THE SCIENCE WRITING HEURISTIC

IN ONLINE EDUCATION

by

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DEDICATION

I joyfully dedicate this paper to my family. Without the tireless support of my wife, who did everything she could to allow me time to work on and complete this project, it would never have been completed. Her support and encouragement have been beyond value and description. To my older kids, who had to do with fewer soccer games, hikes, games of tag, reading of books, drawing pictures, playing in the back yard, and many other things while I worked on writing this project, thank you for your patience. To my baby who joined us for the last leg of the journey, thanks for being a constant reminder that the hard things are often the best things in life. I love you and thank you all.
Aar/Dad.
I would like to acknowledge Dr. John Graves. His patient encouragement and welcoming availability for help were a balm in the busiest of times. I would also like to acknowledge Dr. John Winnie for his patience in awaiting drafts, and the honest and helpful feedback he gave me on my writing. I want to acknowledge the peer-editing and feedback from my classmates which also helped to make this paper better. Thank you all for the work you put forth in helping me.
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ABSTRACT

The author conducted a classroom research project to see whether instruction with the Science Writing Heuristic (SWH) in an online setting would increase evidence for critical thinking in the writing of his students. One unit was taught, and its final writing project was scored with a rubric that assessed critical thinking. Lab reports which were written before the SWH treatment unit was taught were also scored with the critical thinking rubric. Scores were compared and analyzed to ascertain whether the writing after the treatment showed an increase in critical thinking. The author found that there was a significant increase in scores after the treatment. The author concluded that, for a variety of reasons, the score on the final writing project was higher than the score on the previously written work. The author also asked whether using the SWH would increase student confidence in science class and gathered evidence by collecting and evaluating student work, interviewing students, and gathering survey results before and after the treatment. There was evidence that in several aspects of science class, student confidence was boosted. Finally, it was asked whether using the SWH would increase student enjoyment of science class. The same sources of information were used to evaluate whether this happened, and the results were inconclusive on this front.
INTRODUCTION AND BACKGROUND

Context of the Study

St. Labre Catholic Indian High School serves Native American students. It is located in the town of Ashland, MT bordering the Northern Cheyenne Indian Reservation, and 40 miles east of the Crow Indian Reservation. Fifty-three percent of our 130 enrolled students are female, while 47% are male. Forty percent of our students stay at our dormitory through the week and return home for weekends, while the remaining students come to school on busses from the surrounding area and up to 50 miles away (A. Graham, personal communication, May 14, 2020). Most are from either the Northern Cheyenne Tribe or the Crow Tribe. Other tribes from across the country are also represented in our student body, as well as a few non-Native students who are children of staff members (https://www.stlabre.org/about-us/faq/).

I teach biology, advanced biology, and botany in our high school. I usually teach four sections of biology, and one section of both botany and advanced biology. This year my biology classes are comprised of 33 tenth grade students and 6 eleventh grade students. I teach advanced biology to upperclassmen. This year advanced biology is comprised of seven juniors and four seniors. Of these 50 students, 40% are male and 60% are female. Ninety-six percent of these students are Native American, while the remaining 4% are Caucasian.
Rationale

I was curious about how to impart an appreciation for biology to my students. Over the last couple of years, I have explored how writing can be used to enhance student’s engagement in science class. I have noticed that when writing lab reports, many students spend the majority of their time describing the materials that were used and the procedure that was followed. I have also noticed that students rarely spend as much time completing the data analysis and conclusion sections which require higher order thinking skills, and then when asked what they liked least about class they often say, “lab reports.” I hypothesized that students who used writing to analyze and evaluate what they experienced in science class would not only enjoy science more, but understand it better. The question became, what is the best way to engage them? I surveyed the literature about writing in the secondary science classroom and found an instructional methodology called the Science Writing Heuristic (SWH). While learning through this approach, students use observations to formulate claims, which they must support with evidence, for any topic being learned. The culmination of a unit taught through the SWH is often a writing task which requires a demonstration of understanding. Further research revealed that using the SWH improved attitudes toward science class among students. I decided that this was a teaching methodology worth looking into, and it became the subject of my action research project.
Focus Question

The question that this research project sought to answer was, Is there more evidence of higher order thinking in the writing of students after being taught with the SWH than before they were taught with the SWH?

I also sought to answer the following sub-questions:

1. Does using the SWH increase student confidence in science class?
2. Does using the SWH increase student enjoyment of science class?
CONCEPTUAL FRAMEWORK

The following literature review begins with a brief introduction to constructivist learning theory. The importance of critical thinking in American education is then established. Finally, the Science Writing Heuristic (SWH), is described as a teaching methodology that incorporates scientific inquiry to help students think critically.

Constructivism

Constructivism is the theory that individuals build new knowledge using their personal experience and interaction with others (Minner, 2010). As a theory of learning, constructivism rejects the idea that learners are passive recipients of knowledge (Yilmas, 2008). Rather, constructivism holds that the learner himself is primarily responsible for building his knowledge. Modern constructivist theory draws on ideas from thinkers such as Piaget and Vygotsky. Piaget posited that knowledge is primarily constructed by the intellect of the individual. He presupposed that the individual inherently possesses the faculty to do such construction (Liu, C.H., & Matthews, R., 2005). Vygotsky (1978) added that there is a social dynamic to knowledge construction stating, “Every function in the child’s cultural development appears twice: first, on the social level, and later, on the individual level….All the higher functions originate as actual relations between human individuals” (p. 57).
Critical Thinking

Anderson and Smith, “noted that elementary students can pass chapter quizzes on photosynthesis and still not understand that plants make their own food” (as cited in Marzano, 1988, p. 2). This illustrates that knowledge that is memorized is not necessarily understood. Adler and Van Doren emphasize the same point:

“But the packaging [of an idea] is often done so effectively that the viewer, listener, or reader does not make up his own mind at all. Instead, he inserts a packaged opinion into his mind, somewhat like inserting a cassette into a cassette player. He then pushes a button and ‘plays back’ the opinion whenever it seems appropriate to do so. He has performed acceptably without having had to think.”

(Adler, M. J., & Van Doren, C., 1972, p. 4)

According to Adler, ingesting information does not suffice for building understanding. Understanding is constructed by thinking. In a document entitled, “The Central Purpose of American Education,” the Educational Policies Commission (EPC) recognized that the job of educational institutions across the United States is to develop the “rational powers” of those who are educated therein (EPC, 1961). After enumerating the benefits of a honed intellect, the Commission summarized the importance of this goal, “A person with developed rational powers has the means to be aware of all facets of his existence. In this sense he can live to the fullest….He can free himself from the bondage of ignorance and unawareness. He can make of himself a free man” (EPC, 1961, p. 8-9). An American teacher should teach his students to think, enabling them to use facts to effectively solve problems (Marzano, R., et al., 1988).
Theorists and educators constructed a classroom teaching method called scientific inquiry. The premise of this approach is that students should do in the classroom what scientists do in the laboratory. They should observe the world around them and use those observations to formulate answerable questions. Once questions are formed, students should devise schemes to gather information that could answer their questions. They should connect and compare their work with what they already know, and with the findings of other scientists. Finally, they should communicate what they have learned. The goal of scientific inquiry is to understand how real scientists conduct real science (National Research Council, 2000).

The Science Writing Heuristic

The Next Generation Science Standards have outlined eight science and engineering practices that students become familiar with through their education (National Academy of Science, 2013). Students learn to think like scientists as they develop skill in these practices. One way to bring scientific inquiry into the classroom is to use the science and engineering practices as prescribed by the SWH (Bachtold, 2013). In their book outlining how to implement the SWH, Hand, Norton-Meier, Staker, and Bintz (2009) summarized the way that the SWH incorporates critical thinking into the process of scientific inquiry by stating, “Learners are encouraged to make explicit and defensible connections between questions, observations, data, claims, and evidence” (p. 20). The rational connection of the elements of scientific inquiry served to demonstrate critical thinking.
The SWH follows a series of steps, where students first write out their initial understandings, and develop questions about a given topic. This is Step 1, Beginning Ideas. They are then asked to participate in some activity, which is Step 2, Tests. In Step 3, Observations, the activity provides opportunity for gathering data and recording observations. Step 4, Claims, requires students to use their observations to form a claim that answers the question from Step 1. Step 5, Evidence, asks students to cite specific observations from their data as evidence supporting their claim. Step 6, Reading, requires students to share their claim with classmates, and receive feedback, and then to compare their claim with claims from the broader scientific community by researching. Finally, in Step 7, Reflection, students reflect upon the entire process (Table 1).

Table 1. Basic Science Writing Heuristic (SWH) Template shows the progression of questions that students walk through to complete the process.

<table>
<thead>
<tr>
<th>Process Steps</th>
<th>Questions answered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: Beginning Ideas</td>
<td>What are my questions?</td>
</tr>
<tr>
<td>Step 2: Tests</td>
<td>What did I do?</td>
</tr>
<tr>
<td>Step 3: Observations</td>
<td>What did I see?</td>
</tr>
<tr>
<td>Step 4: Claims</td>
<td>What can I claim?</td>
</tr>
<tr>
<td>Step 5: Evidence</td>
<td>How do I know? Why am I making these claims?</td>
</tr>
<tr>
<td>Step 6: Reading</td>
<td>How do my ideas compare with others?</td>
</tr>
<tr>
<td>Step 7: Reflection</td>
<td>How have my ideas changed?</td>
</tr>
</tbody>
</table>

Students complete a number of iterations of the SWH procedure while studying a topic. They will have used critical thinking skills to build arguments throughout the study
of a topic. At the end of the topic, students complete a summative writing experience, where they connect their arguments into a cohesive whole. The target audience of this summative writing project is not their teacher. They must demonstrate understanding by communicating their full argument in language their uninformed peers would be able to understand (Hand et al., 2009).

Efficacy of the Science Writing Heuristic

Hand et al. (2009) found that using the SWH increased all student’s performance on assessments, as well as their understanding of how science works as an overall enterprise. This effect has been demonstrated across scientific disciplines, ages, and cultures. This broad effectiveness makes the SWH a promising tool to implement in the current study (Kingir, 2012; Schroeder, 2008).

In conclusion, knowledge is constructed by the individual. Interacting with others and thinking critically are essential for building knowledge, and are important components of education. Teaching students to think like scientists is called teaching through inquiry, and the SWH is an effective methodology for doing so.
METHODOLOGY

Introduction

Due to the unforeseen move to online instruction caused by the COVID-19 pandemic starting in early March of 2020, my participant pool was enlarged, while my participation went down. In order to find out if students showed more critical thinking in writing after being taught with the Science Writing Heuristic (SWH), I originally collected data from four sections of biology. These sections were comprised of a total of 39 students of whom 22 were female and 17 were male. All of these students were Native American. Of the 39 students in those classes I received completed Science Class Disposition Surveys from 30 students. Some students opted not to participate, while others were absent during the time the surveys were given in class. After the move online, I decided to combine my biology sections with my advanced biology section and complete the treatment with all students. This added 11 upperclassmen students to my potential study group. The new group consisted of 96% Native American students and 4% Caucasian students. There were 20 boys and 30 girls in this group. Seventeen of these students did not participate in the treatment, given almost exclusively online. Of the 33 actively participating students, 3 were seniors, and had graduated from school by the time the second Science Class Disposition Survey and the final writing project were complete. Thirty students were moderately active through the end of the treatment. From those 30, I received 13 completed Post-Treatment Surveys, and a total of 13 completed COVID-19 Community Letter assignments.
Instead of having distinct treatment and non-treatment groups to compare, and in light of making a last-minute obligatory switch to online learning, I decided that comparing writing done before the treatment with writing done after the treatment would be logistically possible while still offering a way to assess gains in critical thinking skills. I assessed student confidence in and enjoyment of science class by giving one survey before the treatment, and another after the treatment was completed.

The research methodology for this project received an exemption by Montana State University’s Institutional Review Board, and compliance for working with human subjects was maintained (Appendix A).

**Intervention**

My treatment unit focused on the immune system and the then burgeoning COVID-19 pandemic. Before asking my students to begin Step 1 of the SWH and come up with questions concerning COVID-19 and the immune system, I spent five weeks giving them necessary background information. I did this by providing articles to read and videos to watch which taught them about vaccines, the human immune system, viruses in general, and SARS CoV-2 in particular. During our fifth week online, I instructed students about some of the elements of good scientific questions. With the background laid, we were able to begin.

Before in-person classes were disrupted, I was teaching students how to create concept maps. No student sample concept maps are included because in-person classes were canceled before I could obtain any samples.
Step 1: Beginning Ideas – Questions

To complete this step of the process, I demonstrated creating a concept map that incorporated what the students had spent the last five weeks learning by creating a video tutorial and posting it on Google Classroom. I demonstrated using the concept map to help me generate a couple of questions about the topic. Their assignment during this week was to write three questions and post them on Google Classroom for their peers to see. I required them to evaluate each other’s questions based on the criteria for good science questions that we had discussed in the preceding week. After all responses had come in, I made another demonstration video in which I grouped similar questions, and then distilled the most common questions into the following: “In light of COVID-19, what weakens the immune system, and what can we do to strengthen it?” This question is what drove the rest of the SWH for the unit.

Steps 2 and 3: Tests and Observations

Steps 2 and 3 were done simultaneously. I taught students how to gather data through research with a tutorial video that I had made. Students were to go through all of the resources on the Gathering Data Through Research worksheet (Appendix B). Under each resource they took notes about information that could help answer the question from Step 1. All of the resources that I listed were online-accessible journal articles, popular science articles, or informational videos. The learning activity for Step 2 was reading articles and watching videos. For Step 3, students wrote down what seemed pertinent to the question from each resource.
Steps 4 and 5: Claims and Evidence

To complete these steps, I created a video about how to take observations and make claims. Students were asked to watch this instructional video, and then given the task of writing three claims. The criteria for the claim was that it must be an answer to the question from Step 1. Students used their notes from the Gathering Data Through Research worksheet as evidence in support of their claim. They cited their evidence in MLA format below each claim. Once they had formulated three claims, they shared their claims with classmates and were required to evaluate each other’s claims by giving feedback and asking clarifying questions of each other. This was done on Google Classroom.

Step 6: Reading

This step did not occur in the order shown on the template. Students were interacting with each other and giving each other feedback from Step 1 through Step 5. They had each other’s ideas to compare with their own. They also encountered the ideas of scientists, educators, and science journalists as they were conducting their research. Step 6 was built in to the previous steps, and did not require a separate allotment of time to complete.

Step 7: Reflection and Final Project

The final project was the COVID-19 Community Letter (Appendix C). In it, students were to establish the importance of what they were going to write, and then give their community practical ways to improve or maintain a healthy immune system. Students reflected on what they had learned and produced a call to action by telling their
communities how to protect themselves from COVID-19 while treatments and vaccines were being developed.

Data Collection

Three sources were used to collect data to answer the Focus Question, and they are described below. A description of how each instrument was used is also included below.

Post-Treatment Interview Questions

I conducted interviews with students after the final writing project for a variety of reasons. First, I wanted to see if the treatment helped students gain confidence in their understanding of science. Second, I wanted to see what students perceived as difficult about the treatment. Third, I wanted to learn what students enjoyed about the treatment. Finally, I wanted to see whether students perceived the final writing project of the treatment as more intellectually strenuous than a standard lab report (Appendix D). Responses were analyzed for patterns, and were then used to support and exemplify general findings from other data collection strategies. Of the 13 students who completed the final writing project of the treatment, 3 students were interviewed.

Critical Thinking Rubric

Samples of student work were analyzed using the Critical Thinking Rubric (Appendix E). The Critical Thinking Rubric was created using the Association of American Colleges and Universities (AAC&U) Critical Thinking VALUE Rubric and retrieved from https://www.aacu.org/value-rubrics (Appendix F). The Critical Thinking
Rubric, assessed four domains. The first domain was the student’s explanation or definition of the issue to be written about. The second domain assessed how critically the student used evidence in support of domain three, which was the student’s position or hypothesis. The final domain assessed the critical nature of the student-written conclusion. Four levels defined the degree to which each domain was mastered. The most basic level of proficiency was called “Benchmark” and received a score of one. The next two levels of proficiency were termed “Milestone 1 and 2” and were assigned scores of two and three, respectively. The fourth level of proficiency was termed “Capstone” and received a score of four. The Capstone level indicated an expert proficiency, akin to what would be expected of a college graduate. A student exhibiting critical thinking skills at the Milestone Two level was demonstrating advanced skill, while a student exhibiting critical thinking skills at the Milestone One level was demonstrating intermediate skill. A student operating at the Benchmark level was demonstrating a basic level of skill.

Each sample was marked with the highest level of each domain which it attained. For example, if a sample contained an intermediate explanation of issues, that sample would receive a score of two for Domain 1. The score for each sample was determined by adding together the scores from each domain. Each sample’s score reflected the amount of critical thinking used to produce the sample. The larger the number, the more evidence there was of a higher degree of critical thinking.

Thirteen samples of lab reports written before the treatment were analyzed. Three of these samples were taken from the previous year. The reason they were taken from previous year was that I wanted to have both pre-treatment and post-treatment samples
from the same students to set up paired samples. I did not have current year sample lab reports on file for three of the 13 students who turned in their post-treatment project. All 13 samples of the final writing project were also evaluated. Normalized gains were calculated for the overall score from the Critical Thinking Rubric. A normalized gain of less than 0.3 was considered low, 0.3 to 0.7 was considered a medium gain, and normalized gains greater than 0.7 were considered high (Hake, 1998).

The Critical Thinking Rubric had a total value of 16 possible points. Developed from the Critical Thinking VALUE Rubric that was created as an assessment tool to use in America’s colleges and universities, I decided that I could expect my best high-school student to exhibit an advanced level of critical thinking, and therefore calculated normalized gain with 12 as the highest possible outcome. No students scored as an expert (Level 4) in any of the domains in any of the samples on which I used the rubric. Finally, a Wilcoxon Signed-Rank Test was performed on the Critical Thinking Rubric data to establish the likelihood that the treatment affected the outcome.

Science Class Disposition Surveys

I gave two iterations of the Science Class Disposition Survey, and each one was slightly different. Before moving online, I had planned to run the SWH with lab experiences rather than a research experience, so my first Science Class Disposition Survey was centered on lab experiences, and was administered before the treatment was given (Appendix G). The second time that I gave out the Science Class Disposition Survey, I changed the questions from asking about lab experiences to asking about the recently completed online research experience, lessening the comparative value for the
two iterations of the Science Class Disposition Survey (Appendix H). The first iteration of the Science Class Disposition Survey was administered while students were in the classroom, whereas the second iteration was administered with an online Google Form. With these surveys, my original purpose was to judge whether instruction with the SWH increased positivity in student outlooks about biology class. The original purpose was still served by these surveys, but an added dimension of lab activity versus online research activity was also added. The demographic of students who completed the survey during the second iteration was not identical to those students who took it the first time. First of all, I offered the second survey to my advanced biology class in addition to all of the students who had the chance to take it the first time. Secondly, I should note that only 13 students responded to the final survey, while 30 students responded to the first survey. Of the 13 students who completed the second Science Class Disposition Survey, at least 3 had not completed the final writing project, demonstrating that they had not participated fully in the treatment. Because of this, I did not include the responses from these students and the sample size for the post-treatment Science Class Disposition Survey was 10. Another note is that four of these 10 responses were anonymous, but I made the assumption that these 4 completed the final writing assignment.
### Data Triangulation Matrix

Table 3. Data Triangulation Matrix

<table>
<thead>
<tr>
<th>Focus Question</th>
<th>Data Source 1</th>
<th>Data Source 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is there more evidence of higher order thinking in the writing of students after being taught with the SWH than before they were taught with the SWH?</td>
<td>Student work will be evaluated with the Critical Thinking Rubric to determine level of thinking demonstrated in writing.</td>
<td>Student writing samples as examples.</td>
</tr>
<tr>
<td>Does using the SWH increase student confidence in science class?</td>
<td>Student interviews will be conducted after unit.</td>
<td>Several questions in the Science Class Disposition Survey address confidence in science class.</td>
</tr>
<tr>
<td>Does using the SWH increase student enjoyment of science class?</td>
<td>Student interviews will be conducted after the unit.</td>
<td>Several questions from the Science Class Disposition Survey address enjoyment of science class.</td>
</tr>
</tbody>
</table>
DATA AND ANALYSIS

Critical Thinking in Science Writing

Samples evaluated with the Critical Thinking Rubric written after the treatment showed an average normalized gain increase of 18% compared with samples written before the treatment ($N=13$). Twenty-three percent of student’s scores decreased, 62% of students increased their scores, while 15% of student’s scores remained the same for both the pre-treatment sample and post-treatment samples. The average normalized gain for the whole sample size fell in the low gain category, but of the 62% of students whose normalized gain was positive, 63% of them were in the medium gain category (Hake, 1998; Figure 1).

Figure 1. Pre and post treatment critical thinking rubric scores, ($N=13$).

The mean changed from 50.3% pre-treatment to 61.5% post-treatment. The range of the pre-treatment results was 33.3% while the range from the post-treatment was 29.2%. The maximum score for the pre-treatment was 66.7% compared to 75% for the post-treatment.
scores. The Wilcoxon Signed-Ranks Test indicated that the median post-treatment scores, \( M = 62.5\% \), were significantly higher than the median pre-treatment scores, \( M = 50\% \), \( W = 15, p < 0.024 \), evidence that the treatment was a factor in the upward movement of the median. Students did a good job connecting their purpose with their evidence which displayed good critical thinking. For example, one student wrote, “I am writing this letter to inform the people of this community about some ways to help protect themselves from viruses, such as COVID-19.” This student then went on to outline ways to bolster the immune system, laying out how each contributed to the overall ability of a person to remain virus-free.

**Confidence in Science Class**

There were four questions from the Science Class Disposition Survey that asked questions regarding student confidence in various aspects of science class. One question asked if students felt they had opportunity for discovery, while another question asked students to identify how comfortable they were with using data they had collected. Another question asked students to identify their comfort in communicating what they learned, and a final question in this grouping asked students to identify how comfortable they were at verbally communicating what they learned from an experience. Results from this group of questions reveal that before the treatment, 77\% of students felt they had an opportunity to discover something during lab. After the treatment, 100\% of students who completed the final project were in agreement that they had opportunity to discover something during the treatment unit. One student found, “reading about the new disease that no one knows about was interesting: getting to learn something more.” Before the
treatment, 63% of students marked that they, to some degree, had a good idea about how to use data that they gathered during a classroom experiment. After the treatment, 100% of students that had finished the survey were in agreement that they had a good idea about what to do with data gathered during research. One student demonstrated confidence in what she had learned from her research by concluding her COVID-19 Community Letter, “I want to thank you for reading this letter, and I hope you take everything into consideration during this very serious pandemic.” Another student demonstrated confidence in the argument from his letter by concluding, “Overall there are many different factors that can affect the immune system, and a lot of them can be fixed or helped by simple changes in your diet or routine. Take the time to follow my advice and help keep yourself, and your community healthy.”
When asked what part of the research project was most difficult, one student responded that, “Choosing what I was going to put into the letter. There was a lot of different evidence. Picking and choosing what to put in the letter was a thing.” In a less drastic, but directionally similar change, 70% of students felt comfortable communicating what they learned in an experiment in writing before the treatment, while 90% of students felt comfortable communicating what they learned from research in writing after the treatment. In an interview, one student said, regarding how the treatment boosted her
confidence in written communication, “It helped you formulate the words in what you were trying to say.” Sixty-six percent of students felt comfortable verbally communicating what they learned from the learning experience before the treatment, but that fell to fifty percent after the treatment. When asked whether the final writing project boosted their confidence in understanding science, one student responded, “It didn’t boost my confidence in understanding. It boosted my confidence in communicating what I learned.”

Enjoyment in Science Class

The other four questions from the Science Class Disposition survey were grouped because these questions focused on various aspects of the student’s enjoyment of science class. The first of these questions generally asked if students enjoyed science class. The next of these questions asked students whether they enjoyed labs in class and whether they enjoyed the SWH unit research project. Another paired couple of questions asked whether students wished the class had more labs and whether they wished the class had more research projects. The final of these questions asked whether students enjoyed working together on labs, and its analog in the post-treatment survey asked whether students enjoyed the online discussion. There was no clear trend for these questions, and it was unclear whether the treatment had an effect on how much students enjoyed science class (Figure 3). The percent of those who affirmed that they generally enjoyed science class increased. Two students responded that they preferred writing a lab report to writing something like the COVID-19 Community Letter. One student, when asked why she would prefer to write a lab report responded, “It’s more fun.” Seventy-nine percent of
students wished that their biology class had more lab experiences, but only fifty percent of students who completed the COVID-19 Community Letter wanted their biology class to have more, similar research projects. Eighty-three percent of students enjoyed working with their partners during lab experiences. Only 50% of students agreed that they enjoyed participating in online discussion with their peers.

![Figure 3. Group B questions from the Science Class Disposition Survey before and after treatment. Note: these questions focus on aspects of student enjoyment of science class. (N=30 for pre-treatment results, N=10 for post-treatment results).](image)

**CLAIM, EVIDENCE AND REASONING**
Several claims came from examining the data and are outlined below. They are organized into claims about critical thinking, confidence in science class, and enjoyment of science class.

Critical Thinking

It appeared that completing a Science Writing Heuristic (SWH) unit with the accompanying final writing project elicited more critical thinking than previously written lab reports. There were several potential reasons that I can think of for this. First of all, I planned the SWH unit, to require a more explicit use of critical thinking in order to successfully complete. The normal lab report assignment followed a traditional rubric, which did not explicitly have this requirement. Students could do well on the lab report, while not demonstrating a high degree of critical thinking. The SWH was planned to elicit more critical thinking, and that is reflected in the Wilcoxon Signed-Ranks Test result, showing that the post-treatment scores according to the Critical Thinking Rubric were significantly higher than the pre-treatment scores according to the Critical Thinking Rubric.

Planning the SWH treatment was by far the most difficult part of its implementation. Teaching students to create concept maps, and how to constructively peer-review were essential skills for doing any SWH units. These pre-requisite skills were themselves critical thinking skills, so in the preliminary steps to completing this SWH unit, I explicitly taught some critical thinking strategies to my students, which was not done before having them complete a laboratory, and then write a lab report.
Another reason that the SWH writing project might have had a higher critical thinking score was that it was so different from writing a lab report. The lab report was written in response to laboratory activities. The COVID-19 Community Letter was written as a response to online guided research. Because of this, it may have been easier for students to find evidence and tailor it to fit the conclusions that they drew for the letter. With the lab report, their evidence came from the experiment, and may have been inconsistent, or, in cases where the students did not follow protocol, nonsensical. An approach which would have given clearer data about whether the SWH was responsible for the higher critical thinking scores, would be to have students complete the same kind of assignment, online research or laboratory experiment, and then adjudge their work with the Critical Thinking Rubric.

This was the first time that I used the Critical Thinking Rubric, and when assessing work with a rubric, I have needed to interpret what my students are trying to say. This interpretation introduces an element of subjectivity to the way I used the Critical Thinking Rubric. For instance, Domain 2 from the Critical Thinking Rubric discussed evidence. For the lab reports, I decided to look at the student’s use and interpretation of the data they had collected. For the COVID-19 Community Letter I decided to evaluate their interpretation of an online source or authority. Those were two different things, and my methodology probably reflects some bias toward the SWH.

Finally, the subject matter might have affected student thinking. The lab reports that I assessed were written about subjects that were introduced in biology class. Though I attempted to get students interested and to show them that the topic at hand was
relevant, I was certainly not fully successful. On the other hand, there was hardly any
topic that could have been more relevant for the final SWH writing project. Students had
witnessed the genesis of a global pandemic, and were on lock-down because of COVID-
19. Their higher degree of interest might have driven their higher degree of critical
thinking.

**Confidence in Science Class**

I wanted to see if students felt more confident while practicing science. The
responses from two questions seemed particularly instructive. I had asked students if they
felt like they had an opportunity to make a discovery while doing a lab activity or doing
research. Nearly 80% of students who answered that question before the treatment
responded that they felt like lab offered them an opportunity for discovery, but seven
students did not feel that way. The essence of science is discovery, thus, if a student feels
unable to make a discovery during science class, that must certainly affect their
confidence in doing science. Giving them the expectation of discovery should give them
confidence that they can learn science. That being said, 100% of the students who
completed the COVID-19 Community Letter felt as though research gave them an
opportunity to discover something. This came through in interviews as well. I asked
students what they enjoyed the most about the COVID-19 Community Letter writing
project, and all three students that I interviewed mentioned learning about COVID-19 or
something related to COVID-19. I think that the successful experience of completing the
project gave them confidence. They also expressed that they were more confident in
actually using what they learned from their research.
One hundred percent of the students that completed their COVID-19 Community Letter assignment responded that they had a good idea about what to do with data gathered from research. I think that this was due, at least in part, to them having created something with the information that they found through their research. They successfully wrote a letter to their community, and they didn’t have to make stuff up. They actually had to, as one student put it, “… sift through all the information to pick out the most important parts.” I think that becoming “experts,” to a small degree, about such a relevant topic gave them confidence that they could repeat this experience with other research.

Finally, 90% of students who completed the COVID-19 Community Letter felt comfortable communicating what they learned from their research in writing. This was up from 67% before the treatment. Certainly, one unit did not help increase student confidence in every regard, but it seems that this unit positively affected their overall confidence, their confidence in using data, and their confidence communicating in writing.

Enjoyment of Science Class

There was not a unified increase in enjoyment of various aspects of science class after the treatment was completed. I asked about several aspects of enjoying science class. Ninety percent of students who completed the treatment responded that they enjoyed science class, while before the treatment, thirty-three percent of students said that they did not. I do not know if the treatment had a bearing on the discrepancy from before and after. Students who responded in the affirmative might have been the same students who completed the COVID-19 Community Letter, and therefore I only received data that
I had already gathered. This might not have been the case, but I cannot rule it out with the data that I have. Most students enjoyed working with partners during labs, while 50% of the students in the treatment did not enjoy the online discussions. Though these two results come from a paired question, question 5, they are really separate questions, and should not be taken to indicate that the treatment affected the way students thought about working in collaboration. I did find it interesting, though, that 80% of students wished the class had more lab activities while only 50% wished the class had more research projects. This could have multiple explanations, but I think that it illustrates that thinking critically is difficult, and human beings tend to avoid difficulties, even though, in the long run, they can lead to greater growth.

Reasoning

One thing that the authors of the SWH stated was that the more this approach was used by teachers, the more value they found in using it. Preliminary iterations were necessary, but did not yield the results that several years of experience using the SWH yielded. I found that one iteration was an almost exclusively positive experience. If I were to complete another iteration of this action research, I would like to gather more uniform survey data. Having switched my demographic after I began gathering data led to results that were, though interesting, not intensely robust. One reason that might have artificially inflated the Critical Thinking Rubric scores for the COVID-19 Community Letter was that it was being compared to a totally different kind of assignment. I would really like to see if the SWH would increase the critical thinking scores of students writing about a laboratory experience.
I think that I will continue implementing the SWH in the future. As I get more adept at planning units in this manner, I hope to see compounded gains. The emphasis of having students critique each other’s work is especially interesting to me. Requiring students to cite reasons they came to a certain conclusion is good practice that the SWH builds into everyday instruction. I will also continue to explicitly teach students the value of being able to create and revise concept maps. This will give students a tool for helping them organize their understanding, and is very much in line with a constructivist understanding of learning.

The future is difficult to predict. No one saw the COVID-19 pandemic on the horizon of 2019, but it happened, and it changed how this school year finished. I believe that some of the changes that came with COVID-19 are here to stay, and that as a teacher I need to be ready to switch my instruction from “in-person” to “online,” at the drop of a virus. Implementing the SWH online was encouraging to me. The SWH is a great tool to use online because it helps students continue their interaction with each other, which is especially important if another extended period of quarantine goes into effect. The SWH is highly adaptable, and a great tool to have in my teachers toolbelt.

**Impact of Action Research on the Author**

The experience of completing an action research project has been impactful for me. Each step in the process helped me to become a better teacher. The introduction helped me to know, and then think about the community in which I teach, to answer the question, who are my students? It also helped me to pick out one aspect of teaching that I wanted to improve and focus on it. The greatest value of having completed the
conceptual framework, is that it opened to me vast stores of research. Searching through databases and reading research articles has given me confidence to search for answers to many of my questions. Writing down the methodology helped me to see that I need to improve my planning practice. I need to figure out some way that consistently helps me map out exactly how to get my students from A to Z. Analyzing the data helped me to do what I often ask my students to do, that is, figure out a way to gather data, and then puzzle about what that data means and how to represent it faithfully. It also helped me realize that I need to be fluent in using technology to represent data, so I can impart that fluency to my students. This final section has helped me to summarize, reflecting upon what I did and distilling it into the most meaningful things that I learned.

I might do another action research in the future. By that, I mean a full-out, written-up action research project. If I remain in education for any length of time, I see this as one of the best ways to keep improving my practice. If I do not complete a full action research project, what I have learned will remain in my mind and in my practice for as long as I teach. If asked to provide evidence for the validity of a certain pedagogical practice, I have a plethora of skills, learned from this project, that will help me build my case. I have gained an appreciation for how complex good teaching is. This project has helped me to see that. I walk away with more than a new teaching strategy called the SWH. I walk away with the skills for systematically becoming a better teacher.


APPENDICES
APPENDIX A

IRB EXEMPTION
INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

2115 Analysis Drive
C/o Microbiology & Immunology
Montana State University
Bozeman, MT 59718
Telephone: 406-994-4706
FAX: 406-994-4104
Email: cheryl@montana.edu

MEMORANDUM

TO: Aaron Devine and John Graves
FROM: Mark Quinn

Chair, Institutional Review Board for the Protection of Human Subjects

DATE: November 19, 2019

RE: “The Science Writing Heuristic and Science Class Engagement” [AD111919-EX]

The above research, described in your submission of November 18, 2019, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

X (b)(1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

X (b)(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects’ responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects’ financial standing, employability, or reputation; and (iii) the information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by section 16.111(a)(7).

(b)(3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

(b)(4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

(b)(5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

(b)(6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.
APPENDIX B

GATHERING DATA THROUGH RESEARCH WORKSHEET
1. **Article:** How Does the Immune System Work?  
   https://www.ncbi.nlm.nih.gov/books/NBK279364/  
   *My Notes:*

2. **Article:** 15 Foods that Boost the Immune System:  
   https://www.healthline.com/health/food-nutrition/foods-that-boost-the-immune-system  
   *My Notes:*

3. **Article:** Foods and Drinks that Compromise Your Immune System:  
   https://www.piedmont.org/living-better/foods-and-drinks-that-compromise-your-immune-system  
   *My Notes:*

   - Types of Immune Responses: Innate and adaptive, humoral vs. cell-mediated (Video)  
     *My Notes:*
   - Role of phagocytes in innate or nonspecific immunity (Video)  
     *My Notes:*
   - Self vs. non-self-immunity (Video)  
     *My Notes:*
   - The immune system review (Article)  
     *My Notes:*

5. **Article:** COVID-19 kills more men than women. The Immune System may be why:  
   *My Notes:*

6. **Article:** How to boost your immune system:  
   https://www.health.harvard.edu/staying-healthy/how-to-boost-your-immune-system  
   *My Notes:*
7. **Video**: Your immune system: Natural Born Killer:  
*My Notes:*

8. **Article**: Why do weather changes make us feel under the weather?  
*My Notes:*

9. **Article Abstract**: Vitamin C and Immune function:  
*My Notes:*

10. **Article**: Vitamin D and the Immune System:  
[https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3166406/](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3166406/)  
*My Notes:*

11. **Article**: Scroll down to “Sources of Vitamin D”  
[https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/](https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional/)  
*My Notes:*

12. **Article**: Could the summer bring an end to COVID-19?  
*My Notes:*
APPENDIX C

COVID-19 COMMUNITY LETTER AND RUBRIC
This assignment is to write a letter that answers the question, **In light of COVID-19, what weakens our immune systems, and what can we do to strengthen it?**

Tell the audience why you are writing this letter, and who it is intended for. Use at least 5 claims to write your letter. Support each claim with evidence from your research. Give your audience at least one practical piece of advice for each claim. Write in a way that is understandable to the average person. In other words, I (Mr. Devine) am not your audience. You are writing to people who may not have studied science or the immune system for years or decades if ever. Use language that they would understand. For example, instead of saying, “phagocytosis,” say, “when a white blood cell eats a virus.”

Write free of spelling and grammar errors. Use the rubric below to guide your writing.
## COVID-19 Community Letter Rubric

<table>
<thead>
<tr>
<th>Purpose/Audience</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student clearly states the reason that they are writing the letter. Student clearly states to whom they are writing the letter.</td>
<td>Student states why they are writing the letter. Student hints at who the audience is.</td>
<td>Student includes something about why they are writing, and who they are writing too, but it is ambiguous.</td>
<td>This section is missing.</td>
<td></td>
</tr>
<tr>
<td>Claim 1</td>
<td>The claim is clearly stated. Multiple lines of evidence support the claim. Advice about how to act because of the claim is clear and doable.</td>
<td>The claim is clearly stated. One line of evidence is used to support the claim. Advice about how to act because of the claim is included.</td>
<td>The claim is stated. Evidence is missing. Advice is missing.</td>
<td>Claim is missing.</td>
</tr>
<tr>
<td>Claim 2</td>
<td>The claim is clearly stated. Multiple lines of evidence support the claim. Advice about how to act because of the claim is clear and doable.</td>
<td>The claim is clearly stated. One line of evidence is used to support the claim. Advice about how to act because of the claim is included.</td>
<td>The claim is stated. Evidence is missing. Advice is missing.</td>
<td>Claim is missing.</td>
</tr>
<tr>
<td>Claim 3</td>
<td>The claim is clearly stated. Multiple lines of evidence support the claim. Advice about how to act because of the claim is clear and doable.</td>
<td>The claim is clearly stated. One line of evidence is used to support the claim. Advice about how to act because of the claim is included.</td>
<td>The claim is stated. Evidence is missing. Advice is missing.</td>
<td>Claim is missing.</td>
</tr>
<tr>
<td>Claim 4</td>
<td>The claim is clearly stated. Multiple lines of evidence support the claim. Advice about how to act because of the claim is clear and doable.</td>
<td>The claim is clearly stated. One line of evidence is used to support the claim. Advice about how to act because of the claim is included.</td>
<td>The claim is stated. Evidence is missing. Advice is missing.</td>
<td>Claim is missing.</td>
</tr>
<tr>
<td>Claim 5</td>
<td>The claim is clearly stated. Multiple lines of evidence support the claim. Advice about how to act because of the claim is clear and doable.</td>
<td>The claim is clearly stated. One line of evidence is used to support the claim. Advice about how to act because of the claim is included.</td>
<td>The claim is stated. Evidence is missing. Advice is missing.</td>
<td>Claim is missing.</td>
</tr>
<tr>
<td>Writing (x2)</td>
<td>All technical terms are explained in non-technical language. No spelling errors. No grammar errors.</td>
<td>Most technical terms are explained in non-technical language. Fewer than 3 spelling errors. Fewer than 3 grammar errors.</td>
<td>Technical language is still used. Between 3 and 5 spelling errors. Between 3 and 5 grammar errors.</td>
<td>Technical language is still used. More than 5 spelling errors. More than 5 grammar errors.</td>
</tr>
</tbody>
</table>

Total = 32 points x 2 = **64 points.**
APPENDIX D

POST-TREATMENT INTERVIEW QUESTIONS
1) Would you rather write a letter or a lab report?

2) What parts of the research/letter writing unit did you find most difficult?

3) What parts of the research/letter writing unit did you find most enjoyable?

4) Do you think that writing a lab report or writing something like a letter requires more thought on your part?

5) Do you feel like writing the letter boosted your confidence in understanding/communicating about science?

6) Do you have anything else that you would like to add about this learning experience?
APPENDIX E

CRITICAL THINKING RUBRIC
<table>
<thead>
<tr>
<th></th>
<th>Capstone 4</th>
<th>Milestone Two 3</th>
<th>Milestone One 2</th>
<th>Benchmark 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explanation of issues</strong></td>
<td>Issue/problem to be considered critically is stated clearly and described comprehensively, delivering all relevant information necessary for full understanding.</td>
<td>Issue/problem to be considered critically is stated, described, and clarified so that understanding is not seriously impeded by omissions.</td>
<td>Issue/problem to be considered critically is stated but description leaves some terms undefined, ambiguities unexplored, boundaries undetermined, and/or backgrounds unknown.</td>
<td>Issue/problem to be considered critically is stated without clarification or description.</td>
</tr>
<tr>
<td><strong>Evidence</strong> <em>Selecting and using information to investigate a point of view or conclusion</em></td>
<td>Information is taken from source(s) with enough interpretation/evaluation to develop a comprehensive analysis or synthesis. Viewpoints of experts are questioned thoroughly.</td>
<td>Information is taken from source(s) with enough interpretation/evaluation to develop a coherent analysis or synthesis. Viewpoints of experts are subject to questioning.</td>
<td>Information is taken from source(s) with some interpretation/evaluation, but not enough to develop a coherent analysis or synthesis. Viewpoints of experts are taken as mostly fact, with little questioning.</td>
<td>Information is taken from source(s) without any interpretation/evaluation. Viewpoints of experts are taken as fact, without question.</td>
</tr>
<tr>
<td><strong>Student's position</strong> (perspective, thesis/hypothesis)</td>
<td>Specific position (perspective, thesis/hypothesis) is imaginative, taking into account the complexities of an issue. Limits of position (perspective, thesis/hypothesis) are acknowledged. Others' points of view are synthesized within position (perspective, thesis/hypothesis).</td>
<td>Specific position (perspective, thesis/hypothesis) takes into account the complexities of an issue. Others' points of view are acknowledged within position (perspective, thesis/hypothesis).</td>
<td>Specific position (perspective, thesis/hypothesis) acknowledges different sides of an issue.</td>
<td>Specific position (perspective, thesis/hypothesis) is stated, but is simplistic and obvious.</td>
</tr>
<tr>
<td><strong>Conclusions and related outcomes</strong> (implications and consequences)</td>
<td>Conclusions and related outcomes (consequences and implications) are logical and reflect student’s informed evaluation and ability to place evidence and perspectives discussed in priority order.</td>
<td>Conclusion is logically tied to a range of information, including opposing viewpoints; related outcomes (consequences and implications) are identified clearly.</td>
<td>Conclusion is logically tied to information (because information is chosen to fit the desired conclusion); some related outcomes (consequences and implications) are identified clearly.</td>
<td>Conclusion is inconsistently tied to some of the information discussed; related outcomes (consequences and implications) are oversimplified.</td>
</tr>
</tbody>
</table>
APPENDIX F

CRITICAL THINKING VALUE RUBRIC
CRITICAL THINKING VALUE RUBRIC

for more information, please contact value@aacu.org

The VALUE rubrics were developed by teams of faculty experts representing colleges and universities across the United States through a process that examined many existing campus rubrics and related documents for each learning outcome and incorporated additional feedback from faculty. The rubrics articulate fundamental criteria for each learning outcome, with performance descriptors demonstrating progressively more sophisticated levels of attainment. The rubrics are intended for institutional-level use in evaluating and discussing student learning, not for grading. The core expectations articulated in all 15 of the VALUE rubrics can and should be translated into the language of individual campuses, disciplines, and even courses. The utility of the VALUE rubrics is to position learning at all undergraduate levels within a basic framework of expectations such that evidence of learning can by shared nationally through a common dialog and understanding of student success.

Definition

Critical thinking is a habit of mind characterized by the comprehensive exploration of issues, ideas, artifacts, and events before accepting or formulating an opinion or conclusion.

Framing Language

This rubric is designed to be transdisciplinary, reflecting the recognition that success in all disciplines requires habits of inquiry and analysis that share common attributes. Further, research suggests that successful critical thinkers from all disciplines increasingly need to be able to apply those habits in various and changing situations encountered in all walks of life.

This rubric is designed for use with many different types of assignments and the suggestions here are not an exhaustive list of possibilities. Critical thinking can be demonstrated in assignments that require students to complete analyses of text, data, or issues. Assignments that cut across presentation mode might be especially useful in some fields. If insight into the process components of critical thinking (e.g., how information sources were evaluated regardless of whether they were included in the product) is important, assignments focused on student reflection might be especially illuminating.

Glossary

The definitions that follow were developed to clarify terms and concepts used in this rubric only.

• Ambiguity: Information that may be interpreted in more than one way.
• Assumptions: Ideas, conditions, or beliefs (often implicit or unstated) that are "taken for granted or accepted as true without proof." (quoted from www.dictionary.reference.com/browse/assumptions)
• Context: The historical, ethical, political, cultural, environmental, or circumstantial settings or conditions that influence and complicate the consideration of any issues, ideas, artifacts, and events.
• Literal meaning: Interpretation of information exactly as stated. For example, "she was green with envy" would be interpreted to mean that her skin was green.
• Metaphor: Information that is (intended to be) interpreted in a non-literal way. For example, "she was green with envy" is intended to convey an intensity of emotion, not a skin color.
<table>
<thead>
<tr>
<th></th>
<th>Capstone</th>
<th>Milestones</th>
<th>Benchmark</th>
</tr>
</thead>
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<td>Issue/problem to be considered critically is stated but description leaves some terms undefined, ambiguities unexplored, boundaries undetermined, and/or backgrounds unknown.</td>
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<tr>
<td><strong>Evidence</strong> Selecting and using information to investigate a point of view or conclusion</td>
<td>Information is taken from source(s) with enough interpretation/evaluation to develop a comprehensive analysis or synthesis. Viewpoints of experts are questioned thoroughly.</td>
<td>Information is taken from source(s) with enough interpretation/evaluation to develop a coherent analysis or synthesis. Viewpoints of experts are subject to questioning.</td>
<td>Information is taken from source(s) without any interpretation/evaluation. Viewpoints of experts are taken as fact, without question.</td>
</tr>
<tr>
<td><strong>Influence of context and assumptions</strong></td>
<td>Thoroughly (systematically and methodically) analyzes own and others' assumptions and carefully evaluates the relevance of contexts when presenting a position.</td>
<td>Identifies own and others' assumptions and several relevant contexts when presenting a position.</td>
<td>Questions some assumptions. Identifies several relevant contexts when presenting a position. May be more aware of others' assumptions than one's own (or vice versa).</td>
</tr>
<tr>
<td><strong>Student's position (perspective, thesis/hypothesis)</strong></td>
<td>Specific position (perspective, thesis/hypothesis) is imaginative, taking into account the complexities of an issue. Limits of position (perspective, thesis/hypothesis) are acknowledged. Others' points of view are synthesized within position (perspective, thesis/hypothesis).</td>
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</tbody>
</table>
APPENDIX G

PRE-TREATMENT SCIENCE CLASS DISPOSITION SURVEY
Participation in this research is voluntary and participation or non-participation will not affect a student’s grades or class standing in any way.

Please indicate whether you Strongly Agree (SA), Agree (A), Disagree (D), or Strongly Disagree (SD) with each statement by circling the appropriate response.

*Strongly Agree – (SA)    Agree – (A)    Disagree – (D)    Strongly Disagree (SD)*

Statement 1: I enjoy science classes.  
SA  A  D  SD

Statement 2: I enjoy lab activities in science classes.  
SA  A  D  SD

Statement 3: I feel as though I have the opportunity to discover something during lab activities.  
SA  A  D  SD

Statement 4: I wish this class had more lab activities.  
SA  A  D  SD

Statement 5: I enjoy working with my peers during science lab activities.  
SA  A  D  SD

Statement 6: I have a good idea about what to do with data that I gather during an experiment.  
SA  A  D  SD

Statement 7: I feel comfortable communicating what I learned from an experiment in writing.  
SA  A  D  SD

Statement 8: I feel comfortable communicating what I learned from an experiment verbally.  
SA  A  D  SD

Please write anything else you’d like me to know about research below:

________________________________________________________________________
________________________________________________________________________
APPENDIX H

POST-TREATMENT SCIENCE CLASS DISPOSITION SURVEY
Participation in this research is voluntary and participation or non-participation will not affect a student’s grades or class standing in any way.

Please indicate whether you Strongly Agree (SA), Agree (A), Disagree (D), or Strongly Disagree (SD) with each statement by circling the appropriate response.

**Strongly Agree – (SA)  Agree – (A)  Disagree – (D)  Strongly Disagree (SD)**

Statement 1: I enjoy science classes.

SA A D SD

Statement 2: I enjoyed the research project on the immune system and COVID-19.

SA A D SD

Statement 3: I felt as though I had the opportunity to discover something while doing this immune system research project.

SA A D SD

Statement 4: I wish this class had more research activities.

SA A D SD

Statement 5: I enjoyed the online discussion with my classmates during this research activity.

SA A D SD

Statement 6: I have a good idea about what to do with data that I gather during my research.

SA A D SD

Statement 7: I feel comfortable communicating what I learned from my research in writing.

SA A D SD

Statement 8: I feel comfortable talking to people about what I learned from my research.

SA A D SD

Please write anything else you’d like me to know about research below:

________________________________________________________________________
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