
		Nontreatment	3	13								
		Nontreatment	5	22								
		Nontreatment	8	35								
		Nontreatment	4	18								
		Nontreatment	1	4								
		Nontreatment	7	31.5								
		Nontreatment	0	1.5								
		Nontreatment	8	35								
		Nontreatment	3	13								
		Nontreatment	5	22								
		Nontreatment	2	7.5								
		Nontreatment	0	1.5								
		Nontreatment	6	27								
		Nontreatment	2	7.5								
		Nontreatment	2	7.5								

Figure K1. Unit 5 Wilcoxon Rank-Sum test results.

APPENDIX L: UNIT 6 WILCOXON RANK-SUM TEST
RESULTS

Unit 6 FRQ Scores Wilcoxon rank sum												
	Treatment	Nontreatment		Score	Rank		Rank Sum					
	9	7	Treatment	9	34	n2 Treatment	400					
	9	8	Treatment	9	34	n1 Nontreatment	341					
	4	8	Treatment	4	3.5							
	7	5	Treatment	7	21.5	n2 Treatment Count	21					
	8	7	Treatment	8	28	n1 Nontreatment Count	17					
	5	9	Treatment	5	8							
	9	7	Treatment	9	34	μ_w	331.5					
	6	4	Treatment	6	14	σ_w	34.06					
	8	4	Treatment	8	28							
	6	6	Treatment	6	14	z	-0.2789					
	5	9	Treatment	5	8	p value	0.39016	0.78032				
	7	10	Treatment	7	21.5			2 tail				
	5	6	Treatment	5	8	alpha	0.05					
	9	7	Treatment	9	34							
	6	5	Treatment	6	14	Reject?		p value > 0.05, fail to reject null,				
	6	6	Treatment	6	14			there is no significant difference				
	3	8	Treatment	3	1			between treatment and				
	7		Treatment	7	21.5							
	7		Treatment	7	21.5							
	4		Treatment	4	3.5							
	9		Treatment	9	34							
Count	21	17	Nontreatment	7	21.5							
			Nontreatment	8	28							
			Nontreatment	8	28							
			Nontreatment	5	8							
			Nontreatment	7	21.5							
			Nontreatment	9	34							
			Nontreatment	7	21.5							
			Nontreatment	4	3.5							
			Nontreatment	4	3.5							
			Nontreatment	6	14							
			Nontreatment	9	34							
			Nontreatment	10	38							
			Nontreatment	6	14							
			Nontreatment	7	21.5							
			Nontreatment	5	8							
			Nontreatment	6	14							
			Nontreatment	8	28							

Figure L1. Unit 6 Wilcoxon Rank-Sum test results.