

POSITIVELY INFLUENCING UNDERSTANDING AND ATTITUDES OF WATER USE IN  
COLORADO THROUGH RAISING TROUT IN THE CLASSROOM

by

Garret Michael Oksness

A professional paper submitted in partial fulfillment  
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY  
Bozeman, Montana

July 2026

©COPYRIGHT

by

Garret Michael Oksness

2026

All Rights Reserved

## DEDICATION

I dedicate this work to my colleagues, students, and friends. To my significant other who has supported me through it all. To my students, whose enthusiasm and excitement about trout has continued to influence me. To my colleagues, who have supported me from beginning to end.

## ACKNOWLEDGEMENTS

I would like to thank Colorado Trout Unlimited and Colorado Parks and Wildlife for their support of the Trout in the Classroom Project. I would like to thank Colorado River Watch for providing quality curriculum for this project. Special thanks to Troy Krotz, our principal, for his support throughout this process.

## TABLE OF CONTENTS

|                                                                |    |
|----------------------------------------------------------------|----|
| 1. INTRODUCTION AND BACKGROUND.....                            | 1  |
| Context of the Study .....                                     | 1  |
| Focus Statement/Question .....                                 | 2  |
| 2. CONCEPTUAL FRAMEWORK .....                                  | 4  |
| 3. METHODOLOGY .....                                           | 8  |
| Demographics .....                                             | 8  |
| Treatment .....                                                | 8  |
| Data Collection and Analysis.....                              | 10 |
| 4. DATA ANALYSIS: CLAIMS AND EVIDENCE.....                     | 12 |
| Results.....                                                   | 12 |
| 5. VALUE: REASONING AND REFLECTION .....                       | 27 |
| Claims From the Study .....                                    | 27 |
| Value of the Study and Consideration for Future Research ..... | 30 |
| Impact of Action Research on the Author .....                  | 31 |
| REFERENCES CITED.....                                          | 32 |
| APPENDICES .....                                               | 34 |
| APPENDIX A: INDIVIDUAL STUDENT INTERVIEW QUESTIONS .....       | 35 |
| APPENDIX B: QUESTIONS FOR PRE- AND POST-SURVEYS .....          | 37 |
| APPENDIX C: DISSOLVED OXYGEN LAB.....                          | 39 |
| APPENDIX D: STREAM TABLE OBSERVATIONS LAB.....                 | 43 |
| APPENDIX E: RIVER MORPHOLOGY LAB.....                          | 46 |
| APPENDIX F: GLADE RESERVOIR PROJECT.....                       | 50 |
| APPENDIX G: MACROINVERTEBRATES LAB.....                        | 53 |
| APPENDIX H: UNIT TEST.....                                     | 57 |
| APPENDIX I: IRB APPROVAL LETTER.....                           | 62 |

## LIST OF TABLES

| Table                                                                                   | Page |
|-----------------------------------------------------------------------------------------|------|
| 1. Table 1. Activities Students Participated in that were not Typical Lessons.....      | 12   |
| 2. Table 2. Questions in order on the Pre- and Post-Surveys.....                        | 15   |
| 3. Table 3. Student Interview Questions Before Treatment. ....                          | 25   |
| 4. Table 4. Student Interview Questions After Implementation of the TIC<br>Program..... | 26   |

## LIST OF FIGURES

| Figure                                                                                                                                          | Page |
|-------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1. Figure 1. Pre-survey responses related to real world issues using percent of responses, (N=22) .....                                         | 15   |
| 2. Figure 2. Post-survey responses related to real world issues using percent of responses, (N=22) .....                                        | 16   |
| 3. Figure 3. Pre-survey responses related to nature and conservation using percent of responses, (N=22). .....                                  | 17   |
| 4. Figure 4. Pre-survey responses related to nature and conservation using percent of responses, (N=22). .....                                  | 17   |
| 5. Figure 5. Pre-survey responses related to natural resource management using percent of responses, (N=22). .....                              | 19   |
| 6. Figure 6. Pre-survey responses related to natural resource management using percent of responses, (N=22). .....                              | 20   |
| 7. Figure 7. Most engaging lessons based on responses from post-interview and post-survey, (N=10 for post-interview, N=17 for post-survey)..... | 23   |
| 8. Figure 8. Comparison of student answers related to hands-on lessons, (N=21).....                                                             | 25   |

## ABSTRACT

This Action Research Project studies the impact of a hands-on unit, which teaches about freshwater ecosystems through raising trout in the classroom, on high school students' understanding of, and attitudes toward real world issues related to nature, conservation, and natural resource management. The project took place in a high school environmental science class at Wellington Middle High School, in Wellington, Colorado. Twenty-two students in grades 11 and 12 participated in the study. The project occurred over a 4-week period. Students filled out pre- and post-surveys with Likert Scale responses. Ten students also participated in individual pre- and post-interviews. Field observations of examples of engagement were made by me, the instructor. The results of my investigation showed that there was a positive effect on students' attitude and understanding of real-world issues relating to stream ecology, water quality, nature and conservation, and natural resource management through raising trout in the classroom. When comparing pre- and post-interviews, students moved from general descriptions of environmental issues, such as littering, to more complex answers involving population growth, water use, and human impacts. Students demonstrated increased understanding of identifying local species and ecological conditions those species indicate. Attitudes toward nature and conservation remained consistently positive. Students felt they had a better understanding of nature and conservation. I also observed that experiential, hands-on activities increased students' engagement and attitudes toward topics covered in this unit. These hands-on, experiential learning activities helped to reinforce key concepts covered throughout the Trout in the Classroom unit. In conclusion, teaching freshwater ecosystems through raising trout in the classroom was an effective strategy for increasing students' understanding of, and attitudes toward real-world issues related to nature, conservation, and natural resource management.

## CHAPTER ONE

## INTRODUCTION AND BACKGROUND

Context of the Study

I began raising trout in the classroom in the 2024-2025 school year. I participated in a program called Trout in the Classroom (TIC) through Trout Unlimited (TU) and Colorado Parks and Wildlife (CPW). Through these partnerships, I was able to raise Rainbow Trout in my classroom using a 55-gallon tank and then release these trout into the local watershed. The program was an excellent way to have hands on learning at my disposal anytime. The trout allowed me to have real-life examples of topics such as nutrient cycling, homeostasis, feedback loops, genetics, cell cycle, and many more. Students could observe the fish and their environment to identify trends, patterns, and make connections to the material we were learning. We received the fertilized eggs at the last stage before they hatch. We received the eggs in mid-October, and we raised the fish until April, when we were able to release them into the Cache Le Poudre River in Northern Colorado.

After running this program for one school year, I began wondering how this program would affect students' understanding of the topics covered in class. I decided to use a curriculum that would teach students about hydrology, stream ecology, water quality, and natural resource management through raising trout in the classroom. I hypothesized that participating in raising trout in the classroom would increase students' understandings of complex topics related to hydrology, stream ecology, water quality, and natural resource management. To investigate this, I used lesson materials from Colorado River Watch to implement curriculum focused on stream

ecology, hydrology, water quality, and natural resource management to my high school environmental science class. The class was taught at Wellington Middle High School in Wellington, Colorado. Wellington is a small town 12 miles north of Fort Collins. As a result, the demographics were a mix between rural Colorado, and the city of Fort Collins. Approximately 22 students participated in the treatment. The students were juniors and seniors in high school with varying academic abilities and backgrounds.

The results will be helpful in designing a hands-on curriculum that future teachers in the TIC program can use to help teach concepts related to their high school classes. I plan to share my results with TIC. I plan to share my results with the students so that they can see how action research works and how their participation will affect future classes. I also shared my results with my administration to help promote this type of curriculum in the future. My hope is to teach a class called River Science which focuses on the concepts that I covered in this AR project. My results from this project will help administration see the benefits of raising trout in the classroom as a tool for experiential learning.

#### Focus Statement/Question

My primary research question was what impact does learning about stream ecology, hydrology, and water chemistry through raising trout in the classroom affect students' understanding of and attitudes toward real-world issues as it pertains to water use and management? My secondary questions were: (1) What impact does learning about stream ecology, hydrology, and water quality through raising trout in the classroom have on students' understanding of and attitudes toward nature and conservation? (2) What impact does learning about stream ecology, hydrology, and water quality through raising trout in the classroom have

on students' understanding of and attitude toward natural resource management? (3) What impact does raising trout in the classroom have on student engagement and interest?

As a teacher, information gathered from this unit will help me determine the effectiveness of raising trout in the classroom, and hopefully, provide interesting curriculum that will encourage students to continue to think about water use in the state of Colorado.

## CHAPTER TWO

### CONCEPTUAL FRAMEWORK

The first article I explored reviewed Project-Based Learning and Place-Based Learning in rural high school classrooms. The authors explored how studying local watersheds and engagement with local professionals affected students' perceptions of science and its importance in societal and personal decision-making. Students took pre- and post- surveys to measure differences before and after The Confluence Approach (TCA) program. Overall, the authors found that students gained a more positive perception of science after completing one year of the TCA program. This study focused on student engagement, and the outcome of that particular engagement (Engels, M., Miller, B., Squires, A., Jyoti S., & Jennewein, K. E., 2019). This article influenced my AR project greatly.

I will start with a quote from the next article I reviewed. "Attempting to address the environmental challenges we face at a distance within traditional classroom spaces presents a disconnect for learners and environmental educators alike" (Kinslow, A., Sadler, T., & Nguyen, H., 2019, pp. 388). I believe this quote from the introduction gives a good perspective of how this paper aligns with my ideas for my action research topic. The study follows a high school field-based ecology class and the effects it has on student learning while implementing field-based learning (FBL), learning in the natural environment (LINE), and experiential education. The authors discuss the concepts of socio-scientific issues and that these concepts go further than just scientific content and practices but rather include concepts of integrating social issues, and complex problems that need dynamic solutions and multiple perspectives. Cognitive,

social/interpersonal, and physical impacts on students from the project were related to these socio-scientific issues (Kinslow, et al, 2019).

These two papers had strong overlap with each other and provided a greater degree of perspective on how to measure experiential learning as it relates to environmental science and a student's perspective of real-world issues and how likely students are to be positively engaged in these issues. These articles are useful in what methods I could use to measure how experiential learning such as raising trout affects student understanding and engagement in learning.

For methods, I researched different articles relating to environmental literacy and student engagement. A paper by McBeth and Volk focused on a National Environmental Literacy Project (NELP) where students were assessed using the Middle School Environmental Literacy Survey (MSELS), which could be given during a 50-minute class period, that focused on four critical Environmental Literacy (EL) components: knowledge, affect, cognitive skills, and behavior toward in environmental issues. They tested samples of 6<sup>th</sup> grade and 8<sup>th</sup> grade students (McBeth and Volk, 2010). This article gave excellent examples of ways to quantitatively measure environmental literacy, which was supportive of my AR project.

The second article I reviewed for methods had similar relations to the McBeth article in that the article was reviewing more effective ways to measure environmental literacy. It focused on the same four environmental literacy components. The difference was that this research was focused on making a more effective and concise EL instrument for students ages 14 to 19 years of age (Szczytko, R., Stevenson, K., Peterson, M., Nietfeld, J., & Strnad, R., 2018). This article developed and validated an EL instrument that could be assessed with 5-15 minutes, making it more usable and applicable to practitioners. I was excited to read about this article as it would

provide an excellent instrument in assessing environmental literacy that could be used before and after experiential learning in the classroom.

An additional article I found very helpful and interesting was an article that discussed how we, as educators, can help repair the relationship between students and nature. The authors discuss how meaningful conversations describing what nature is, the benefits (e.g. justifications) for natural experiences, how nature influences humans, how humans impact nature, and human responsibility to conserve and preserve nature (Roberts and Kruse, 2019). The authors also provide several resources and recommendations on how to facilitate these conversations. This article was informative and will be useful in helping to design discussions related to environmental literacy, student engagement, and experiential learning.

Another paper I found useful, and increasing my confidence in the topic, was another Master's capstone project dealing with a very similar project. This teacher raised trout in the classroom in a 6<sup>th</sup> grade science class. The author found that there was a strong gain in content knowledge, especially in the ecology unit, by having the real-world content (trout) as a supplement to the curriculum (Ziegler, 2011). The author found that there were significant gains from the pre-test to the post-test in content knowledge. On the constructed response part of the test, students showed significant improvement on the higher-level cognitive items. These findings were reinforced with student interviews after the post-test that also showed a deeper knowledge of ecosystem concepts (Ziegler, 2011).

The last article I reviewed was a literature review that investigated the effects of inquiry-based practices and how these practices correlate to science achievements. The article reviewed not only the practice, but the frequency of the practice and its overall effects on science

achievements in 69 different countries (Cairns, 2019). The study found that scientific achievement was higher in groups of students who performed some inquiry-based investigations in some lessons compared to students who performed inquiry-based investigations in all lessons. From the study, the negatively associated items were explaining their ideas and doing experiments (Cairns, 2019). I found this very interesting and informative. Based on what I have experienced in the classroom, more inquiry-based learning is not always better. Students can become too distracted by the projects and labs. Students need time to focus on the content. From my previous experience as an educator, I believe inquiry-based learning helps to reinforce content knowledge. This study provides more understanding for what I have experienced.

This literature review also found that certain activities had more impact on student achievement. The author states, “The approaches found to be associated with the highest levels of achievement at all frequencies of reported exposure involved the teacher explaining how a science idea can be applied and the teacher clearly explaining the relevance of science concepts to their everyday lives” (Cairns, 2019, p. 2123). I believe that raising trout in the classroom is a particularly applicable activity to engage students in science where students can clearly identify its relevance to river systems and how science affects their everyday lives. This article provided me with more evidence that this unit will have a positive effect on student achievement.

## CHAPTER THREE

### METHODOLOGY

#### Student Demographics

Wellington, Colorado is a small, agricultural community 12 miles north of Fort Collins, Colorado. The experiment was run in two sections of high school environmental science. 22 students participated in the study. These students were juniors and seniors, taking their third science as required for graduation. Students' abilities ranged greatly from gifted and talented to students with intensive Individualized Education Plans (IEP). 75% of the student population is White, 19% Hispanic, 5% Multi-race, and less than 1% Asian, Black, and American Indian/Alaska Native. 7% of our student population have a home language other than English.

#### Treatment

The unit was taught starting in the third week of a semester-long environmental science class. Students first learned how to observe water temperature, pH, nitrate/nitrite concentrations, ammonia concentration, and size of the trout using thermometers, test strips, and photographs of the fish. Students were then responsible for collecting and recording this data every other day. As a class, we made comparisons of the data collected in previous days to identify trends that we were seeing in the trout tank. Twice a week, these data collected from the fish tank were recorded for Trout Unlimited. Trout Unlimited required all classrooms participating in TIC to record their tank observations to create a database of all tank observations. Students then learned about how temperature, pH, and dissolved oxygen affect life in river systems. Students took notes during lecture and practiced their understandings of these topics with formative assessments. Students

then participated in a hands-on lab testing the relationships between water temperature and dissolved oxygen using dissolved oxygen and temperature probes from Vernier. Students compared dissolved oxygen levels in cold water, room temperature water, and warm water. Students interpreted the relationship between the temperature of the water sample and the amount of dissolved oxygen present in the water sample.

Most of the unit used lessons from Colorado River Watch, a nonprofit organization that trains high school students to earn industry-recognized certifications in hydrology, watershed management, water chemistry, and riparian ecology. In order to receive these certificates, students must show proficiency through these lessons. Therefore, these lessons have been vetted and have been found to be effective.

Next, the students learned about stream morphology and hydrology. Students learned how to identify different parts of a river such as runs, riffles, and pools, and how rivers change over time using stream tables. Students identified how rivers meander and change naturally, and how human-caused changes, such as the building of a reservoir, can affect parts of the river system. Students participated in two different labs. The first lab looked at a stream created on a stream table. Students were to identify parts of the river such as the pools, riffles, and runs and describe why these parts were found where they were. The next day, students used the stream tables in the second lab to observe how rivers change. Students first created a straight channel and compared how sediments move in a meandering channel. Students then introduced an obstruction, whether natural, or human caused such as a culvert or dam, and observed the changes to the stream. Students then investigated how a potential dam project in our local watershed would affect river systems in Northern Colorado. Students researched the Glade

Reservoir Project, which is a proposed dam project in northern Colorado, and used both resources for the proposed project and against it. Students compared the benefits and drawbacks to the proposed project and formed their own opinions on the reservoir project.

Students then learned about macroinvertebrates found in our local watershed. Students learned about the life cycle of these macroinvertebrates and what ecological roles they play. Students also learned how these organisms act as indicator species for the health of the river system. Students then participated in a macroinvertebrates lab where specimens were collected the night before and students used stereoscopes and dichotomous keys to identify which macroinvertebrates were found, or not found, in their water samples.

Lastly, students studied the life cycle of salmonids, and more specifically, freshwater rainbow trout. Students participated in a perch dissection. A perch was used instead of trout due to access of dissecting specimens. Students made comparisons of the perch anatomy to that of a rainbow trout. After concluding the perch dissection, students moved into the final project, where students created a story about the life of a trout where they had to incorporate information learned throughout the unit and how these topics affect the life cycle of the trout. Students finished the unit and a final summative was given at the end of the unit. In total, the treatment was about four weeks long.

### Data Collection and Analysis

Before the unit began, I selected ten students who represented the academic range of abilities in the classroom to participate in individual interviews. Of the students chosen for the interview, four were considered gifted and talented, three had IEP's with lower academic abilities, and one was bilingual. The remaining two students who participated represent the

middle portions of the class. Students who participated in the interviews represented the demographics of the rest of the students in the study. These students participated in an interview before we started the unit, and another interview after the unit was completed. These interviews were recorded, transcribed, and compared to see changes in understandings and attitudes as they relate to the focus questions.

Before the unit began, students filled out a pre-survey where students ranked their understandings and attitudes toward real-world issues, nature and conservation, and natural resource management using Likert scale responses. For the Likert scale responses, students read the statement in the survey and responded whether they strongly agreed, agreed, were neutral, disagreed, or strongly disagreed. These responses were assigned to numbers of 5, 4, 3, 2, and 1, respectively. The assigned numbers to the responses allowed me to assess the responses quantitatively. Then, after the unit, students filled out a post-survey. The surveys were compared quantitatively to observe changes after treatment. There were some questions on the pre- and post-surveys that allowed students to elaborate on their responses. These specific questions gave qualitative data that I assessed as well. The survey questions were vetted through peers in my MSSE cohort and reviewed by my instructional advisor with the MSSE program. The surveys were approved through an Internal Review Board (IRB) at MSU.

Throughout the unit, there were several labs and hands-on activities that were designed to help reinforce content that was covered throughout the unit. These activities are listed in Table 1. During these activities, I made and recorded field observations during class. These field observations were focused on student engagement and interest. I recorded how students responded to these activities. I recorded student quotes that showed engagement. I also recorded

how many students appeared to be engaged and focused on the activity and examples of students collaborating and interacting with the material being covered.

Table 1: Activities Students Participated in that were not typical lessons

| <b>Activity</b>               | <b>Description</b>                                                                                                                                                                                                                                                                    |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Testing of the Fish Tank      | Every other day, students observed observe water temperature, pH, nitrate/nitrite concentrations, ammonia concentration, and size of the trout using thermometers, test strips, and photographs of the fish (Not in appendix. This was an activity with verbal instruction).          |
| Dissolved Oxygen Lab          | Students compared dissolved oxygen levels in cold water, room temperature water, and warm water. Students measured temperature and dissolved oxygen with Vernier probes (Appendix C)                                                                                                  |
| Watershed Activity            | Students crumpled paper and taped the paper on the desk. Students traced the ridges of paper with a water-soluble marker. They then dripped water onto the ridges and watched where the colors of the markers ran to (Not in appendix. This was an activity with verbal instruction). |
| Stream Table Observations Lab | On a stream table, students were to identify parts of the river such as the pools, riffles, and runs and describe why these parts were found where they were (Appendix D).                                                                                                            |
| River Morphology Lab          | Students compared a straight channel to a meandering channel using stream tables. Students then observed how the channels changed when an obstruction was added (Appendix E).                                                                                                         |
| Macroinvertebrates Lab        | Macroinvertebrates were collected the night before by the me and students used stereoscopes and dichotomous keys to identify which macroinvertebrates were found, or not found, in their water samples (Appendix G).                                                                  |
| Fish Dissection               | Students participated in a perch dissection. A perch was used instead of trout due to access of dissecting specimens. Students made comparisons of the perch anatomy to that of a rainbow trout (Not in appendix. This was an activity with verbal instruction).                      |
| Glade Reservoir Dam Project   | Students compared benefits and drawbacks to reservoir construction and formed an opinion (Appendix F).                                                                                                                                                                                |
| Final Project                 | Students developed a story of the life cycle of a trout where each of the topics in the unit is represented in the trout's life cycle (not included in appendix).                                                                                                                     |

At the end of the unit, a summative assessment was given. The summative assessment was used to measure student understanding of complex topics related to real world issues, nature,

conservation, and natural resource management covered in the unit These data were used to measure changes in understandings and attitudes of students as they relate to the focus questions.

## CHAPTER FOUR

## DATA ANALYSIS: CLAIMS AND EVIDENCE

Results

I analyzed the pre- and post-surveys where students gave responses on a Likert scale. The questions were aimed at measuring students' understandings and perspectives related to three topics: real world issues relating to water, nature and conservation, and natural resource management. The first topic analyzed was how students' perspectives changed related to real world issues. I compared the sums of each category on the Likert scale for the pre- and post-surveys. Question 1, which related to students' confidence in explaining environmental issues related to water, had the largest change. In the pre-survey, 27% of respondents disagreed, 64% were neutral, and 5% agreed (Figure 1). In the post-survey, no respondents disagreed, 41% were neutral, 50% agreed, and 9% strongly agreed (Figure 3). Another large change was observed in question 7 about protecting water systems. In the pre-survey, 9% of respondents disagreed and 18% strongly agreed compared to 0%, and 27% in the post-survey, respectively. Lastly, only 9% of respondents agreed with Question 9 where students rated their own understandings of how pH, temperature, dissolved oxygen, and turbidity affect stream ecology in the pre-survey (Figure 1) compared to 59% of respondents agreed in the post-survey (Figure 2).

Table 2: Questions in order on the Pre- and Post-Surveys

|             |                                                                                                       |
|-------------|-------------------------------------------------------------------------------------------------------|
| Question 1  | I am confident in my ability to explain environmental issues that affect the water cycle in Colorado. |
| Question 2  | I feel a strong sense of connection to nature.                                                        |
| Question 3  | Wild places have an important role in our world, and I think it is important to protect them.         |
| Question 4  | I know my local watershed and the organisms that live in that watershed.                              |
| Question 5  | Conservation is important and we need to use land and water in a sustainable way.                     |
| Question 6  | I understand the risks of not conserving land and water.                                              |
| Question 7  | We should protect our water systems, even if it means slowing down economic development.              |
| Question 8  | I understand how nutrients move through the water cycle.                                              |
| Question 9  | I understand how pH, temperature, dissolved oxygen, and turbidity affect stream ecology.              |
| Question 10 | It is important to understand what goes into our rivers.                                              |
| Question 11 | I understand how natural resources are managed in Colorado, especially freshwater.                    |

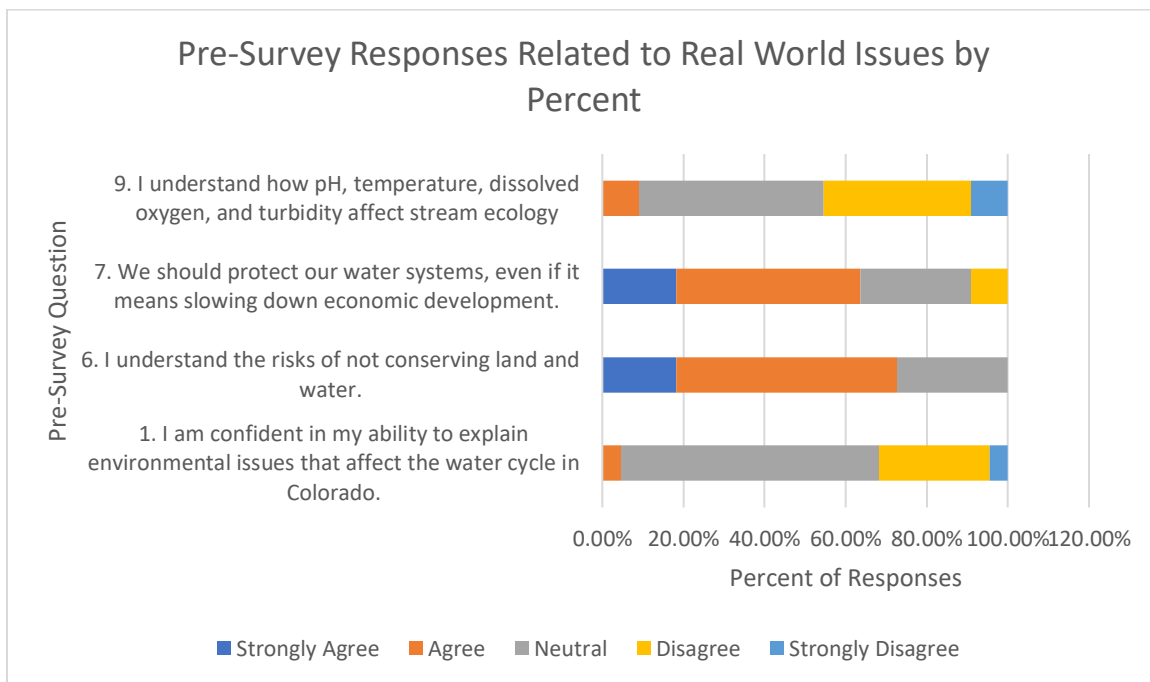


Figure 1. Pre-survey responses related to real world issues using percent of responses, (N=22).

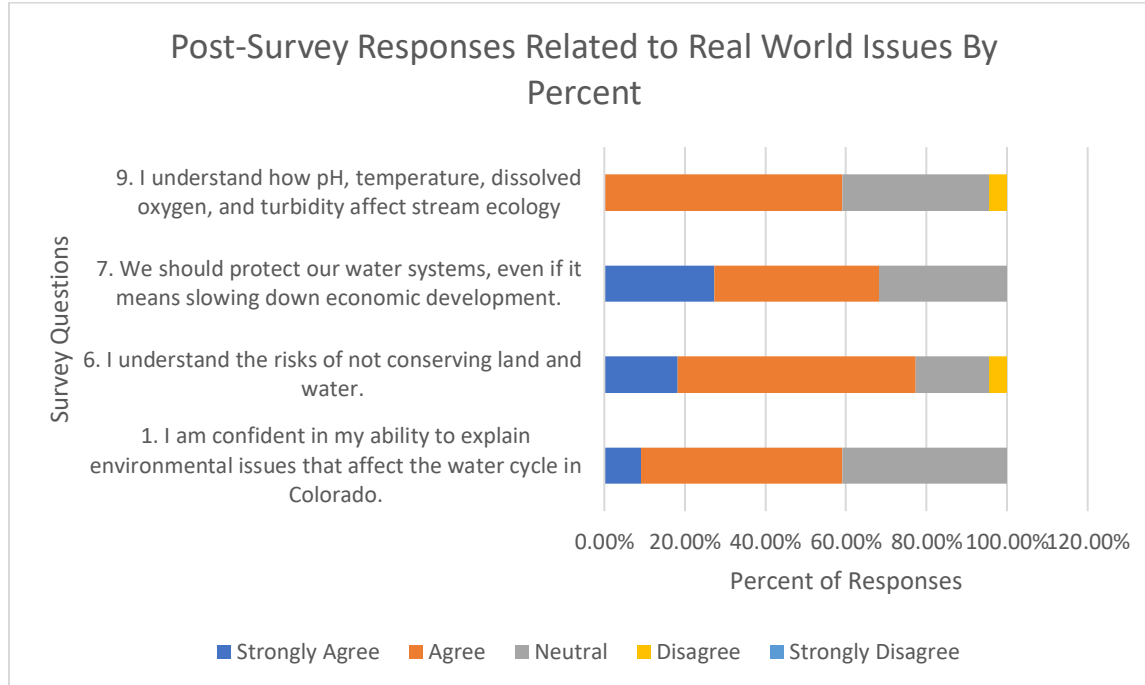


Figure 2. Post-survey responses related to real world issues using percent of responses, ( $N=22$ ).

The second topic of Nature and Conservation did not have large changes between the pre-survey and post-survey Likert responses. I observed a small shift in Question 2, which asked about the student's sense of connection to nature. In the pre-survey, approximately 5% disagreed with the statement (Figure 3). In the post-survey, no students disagreed with Question 2 (Figure 4). Although this was not a large change, it may have represented a change in one student's attitude. More investigation would be needed to represent if there was a change in student attitude related to the topic of Nature and Conservation.

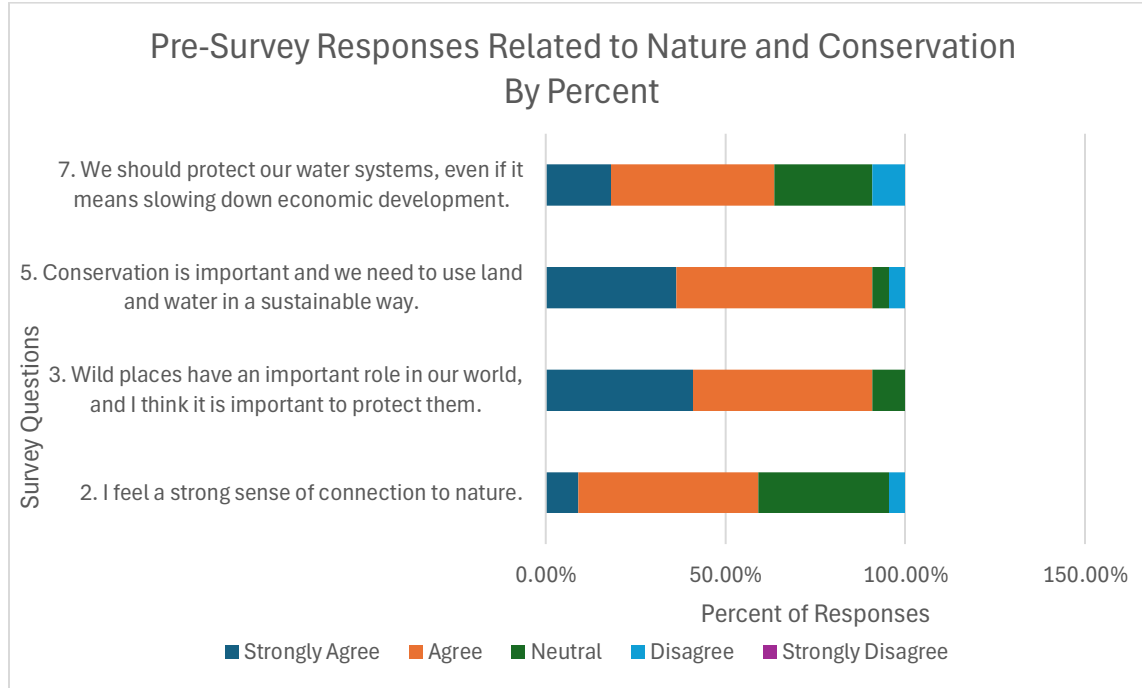


Figure 3. Pre-survey responses related to nature and conservation using percent of responses, ( $N=22$ ).

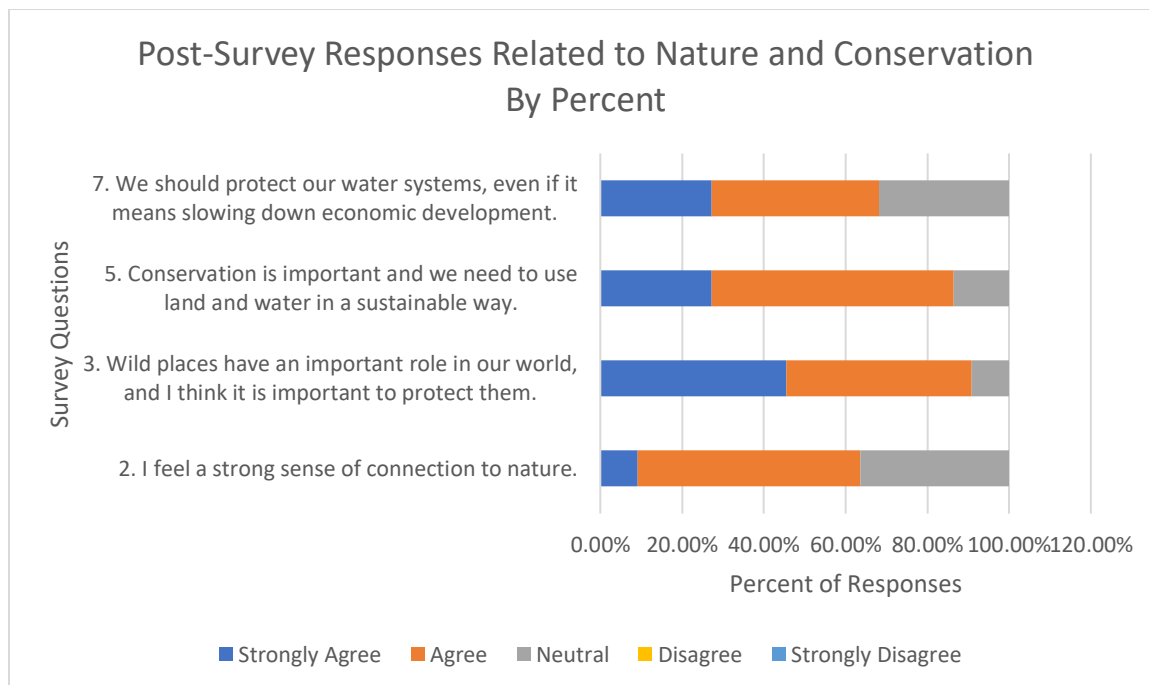


Figure 4. Pre-survey responses related to nature and conservation using percent of responses, ( $N=22$ ).

The last topic of Natural Resource Management had larger changes. The largest changes happened in Questions 4, 8, 9, and 11. For Question 4 about knowledge of the local watershed and its organisms, 27% of students were neutral, 50% of students disagreed, and 23% of students strongly disagreed in the pre-survey (Figure 5). On the post-survey, 55% of students agreed, 32% were neutral, and only 14% disagreed, and no students strongly disagreed (Figure 6). For Question 8 asking how nutrients move through the water cycle, 18% of students agreed on the pre-survey and 45% disagreed (Figure 5) compared to 50% of students who agreed on the post-survey, and 9% of students who disagreed (Figure 6). Question 11 which asked about understanding how natural resources are managed in Colorado had the largest change between the pre-survey and post-survey in this topic. In the pre-survey, 5% of respondents agreed, 73% were neutral, and 23% disagreed (Figure 5). In the post-survey, 41% of respondents agreed, 55% were neutral, and 5% disagreed (Figure 6).

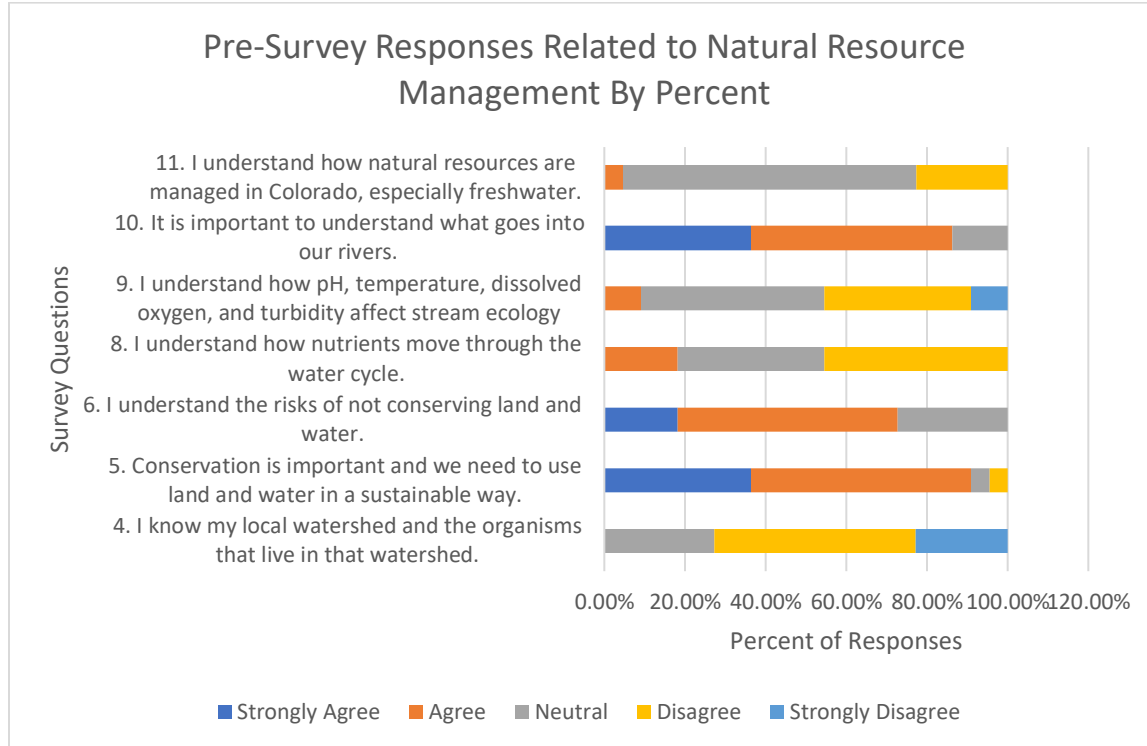


Figure 5. Pre-survey responses related to natural resource management using percent of responses, ( $N=22$ ).

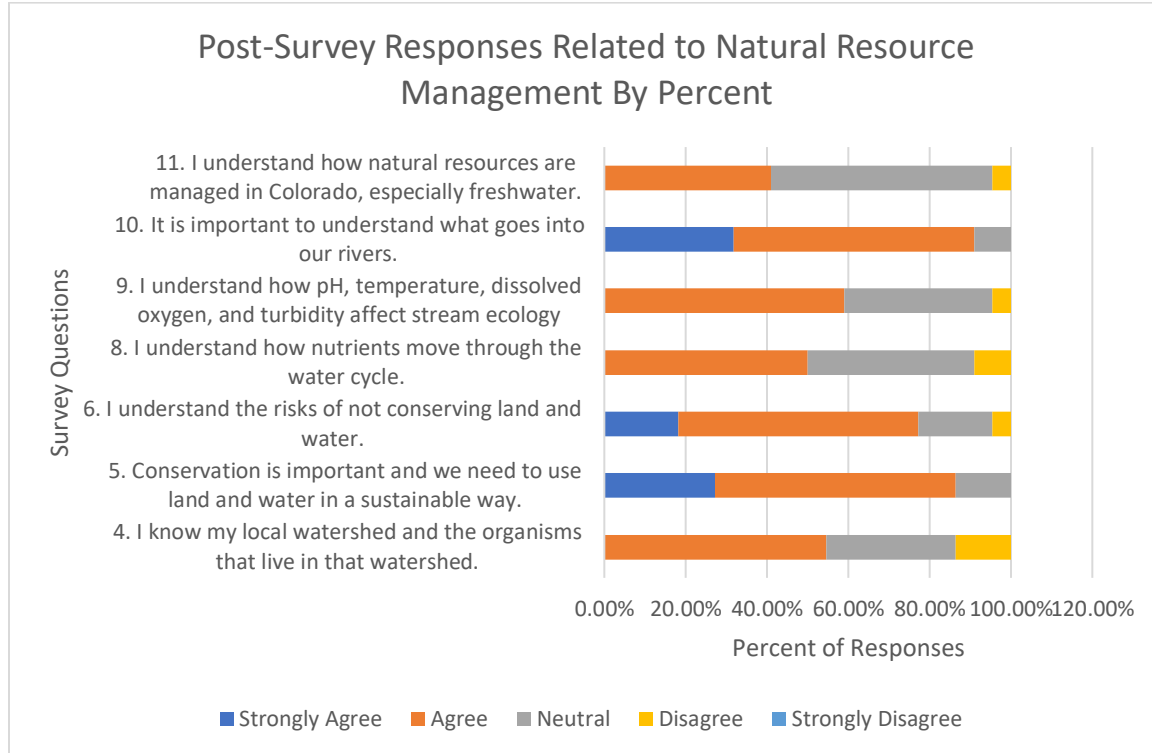


Figure 6. Pre-survey responses related to natural resource management using percent of responses, (N=22).

From the analysis of the pre- and post-survey data, I do believe that participation in the Trout in the Classroom unit increased students' understandings of real-world issues and natural resource management. I also believe that students' attitudes towards real world issues and natural resource management also changed. Next, I will use student interviews to further support this pattern.

A total of ten students participated in pre- and post-interviews. The qualitative data from these interviews reinforced some of my findings from the quantitative data collected from the Likert scales. Students were asked the same questions in the pre- and post-interviews. Question 1 in the interviews had some of the largest changes in student perspective and understanding. When students were asked to define some real-world issues affecting our water in Colorado,

students described issues such as pollution and trash being put into river systems. One student said, “Um, I think some real-world issues affecting our water in Colorado would be pollution or, um, pollution from trash or whatever is left, uh, in discarded that, uh, pollutes the water and contaminates it”. This same student on the post-survey answered differently to this question by saying, “Uh, some real-world issues that are affecting our water in Colorado right now could be umm...I think one could be overpopulation and just trying to equally distribute water sources to growing, uh, growing regions across Colorado, and just having to build more reservoirs and more dams that could, uh, potentially be consequential to river systems”. Another student showed change in his understanding of real-world issues between the pre-interview and post-interview. In the pre-interview he said, “I don’t really know. I haven’t really looked into that environmental change and conservation stuff, so I don’t really know”. After the unit his answer to this question changed by saying, “Um, I would say building of dams. Like when we were learning about the dam project and realized, like, how non-beneficial it was-I mean, beneficial to humans, but non-beneficial to like aquatic life and the other ecosystems. So, I think that’s one issue that is real-world to me”. There were students in the interview that their changes in understanding were less on this question. Four of the students who described trash and pollution in the pre-interview also answered it for the post-interview and were unable to give more details. Two students described drought and overuse both in their pre-interview and post-interview.

The next two questions asked in the pre-interview and post-interview were identifying if students could name organisms in their local watershed and what relationships these organisms play in their ecosystems. These questions align with both focus questions relating to nature and conservation and natural resource management because having a baseline knowledge of the

ecosystem would help influence understanding and attitudes toward nature and conservation and natural resource management. These questions had the most significant changes in understanding between the pre- and post-interviews. Nearly every student interviewed had significant changes to their answers between the pre- and post-interviews. Only two students who were interviewed did not show changes in understanding of organisms found in the local watershed. Most students interviewed were able to identify specific organisms we discussed including rainbow trout and different types of macroinvertebrates. Several students were even able to identify why specific macroinvertebrates were considered indicator species. For example, one student who could not name specific bugs in the pre-interview went on to say in the post-interview, “Salmonids and just that whole group of fish, and then there’s macroinvertebrates like caddisflies and mayflies, and then bacteria and more crawdads”. This same student when asked a clarifying question about how these macroinvertebrates are indicator species, answered, “they indicate the health of the ecosystem. Macroinvertebrates like, uh, mayflies, they need oxygen-rich waters and, like, pretty low pollution levels”.

Another observation that was made from the interviews was that students’ attitudes toward nature and conservation didn’t necessarily change, they just gained more knowledge in how nature and conservation are affected by human activities. On the post-interview, I asked how their viewpoints changed in their connections to nature and the importance of conserving wild places. The majority of students reflected that their beliefs did not change, but they felt that the unit reinforced what they already believed. For example, on the post-interview a student responded, “I don’t think they’ve changed, I’ve just come to understand, like, possible human impacts better”.

The last observation made from the interviews and surveys was how the responses overwhelmingly showed that the most engaging lessons for the students were hands-on activities. On the post-survey, and post-interview I asked what was the most engaging lesson of this unit on stream ecology and water quality? On the post-survey, 16 out of the 17 total responses identified a hands-on activity as the most engaging lesson (Figure 7). Out of 10 post-interview responses, 7 of them identified a hands-on activity as their most engaging lesson in the unit. These responses show a positive correlation to the hands-on learning activities in the trout ecology unit and student engagement. The most engaging activity in the post-surveys was the stream table activity. 47% of responses identified that the stream table activity was the most engaging (Figure 7). One response stated, “Using the stream tables to see river morphology in real-time, then seeing how human infrastructure can affect it”.

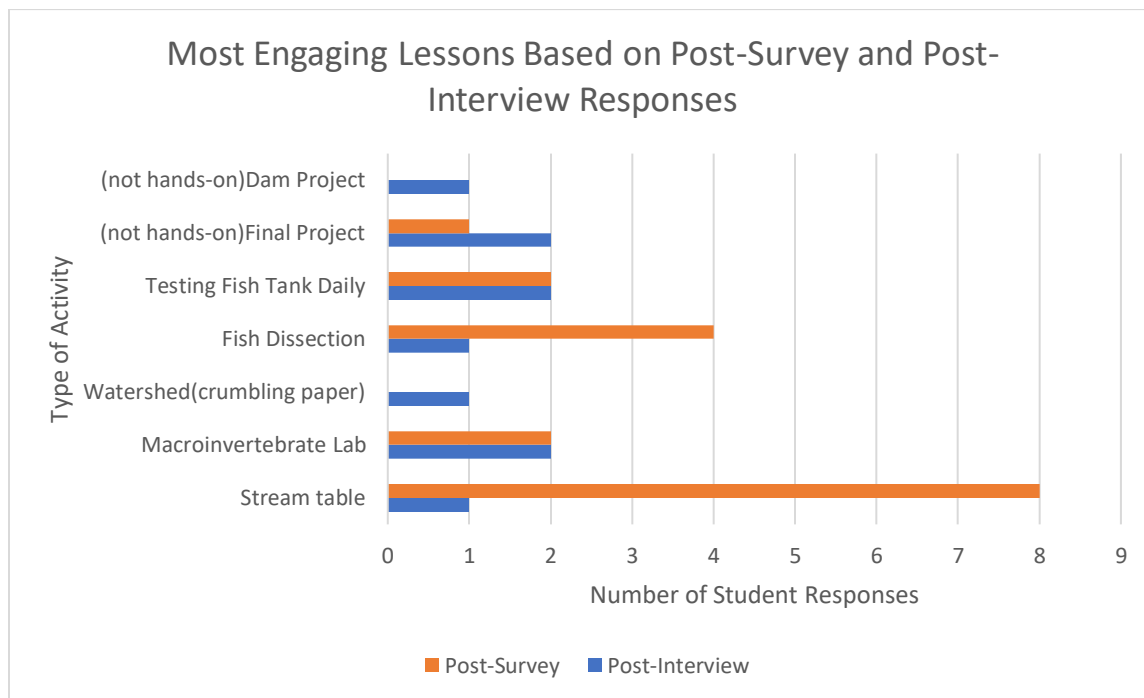


Figure 7. Most engaging lessons based on responses from post-interview and post-survey, (N=10 for post-interview, N=17 for post-survey).

To further investigate my observation that student engagement was positively affected by hands-on learning, I compared 11 questions on the summative assessment that were related to hands-on learning activities in this unit. For these questions, I compared how many students answered the questions correctly, partially correct, or incorrectly and represented the data in Figure 8. For many of these questions, there was not a significant difference than a somewhat normal distribution within a classroom, but there were three questions that had a distribution that seemed to be different than what I would expect as a normal distribution within a classroom data set. Question 3 asked students to describe the relationship between temperature of the water and the amount of dissolved oxygen in the water. 16 out of 21 students answered this question correctly and only 2 students were completely incorrect. This means that less than 10% of students answered this question incorrectly. From my experience as an educator, less than 20% of students answering a question incorrectly indicates that the students tested are showing higher than normal levels of proficiency. Question 5, which asked about rivers being static or dynamic, had similar distributions with 19 students answering it correctly versus only two answering incorrectly. Questions 15, 24, and 26 had even more impressive distributions. For question 15, 20 students answered this question correctly with only one student not answering it correctly (Figure 8). For question 24, 90% of students were correct. For question 26, 85% of students were correct. There could have been many reasons why these questions had such high percentages of proficiency, but their relationship with the hands-on lessons that students found to be engaging should not be ignored and I would be interested in investigating this correlation further in a future study.

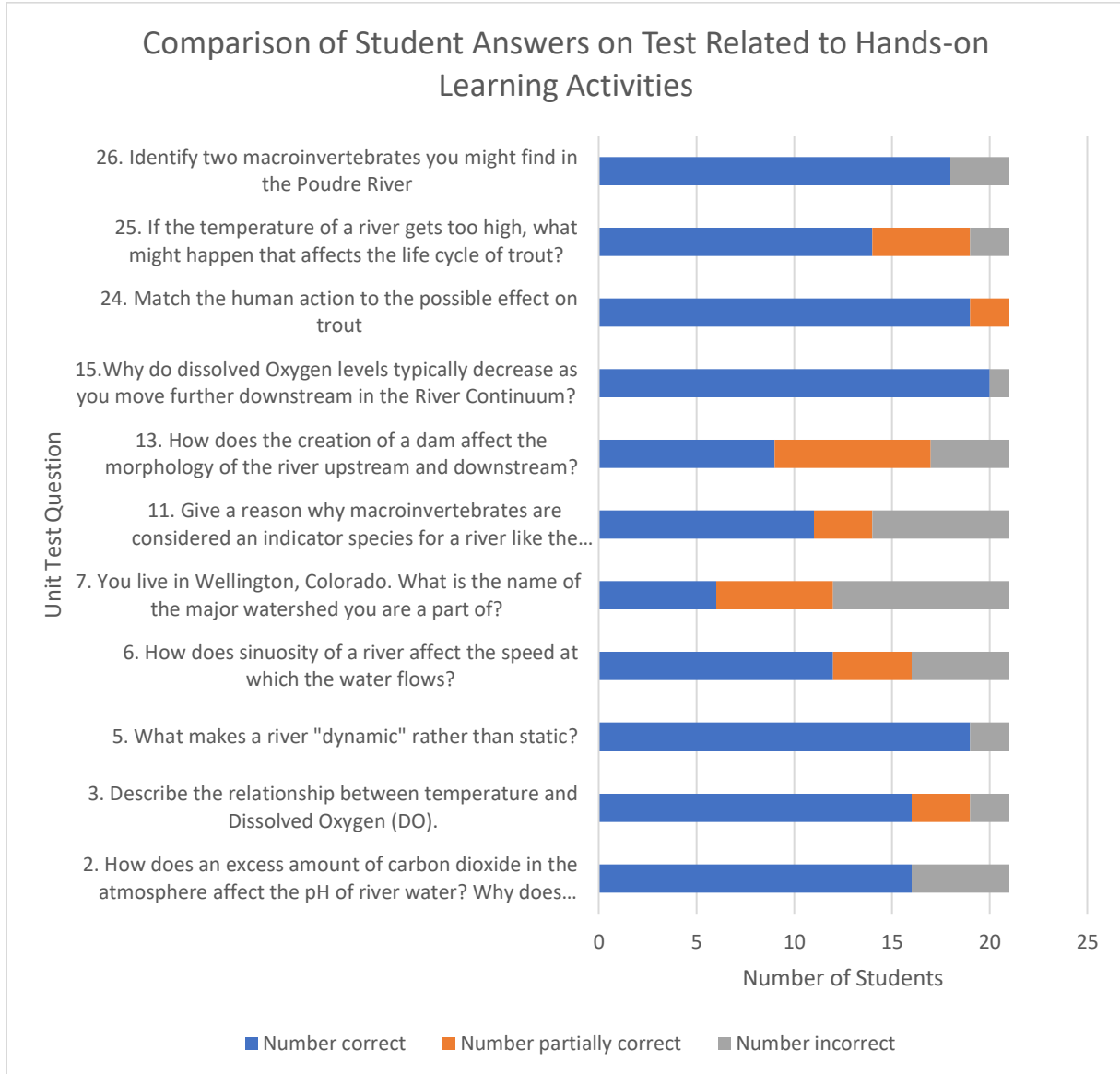


Figure 8. Comparison of student answers related to hands-on lessons, ( $N=21$ ).

Table 3: Student Interview Questions Before Treatment

|                                                                                   |
|-----------------------------------------------------------------------------------|
| Question 1: What are some real-world issues affecting our water in Colorado?      |
| Question 2: Please name some organisms in our local watershed?                    |
| Question 3: What relationships do these organisms play in their ecosystem?        |
| Question 4: What is your connection to nature and open spaces?                    |
| Question 5: Do you think it is important to conserve wild places? Why or why not? |
| Question 6: Describe an engaging and interesting science lesson?                  |
| Question 7: What specific activities make science engaging and interesting?       |
| Question 8: What about raising trout in the classroom sounds interesting to you?  |

Table 4: Student Interview Questions After Implementation of the TIC Program

|                                                                                                   |
|---------------------------------------------------------------------------------------------------|
| Question 1: What are some real-world issues affecting our water in Colorado?                      |
| Question 2: Please name some organisms in our local watershed?                                    |
| Question 3: What relationships do these organisms play in their ecosystem?                        |
| Question 4: What is your connection to nature and open spaces?                                    |
| Question 5: Do you think it is important to conserve wild places? Why or why not?                 |
| Question 6: Have any of your viewpoints from the previous questions changed? How so?              |
| Question 8: What was the most engaging lesson of this unit on stream ecology and water quality?   |
| Question 9: What was the most interesting thing you learned while raising trout in the classroom? |

## CHAPTER FIVE

## VALUE: REASONING AND REFLECTION

Claims From the Study

The results of my investigation show that there was a positive effect on students' attitude and understanding of real-world issues relating to stream ecology, water quality, nature and conservation, and natural resource management through raising trout in the classroom.

My primary focus question was what impact does learning about stream ecology, hydrology, and water quality through raising trout in the classroom has on students' understanding of real-world issues as it pertains to water use and management? My first claim is that there was a positive effect on both students' understandings and their attitudes toward real-world issues as it pertains to water use and management. This was most obvious in the surveys and the interviews. In the pre-survey, almost all students either answered strongly disagree, disagree, or neutral with their confidence in identifying environmental issues that affect the water cycle in Colorado. In the post-survey, the majority of students identified that they agreed or strongly agreed. There was still a large number of students that identified as neutral, but there was a positive movement on the Likert scale. The increase in these responses on the Likert scale supports that students' understandings and attitudes toward real-world issues did positively increase after the unit.

In the interviews, several students were able to elaborate on issues such as drought, overuse, and the establishment of more reservoirs in Northern Colorado as real-world issues affecting our water in Colorado, where they did not identify these issues before the unit. In the

pre-interviews, most students defined real-world issues in broad terms such as pollution. After the treatment, most students interviewed were able to elaborate on more specific examples of real-world issues affecting freshwater in Colorado.

My second claim is that although students' attitudes toward nature and conservation did not change, their understanding of nature did. Data collected from the surveys and interviews support this claim. For the questions related to nature and conservation on the survey, there was not a large difference between the pre- and post-surveys to indicate a change in attitude. The average responses for pre- and post-surveys also show this being that the changes weren't as significant as for the other focus questions. Most students already had a positive attitude toward nature and conservation to begin with. Most students in the post-interviews and post-surveys identified that their attitudes did not change, just that they understand more about their local watershed and the organisms inside it. Evidence of student understanding was observed in question 4 of the survey and the post-interviews. Question 4 in the pre- and post-survey had a large change, which helps show that students felt they understood more about the organisms in their local watershed after the unit. Many of the students who participated in the interviews did not know any species in our local watershed. In the post-interviews these same students were able to identify rainbow trout as salmonids and the different macroinvertebrates that exist in their different life stages. When asked guiding questions related to how these different macroinvertebrates act as indicator species, most students who participated were able to identify the relationships between high dissolved oxygen levels, water clarity, and temperature of the water and these indicator species.

My third claim is that there was a positive change in student understandings of natural resource management. The evidence was most prominent in the pre- and post-surveys. For question 8, 18% of students agreed and 45% disagreed in the pre-survey compared to 50% agreed and only 9% disagreed. For question 9, only 9% agreed in the pre-survey compared to 59% in the post-survey. Question 11 had 5% agree in the pre-survey compared to 41% in the post-survey. Questions 8 and 9 represented students' understanding in nutrient cycling. Nutrient cycling is such an important part of natural resource management that I believe a growth in understanding of these topics will only help students in their understanding of natural resource management. Question 11 directly measured whether students felt they understood natural resource management, especially freshwater.

My final claim is that I believe there was a positive correlation between hands-on learning in this unit and student engagement and interest. This unit was generally a hands-on unit and most students appeared to be engaged and interested in most of the activities we did in class, but there were some that stood out. Most days, we started class by collecting data from the fish tank, then we would move on to the rest of the lesson. All students in the class participated in these hands-on lessons. From what I observed throughout the unit, it was not a surprise that 16 out of the 17 students on the post-survey, and 7 out of 10 in post-interviews, responded that a hands-on lesson was the most engaging lesson of this unit. Using the stream table to represent how a dam would affect stream deposition, morphology, and water temperature stood out to me as an excellent example of an engaging lesson using hands-on learning. During this lesson, I observed students interacting with each other, asking each other questions, and simply showing a higher level of curiosity compared to other lessons. It is no surprise that 8 out of 17 students

chose this as the most engaging lesson. Another example of excellent student engagement during a hands-on activity was during the macroinvertebrate Identification lab. I collected river samples the night before, and students tried to identify at least three different macroinvertebrates using stereoscopes. Students were very engaged. It was like teaching in a middle school science class. Students were excited about what they were observing saying things like, “Mr. O, I found another type of mayfly!”, and “I see its face, cool! I can see another one!”. One student even finished her lab and wanted to keep looking at other specimens just because it was cool, and this student normally does not engage any more than she must. In conclusion, I believe this unit had excellent student engagement and interest, especially in the hands-on lessons. Teacher observations, interviews, and surveys all showed that when the students participated in the hands-on learning, they were engaged. I will greatly consider this connection between hands-on learning and student engagement as I continue to find ways to engage students differently in the classroom.

#### Value of the Study and Consideration for Future Research

Results from my AR project will help influence future curriculum development in our building as well as providing curriculum that is accessible to other teachers who participate in the TIC program. Raising trout in the classroom is a decent amount of work for a regular teacher. My results from this AR project have provided more evidence and reasoning for why a teacher would want to raise trout in the classroom. I conclude that raising trout in the classroom is an effective strategy for having students participate in experiential learning while interpreting how humans affect local ecosystems through studying our local watershed.

Impact of Action Research on the Author

My hope is that this study can lead to further investigations in future courses. I hope to teach a course called River Science. This course would be focused on many of the topics covered during my AR project, but the emphasis will be to allow students to earn industry-recognized certifications in hydrology and watershed management, and water quality and riparian ecology. These certifications are part of the Career Development Incentive Program (CDIP) in Colorado. This program allows high school students to access industry recognized certifications in their high school classes. My hope is to implement this program at our school and use TIC to help further students' progress in this new curriculum. Once I begin teaching this new curriculum, I hope to further understand how receiving an industry recognized certification affects student engagement in the program.

## REFERENCES CITED

- Dean Cairns (2019). Investigating the relationship between instructional practices and science achievement in an inquiry-based learning environment, *International Journal of Science Education*, 41:15, 2113-2135, DOI: 10.1080/09500693.2019.1660927.
- Engels, M., Miller, B., Squires, A., Jyoti S., & Jennewein, K. E. (2019). The confluence approach: Developing scientific literacy through project-based learning and place-based education in the context of NGSS. *Journal of Science Education*, 23(3), 33-58.
- Kinslow, A., Sadler, T., & Nguyen, H. (2019). Socio-scientific reasoning and environmental literacy in a field-based ecology class. *Environmental Education Research*, 25(3), 388-410. <https://doi.org/10.1080/13504622.2018.1442418>.
- McBeth, W., & Volk, T. (2010). The national environmental literacy project: A baseline study of middle school students in the United States. *The Journal of Environmental Education*, 41(1), 55–67. doi: 10.1080/00958960903210031.
- Roberts, K., Kruse, J. (2019). Repairing the relationship between students and nature. The Clearing House: *A Journal of Educational Strategies, Issues and Ideas*, 92(1-2), 23-27. doi: 10.1080/00098655.2018.1547265.
- Szczytko, R., Stevenson, K., Peterson, M., Nietfeld, J., & Strnad, R. (2018). Development and validation of the environmental literacy instrument for adolescents. *Environmental Education Research*, 25(2), 193–210. <https://doi.org/10.1080/13504622.2018.1487035>.
- Ziegler, Erich, "Improving sixth grade student knowledge of ecology using fish rearing and release as a real-world context ", Master's report, Michigan Technological University, 2011. <https://doi.org/10.37099/mtu.dc.ets/531>.

## APPENDICES

## APPENDIX A: INDIVIDUAL STUDENT INTERVIEW QUESTIONS

Table 1: Student Interview Questions During Implementation of the TIC Program

|                                                                       |
|-----------------------------------------------------------------------|
| What are some real-world issues affecting our water in Colorado?      |
| Please name some organisms in our local watershed?                    |
| What relationships do these organisms play in their ecosystem?        |
| What is your connection to nature and open spaces?                    |
| Do you think it is important to conserve wild places? Why or why not? |
| Describe an engaging and interesting science lesson?                  |
| What specific activities make science engaging and interesting?       |
| What about raising trout in the classroom sounds interesting to you?  |

Table 2: Student Interview Questions After Implementation of the TIC Program

|                                                                                       |
|---------------------------------------------------------------------------------------|
| What are some real-world issues affecting our water in Colorado?                      |
| Please name some organisms in our local watershed?                                    |
| What relationships do these organisms play in their ecosystem?                        |
| What is your connection to nature and open spaces?                                    |
| Do you think it is important to conserve wild places? Why or why not?                 |
| Have any of your viewpoints from the previous questions changed? How so?              |
| Describe an engaging and interesting science lesson?                                  |
| What was the most engaging lesson of this unit on stream ecology and water quality?   |
| What was the most interesting thing you learned while raising trout in the classroom? |

## APPENDIX B: QUESTIONS FOR PRE- AND POST-SURVEYS

### Questions for Pre- and Post-Survey

Create 10 survey questions using a Likert scale responses of 1 to 5 that measure student attitudes about their connections to nature and conservation, their understanding of environmental issues relating to local watersheds, and how they feel about conserving wild places.

Likert Scale:

- 1 Strongly Disagree
- 2 Disagree
- 3 neutral
- 4 Agree
- 5 Strongly Agree

1. I am confident in my ability to explain environmental issues that affect the water cycle in Colorado.
2. I feel a strong sense of connection to nature.
3. Wild places have an important role in our world, and I think it is important to protect them.
4. I know my local watershed and the organisms that live in that watershed.
5. Conservation is important and we need to use land and water in a sustainable way.
6. I understand the risks of not conserving land and water.
7. We should protect our water systems, even if it means slowing down economic development.
8. I understand how nutrients move through the water cycle.
9. I understand how pH, temperature, dissolved oxygen, and turbidity affect stream ecology.
10. It is important to understand what goes into our rivers.
11. I understand how natural resources are managed in Colorado, especially freshwater.

## APPENDIX C: DISSOLVED OXYGEN LAB

## Dissolved Oxygen Lab

Name: \_\_\_\_\_

### The Effect of Temperature on Dissolved Oxygen and pH

#### Objective:

To determine how changing the temperature of tap water affects its ability to hold Dissolved Oxygen (DO) and its pH level.

#### Hypothesis: ANSWER THESE PLEASE

1. *As the temperature of the water increases, the dissolved oxygen levels will*  
\_\_\_\_\_.
2. *As the temperature of the water increases, the pH levels will*  
\_\_\_\_\_.

#### Background Information

Water quality is heavily influenced by temperature. One of the most critical factors for aquatic life is **Dissolved Oxygen (DO)**. Just like sugar dissolves in tea, oxygen gas dissolves in water. However, gases behave differently than solids. according to gas laws, the solubility of a gas generally decreases as the temperature of the liquid increases.

**pH** measures the concentration of hydrogen ions in the water. While pure water is neutral, temperature can affect the dissociation of water molecules, leading to slight changes in pH readings. Understanding these relationships is vital for studying thermal pollution and aquatic ecosystem health.

#### Materials Needed

- **Water Source:** Tap water
- **Glassware:** Three 500mL Beakers.
- **Measurement Tools:**
  - Thermometer
  - Dissolved Oxygen Sensor
  - pH Test Strips.
- **Temperature Control:**
  - Hot plate or kettle
  - Ice bucket with crushed ice
- **Safety Gear:** Goggles, heat-resistant gloves.

#### Safety Precautions

- **Hot Surfaces:** Use caution when using the hot plate. Do not boil the water; we only need it to be warm (approx. 40°C - 50°C or just under or around 190 degrees fahrenheit).
- **Glassware:** Handle glass beakers carefully to avoid breakage, especially when alternating between hot and cold environments.
- **Chemical Safety:** If using a chemical titration kit for DO, wear goggles and wash hands immediately if chemicals touch skin.

## Procedure

### Part A: Preparation of Water Baths

1. Label your three beakers: **Cold**, **Room Temp**, and **Warm**.
2. Fill the **Room Temp** beaker with 300mL of tap water and let it sit on the counter.
3. Fill the **Cold** beaker with 200mL of tap water and add a large handful of crushed ice. Stir gently until the temperature drops below 10°C.
4. Fill the **Warm** beaker with 300mL of tap water and place it on a hot plate (set to low/medium). Heat until the water reaches approximately 45°C or around 190 degrees Fahrenheit. **Do not boil.**

### Part B: Data Collection

*Perform the measurements quickly to ensure the temperature does not shift significantly during testing.*

1. **Room Temperature Trial:**
  - Place the thermometer in the **Room Temp** beaker. Record the exact temperature in Table 1.
  - Submerge the pH probe. Wait for the reading to stabilize and record.
  - Submerge the DO probe. Record the DO in mg/L.
2. **Cold Water Trial:**
  - Place the thermometer in the **Cold** beaker. Record the exact temperature.
  - (Remove any large ice chunks before testing to avoid damaging fragile sensors).
  - Measure and record pH.
  - Measure and record DO.
3. **Warm Water Trial:**
  - Place the thermometer in the **Warm** beaker. Record the exact temperature.
  - Measure and record pH.
  - Measure and record DO.

## Data Table

| Condition | Temperature (°C) | Dissolved Oxygen (mg/L) | pH Level | Observation / Notes |
|-----------|------------------|-------------------------|----------|---------------------|
| Cold      |                  |                         |          |                     |

|                  |  |  |  |  |
|------------------|--|--|--|--|
| <b>Room Temp</b> |  |  |  |  |
| <b>Warm</b>      |  |  |  |  |

### Analysis & Discussion

1. **Graphing:** Create 2 scatter plot graphs on a separate piece of graphing paper.
  - **X-axis:** Temperature (°C)
  - **Y-axis:** Dissolved Oxygen (mg/L)
  
  - **X-axis:** Temperature (°C)
  - **Y-axis(2):** pH level
2. **Trend Identification:** Describe the relationship between Temperature and Dissolved Oxygen based on your graph. Was it a direct or inverse relationship?
3. **pH Analysis:** Did the pH change significantly with temperature?
4. **Real-World Application:** "Thermal Pollution" occurs when factories discharge hot water into rivers. Based on your data, explain why this is dangerous for fish that require high oxygen levels (like Trout).

**(Artificial Intelligence (Gemini) was used to assist in the formatting of this activity.  
Concepts and ideas were original to this project)**

APPENDIX D

STREAM TABLE OBSERVATION LAB

## Stream Table Observation Lab

---

**Objective:** To make observations about the flow of a river and identify key terminologies when observing certain parts of the river.

### Procedure

1. **Setup:** The stream tables will be set up for you. There will be one winding stream, and one straight stream.
2. **Take a picture:** Once the stream has been running for a little bit, take a picture of each of the rivers. Make sure that you have the whole stream table in frame.
3. **Upload image:** Upload your images to your google drive or just straight to google slides. One picture for each slide. If uploading does not work, picture will be provided for you on classroom.
4. **Observation:** Look at each picture and label (step 2) the slide using lines/arrows and text boxes. Each term in our list should be labeled on **BOTH** images of rivers.
5. **Conclusion:** On a third slide, after your label, answer the questions in the conclusion.

### Data & Analysis (The "Label List")

Students must find and label all of the following on their photos:

- Watershed
- At least two pools on each photo
- At least two riffles on each photo
- Headwaters
- Transfer Zone
- Depositional Zone
- Baseflow
- Stormflow
- Floodplain

**Conclusion**

- On a third slide, Answer the following questions
  - What were some key similarities between the two rivers?
  - What terms did you label that were different on each photo?
  - What would be the stream order number of this?
  - How does the sinuosity of the river change how it is identified?
  - What makes a river dynamic? (why does it move and change)

**(Artificial Intelligence (Gemini) was used to assist in the formatting of this activity.**

**Concepts and ideas were original to this project)**

APPENDIX E

RIVER MORPHOLOGY LAB

Name \_\_\_\_\_

**Lab: River Morphology****Part 1: Initial Setup**

1. Make sure the sand and dirt in your stream table is relatively flat. Make sure the gradient (steepness) is on the 2nd level.
2. Create a **straight** channel in your stream table. Leave a good amount of dirt on the bottom of your channel. The width should be about 2 inches wide and an inch deep. Record data from the middle of your river and record them here:
  - a. Length \_\_\_\_\_.
  - b. Width \_\_\_\_\_.
  - c. Depth \_\_\_\_\_.
3. Once everything is put together and measured, go ahead and plug in the table to turn on the water, adjust which channels the water is coming out of based on where your river starts.
4. Every two minutes, measure and record your data. Mark any observations that you notice. Turn off your table when done.

| Time  | Channel Width | Channel Depth | Sinuosity (Qualitative) | Observations |
|-------|---------------|---------------|-------------------------|--------------|
| 2 min |               |               |                         |              |
| 4 min |               |               |                         |              |
| 6 min |               |               |                         |              |

### Part 2: Sinuosity

1. Give some time for most of the water to drain out
2. Once mostly drained, flatten out your dirt and create a new river, with 2-5 curves in it.
3. Leave a good amount of dirt on the bottom of your channel. The width should be about 2 inches wide and an inch deep. Measure those in the middle of your river and record them here:
  - a. Length \_\_\_\_\_.
  - b. Width \_\_\_\_\_.
  - c. Depth \_\_\_\_\_.
4. Once everything is put together and measured, go ahead and plug in the table to turn on the water, adjust which channels the water is coming out of based on where your river starts.
5. Every two minutes, measure and record your data. Unplug the table when done.

| Time  | Channel Width | Channel Depth | Sinuosity (Qualitative) | Observations |
|-------|---------------|---------------|-------------------------|--------------|
| 2 min |               |               |                         |              |
| 4 min |               |               |                         |              |
| 6 min |               |               |                         |              |

### Part 3: Introducing a Variable

On your curvy river, fix it up a little bit and then **choose one** variable to implement. No need to measure the river, just make observations.

- Increase or decrease the amount of faucets running into your stream table to increase or decrease flow.
- Increase or decrease the gradient of the stream table
- Add obstructions to the river bed in various places

- Add obstructions to the sides of the river banks and in other places
- Make a dam using a large obstruction (popsicle sticks)

After 5 minutes of flow on and observations, unplug your table.

1. **Variable changed:** \_\_\_\_\_
2. **Observations** list observations and changes that occurred in this box:

|  |
|--|
|  |
|--|

#### **Part 4: Analysis Questions**

1. What happened to your straight river over time?
2. At which part of a meander curve is the water moving the fastest? Where did you see the most erosion?
3. What processes are causing the rivers to physically change?
4. Why should we study how rivers move?
5. How does river morphology affect wildlife in and around the river?

**(Artificial Intelligence (Gemini) was used to assist in the formatting of this activity.  
Concepts and ideas were original to this project)**

APPENDIX F

GLADE RESERVOIR PROJECT

## Glade Reservoir Research Project

**Purpose:** Glade Reservoir is a proposed 170,000 acre-foot reservoir (slightly larger than Horsetooth) to be built northwest of Fort Collins. It will involve pumping water from the **Poudre River** into the reservoir. Chimney Hollow was a similar project that has already been built.

Using resources from Chimney Hollow, things we have learned in class, and research on the environmental impacts of the Glade Reservoir...

You will write two letters to your local government, one that is FOR building of the reservoir, and one that is AGAINST.

For those who are more artistically inclined, you may create two different propaganda posters, one that is pro Glade reservoir, and one that is against.

### What you need to cover:

To get full credit on their letter or poster, students must address:

- **Chimney Hollow**
  - Use it as a case study and give examples to where it may have succeeded or failed
- **Temperature of the river (Dissolved Oxygen)**
- **Fish populations**
- **Macroinvertebrates**

And at least 2 of the following

- **River morphology**
- **Erosion and Deposition**
- **Economic benefits and drawbacks**
- **Recreational affects**
- **Land Acquiring (public or private land)**
  - Is someone losing their land to this?
- **Any other points that you seem fit for this project**

### Parameters of the Letters

- Double Spaced
- One page for Pro Glade Reservoir
- One page against Glade Reservoir
- Must be addressed to a specific person or agency
- Must be persuasive
- USE EXAMPLES AND EVIDENCE TO SUPPORT YOUR CLAIMS
- Include your sources used (MLA or APA format)

### Parameters of the Posters

- Must make two separate posters
  - One pro Glade, one against Glade
- Must be fully hand drawn and colored
- Must include an artistic depiction of all 6 specific points to address
  - You may combine two points into one
  - Ex. dead fish might be used to symbolize two specific points
- May have only a limited amount of text (no full paragraphs)
- Must attempt to persuade its audience
- Include a slogan for each poster
  - Like a title or tagline
- Explain each specific point (bullet points are fine) and why you included it
  - **Use evidence** from research to support your claims
  - Ex. Fish Populations: I used a dead fish to symbolize that the decrease in dissolved oxygen in the river and reservoir would harm the fish populations.
- Include sources for where you got the information

**(Artificial Intelligence (Gemini) was used to assist in the formatting of this activity.**

**Concepts and ideas were original to this project)**

APPENDIX G

MACROINVERTEBRATES LAB

Name: \_\_\_\_\_ Date: \_\_\_\_\_

### Macroinvertebrate Lab

#### Directions

1. Get into groups of two, and grab one stereoscope from the back
  - a. Turn on your stereo scope
  - b. Turn on the lights
  - c. Take off the cap on the bottom of the lens
2. Get a sample of water from the bucket that holds the Macros. Use a turkey baster to grab water to put into a beaker. **Make sure you have at least 5 to 10 insects in your beaker before bringing it back to your desk.**
3. Get a pipette, and cut off the tips of them so the mouth is wider.
4. Find one macro in your beaker, and suck it up with your pipette. Once you have one, release it into a petri dish.
5. Put it under your stereoscope and follow the worksheet below.
  - a. If your organism is moving too much, try and place them onto a cotton ball to keep them still, return it to the water after viewing.
6. Return your macro to the water
7. repeat steps 3-6 while picking up **3 different species' of macroinvertebrates**

---

#### Organism one

##### A. Scientific Illustration

*View the specimen under the stereoscope. Draw a detailed diagram below in the circle. Any zoom level, any part you want.*

##### B. Identity & Path

Using [Macorinvertebrates.org](http://Macorinvertebrates.org), click on the actual organism that you find. Use that information to answer the following:

- **Common Name:** \_\_\_\_\_
- **Taxonomic Order:** \_\_\_\_\_
- **Diagnostic Characteristics (at least two):** \_\_\_\_\_

Click on the “i” for more information, read order overview and life history, find one fun fact about the macro that you did not know and **write it here:**

---



---

### C. Ecological Dossier

1. **Feeding Group:** (Scraper, Shredder, Collector, or Predator?) \_\_\_\_\_
2. **The Niche:** Based on its mouthparts or body shape, how does it get energy?  
\_\_\_\_\_
3. **Pollution Tolerance:** (Sensitive, Facultative, or Tolerant?) \_\_\_\_\_

### Organism Two

#### A. Scientific Illustration

*View the specimen under the stereoscope. Draw a detailed diagram below. Any zoom level, any part you want.*

#### B. Identity & Path

Using [Macorinvertebrates.org](http://Macorinvertebrates.org), click on the actual organism that you find. Use that information to answer the following:

- **Common Name:** \_\_\_\_\_
- **Taxonomic Order:** \_\_\_\_\_
- **Diagnostic Characteristics (At least two):** \_\_\_\_\_

Click on the “i” for more information, read order overview and life history, find one fun fact about the macro that you did not know and write it here:

---



---

### C. Ecological Dossier

4. **Feeding Group:** (Scraper, Shredder, Collector, or Predator?) \_\_\_\_\_
5. **The Niche:** Based on its mouthparts or body shape, how does it get energy?  
\_\_\_\_\_
6. **Pollution Tolerance:** (Sensitive, Facultative, or Tolerant?) \_\_\_\_\_

### Organism Three

#### A. Scientific Illustration

*View the specimen under the stereoscope. Draw a detailed diagram below. Any zoom level, any part you want.*

### **B. Identity & Path**

Using [Macorinvertebrates.org](http://Macorinvertebrates.org), click on the actual organism that you find. Use that information to answer the following:

- **Common Name:** \_\_\_\_\_
- **Taxonomic Order:** \_\_\_\_\_
- **Diagnostic Characteristics (At least two):** \_\_\_\_\_

Click on the “i” for more information, read order overview and life history, find one fun fact about the macro that you did not know and write it here:

---



---

### **C. Ecological Dossier**

7. **Feeding Group:** (Scraper, Shredder, Collector, or Predator?) \_\_\_\_\_
8. **The Niche:** Based on its mouthparts or body shape, how does it get energy?

9. **Pollution Tolerance:** (Sensitive, Facultative, or Tolerant?) \_\_\_\_\_

---



---

**(Artificial Intelligence (Gemini) was used to assist in the formatting of this activity.  
Concepts and ideas were original to this project)**

APPENDIX H

UNIT TEST

Name \_\_\_\_\_

## Unit 2 Test

1. Substances that have higher pH value are \_\_\_\_\_. pH measures the molar concentration of \_\_\_\_\_ ions
2. How does an excess amount of Carbon Dioxide in the atmosphere affect the pH of river water?
  - A. It becomes more basic
  - B. It becomes more acidic
  - C. It has no effect on pH.
  - D. It turns the water into a salt.
3. **Short Answer:** Describe the relationship between temperature and Dissolved Oxygen (DO). Why does warming water physically change the amount of oxygen available for fish?
4. What would the resulting number be in terms of Stream Order if two rivers joined together:
  - A 1st Order joins a 1st Order: \_\_\_\_\_
  - A 2nd Order joins a 3rd Order: \_\_\_\_\_
  - A 3rd Order joins a 3rd Order: \_\_\_\_\_
  - A 6th Order joins a 4th Order: \_\_\_\_\_
5. What makes a river "dynamic" rather than static?
  - A. It stays in the same channel forever.
  - B. The pH never changes.
  - C. It only flows when humans release water from a dam, draining the reservoir.
  - D. It is constantly moving sediment and changing its shape over time.
6. **Short Answer:** How does the sinuosity of a river affect the speed at which the water flows?
7. You live in Wellington, Colorado. What is the name of the major watershed you are a part of?
8. What is a **REDD**, and which specific river feature (Riffle or Pool) is it usually found in?
9. Put the following life cycle stages of a Salmonid in the correct order from youngest to oldest:
  - Adult
  - Alevin
  - Egg

- Fry

**10.** Trout interact with different parts of the river for different needs. They generally use \_\_\_\_\_ (**Riffles or Pools**) for spawning and as young fish, but prefer \_\_\_\_\_ (**Riffles or Pools**) when they are grown.

**11. Short Answer:** Give a reason why macroinvertebrates are considered an indicator species for a river like the Poudre.

**12.** When a dam is built, it creates a "still water" environment. What is the technical name for this man-made water body?

- A. Aquifer
- B. Tributary
- C. Watershed
- D. Reservoir

**13. Short Answer:** How does the creation of a dam affect the **morphology** of the river upstream and downstream?

**14.** In a sustainable nutrient cycle (Nitrogen/Phosphorus), how do nutrients move through the system?

- A. They move from the soil/atmosphere into plants, then animals, and return to the system via decomposition.
- B. They move from the soil/atmosphere into animals, then plants, and return to the system via decomposition.
- C. They stay in the water forever and never leave.
- D. They move from the soil/atmosphere into animals, then plants, and return to the system via assimilation.

**15.** Why do dissolved oxygen levels typically **decrease** as you move further downstream in the River Continuum?

- A. The water gets warmer.
- B. There is increased biological decomposition.
- C. There are fewer plants to perform respiration.
- D. The stream order becomes lower (closer to Order 1).

**16.** In the process of **Eutrophication**, why does an increase in nutrients like Nitrogen and Phosphorus eventually lead to a dead zone?

- A. The nutrients themselves are poisonous to the trout's blood.
- B. The nutrients block the sun, preventing fish from seeing their prey.

C. The nutrients cause an algae bloom; when the algae dies, bacteria use up all the dissolved oxygen while decomposing it.

D. The nutrients cause the water to become so thick that the fish cannot swim.

**17.** Why is **irrigation diversion** particularly harmful to trout populations in the summer?

A. It makes the water too deep for the fish to spawn.

B. It increases the pH to 14.

C. It adds too much cold water back into the river, increasing the dissolved oxygen content.

D. Water is diverted most when the river is already at its lowest due to dry conditions.

**18.** If a section of the Poudre River is an **Effluent (Gaining) reach**, where is the "new" water coming from?

A. It is being pumped in by a factory.

B. It is entering the channel from the groundwater.

C. It is falling directly from the clouds as rain.

D. It is leaking out of the river into the sand.

**19.** Natural rain is already slightly acidic. What makes Anthropogenic (human-caused) acid rain different?

A. It involves reactions with Nitrogen and Sulfur oxides from mining and fossil fuel combustion, dropping the pH.

B. It is caused by carbon dioxide being released from the trees into the atmosphere, into the clouds.

C. It only happens in the effluent reaches of the river.

D. It increases the molar concentration of OH<sup>-</sup> ions.

**20.** When humans channelize a stream, which of the "4 C's" is most directly destroyed by removing the natural curves and deep pools?

A. Cold

B. Clean

C. Complex

D. Connected

**21.** Why is **Clean** water specifically more important for the **Egg and Alevin** stages than for the Adult stage?

A. Adults don't need oxygen to breathe.

B. Embryos use diffusion to get oxygen.

C. Adults prefer to live in Losing reaches where there is no water.

D. Embryos are the only stage that uses the "4 C's."

**22.** During a long Colorado drought with no rain, why is there still water flowing in the Poudre River?

A. Because of **Stormflow** from recent floods.

B. Because **Baseflow** sustains the stream.

C. Because the river is an **Influent** reach.

D. Because the trout are moving the water themselves.

**23. Short Answer:** How does an excess of nutrients like Nitrogen affect the water system's Dissolved Oxygen levels?

**24.** Match the human action to the possible effect on trout:

- **Dams** \_\_\_\_\_
- **Urbanization** \_\_\_\_\_
- **Removing Trees** \_\_\_\_\_
  - a.) Increases water temp via runoff
  - b.) Blocks migration/connectivity
  - c.) Reduces shade and increases temp

**25. Short Answer:** If the temperature of a river gets too high, what might happen that affects the life cycle of trout?

**26.** Identify two macroinvertebrates you might find in the Poudre River.

1. \_\_\_\_\_
2. \_\_\_\_\_

**27. Short Answer:** Why is it important for people to study the health of river systems?

APPENDIX I

IRB APPROVAL LETTER

## IRB APPROVAL LETTER

Hello Oksness, Garret,

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

PI: Oksness, Garret

Approval Date: 6/11/2026

Title: Positively Influencing Understanding and Attitudes of Water Use in Colorado Through Raising Trout in the Classroom

Protocol #: 2026-2718-EXPEDITED

Review Type: Expedited Review

Expiration Date: 6/11/2031

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