IMPACT OF PRE-LABORATORY VIDEOS ON CONCEPT RETENTION AND LABORATORY PERFORMANCE

by

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of the requirements for the degree

of

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in

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DEDICATION

I would like to dedicate my study to my family. To my parents and my sisters, who encouraged me and proofread my many papers. To my husband, who supported me through each step of this journey. Without your unwavering support, this achievement would not have been possible. To my daughter, I want you to see that you can achieve anything you set your mind to. I hope you will be proud of my accomplishments and inspired to pursue your own dreams.

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ABSTRACT

This action research project investigated how the use of pre-laboratory videos, in contrast with pre-laboratory questions, impact student success and performance in a laboratory activity. In a learning goal on types of chemical reactions and balancing chemical equations, one laboratory was performed. The treatment group was assigned pre-laboratory videos to watch, while the non-treatment group was given pre-laboratory questions to answer. Data was collected before, during, and after the laboratory activity. Data collection tools included (a) Pre-Laboratory Quiz, (b) Pre- and Post-Laboratory Survey, (c) Post-Laboratory Questions, (d) Student Interviews, (e) Teacher Observations, and (f) Cumulative Assessment. While the data did not support the use of pre-laboratory videos over pre-laboratory questions to improve student's retention and application of concepts, strong qualitative data indicates that the visual component of the video improved student's performance and confidence in the laboratory. Students discussed the benefit of the review of (a) safety information, (b) chemical information, (c) techniques, and (d) equipment, while describing how a combination of video and questions may be even more effective. While within the purview of this study the pre-laboratory video did not have an academic impact, the literature suggests otherwise, indicating further research may be required. The positive impact on student preparedness and confidence alone makes pre-laboratory videos a powerful tool to be used within a science classroom.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

Over the span of my teaching career, I have taught a wide range of science courses spanning grades 6 through 12 in three different school districts, where I was consistently the sole instructor for each course. I currently teach at Hudson High School, in Hudson, Iowa - a suburban town on the edge of Cedar Falls and Waterloo. Although Hudson has a population of 2,557 people (U.S. Census Bureau, 2023), it maintains a close-knit, classic Midwest small-town atmosphere where everyone knows everyone. Hudson High School, which has a population of 237 students (U.S. News & World Report, 2022), has a similar community feel. Many students have been classmates since early childhood and maintain long-standing relationships with their peers. The students in Hudson are primarily Caucasian, with 14.3% identified as ethnic minorities and 27% of students receiving free or reduced cost school lunch (U.S. News & World Report, 2022). Most students within the same year work and communicate easily with their peers. There are divides and altercations, but they are few and infrequent. Students are held accountable for poor decisions, and administration is heavily involved with the school and students, promoting accountability while supporting teacher decisions.

In addition to a welcoming and strong community, Hudson staff hold students to a high standard. Hudson is a high achieving school, ranked #23 in the state of Iowa and #3 in the Waterloo Metro Area (U.S. News & World Report, 2022) along with being designated as Commendable by the Iowa Department of Education (2024). Hudson is a desirable school

district with many students open enrolling. The student population has been consistently growing, requiring more teachers to be hired in recent years. The strong culture of community and excellence supports high expectations but also creates pressure for students to succeed in all courses, including laboratory-based science classes. Many students describe Biology and Chemistry as the hardest classes they took at Hudson High School.

In my current role, I teach three different high school science classes: Biology, Chemistry, and Anatomy. I am the sole teacher for each of these classes, meaning I often have students for two or even three consecutive years. This allows me freedom in my classroom, as I don't need to collaborate with a coworker who teaches the same subject. It also provides flexibility, as I know where gaps in knowledge may be from topics not covered in the previous year. I can form close bonds with students, especially those I have from their sophomore year through their senior year. Over the course of my students' high school career, my goals for them shift. My focus changes from ensuring students are comfortable working and thinking like a scientist, to focusing on using critical thinking skills in combination with the concepts taught, to helping students prepare for college-level science courses. As students move through increasingly complex content, I have found that many students struggle to connect lecture content to hands-on laboratory activities.

The participants of this study consisted of 11 Junior (11th grade) students (four female, seven male) drawn from two different class periods. One student is an ethnic minority, and no students have IEPs (Individualized Education Plan), 504s, or are ELL (English Language Learner) students. Students taking Chemistry generally intend to attend some form of post-secondary education (e.g. college or university, community college, trade school), and those

who are not college-bound have an alternative science class they can take to fulfill the required credit. My approach to Chemistry is through the lenses of problem-solving and critical thinking. Throughout the course, students are provided with many examples of working through problems. Each unit involves activities where students are required to use critical thinking skills to find the answer. The goal is to develop these skills as they learn the content. Despite this goal, students are unable to consistently connect laboratory activities with course content, suggesting that a change is needed.

The use of laboratory activities is consistent across all the wide variety of courses I have taught. I have relied on laboratory activities to investigate, apply information, and spark an interest in the topic at hand. I, like many other science teachers, have nearly universally used pre-laboratory and post-laboratory questions in conjunction with the activities. The goal of these questions is to (a) set students up for success, (b) review critical safety information, (c) recall relevant topics, and (d) apply the information. However, as I continued my career as a teacher, I realized that my pre-laboratory and post-laboratory questions were falling to the side in importance. Where I used to take time to go over the information or answers, they have now become more of a checkbox to complete. Although students completed the pre-laboratory work, they weren't retaining the information in a way that supported their performance or understanding during the laboratory itself.

If the goal of a pre-laboratory activity is to prepare students effectively for the laboratory itself, the activities must be purposeful and well-implemented. It is evident that what I was doing wasn't working. My students would complete the questions, receive no feedback on them, and struggle to complete laboratories or draw connections. Therefore, the

purpose of this study is to examine how pre-laboratory videos impact students' ability to perform a laboratory activity and make meaningful connections between scientific concepts and laboratory activities. Understanding and retention will be evaluated using a pre-laboratory quiz, post-laboratory questions, cumulative assessments, and surveys.

Focus Statement/Question

My focus question was, How does the use of pre-laboratory videos impact students' academic success and laboratory performance?

My sub-questions include the following:

1. Do pre-laboratory videos result in better retention and application of scientific concepts?
2. Do pre-laboratory videos better prepare students to perform a laboratory, compared to pre-laboratory questions?
3. Do pre-laboratory videos improve student confidence before performing a laboratory?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Introduction

Laboratory work is a keystone feature of science classes. They provide many functions and benefits, including increased understanding of scientific concepts, drawing connections, and increasing students' success. In addition, participation in laboratory activities can increase student confidence in science. Pre-laboratory activities are often used to prepare students for the laboratory. These activities need to be carefully curated to support students and the large cognitive load that laboratory activities bring. This chapter will focus on how cognitive and metacognitive supports, such as pre-laboratory videos, address challenges in laboratory learning.

Laboratory Work in Science Education

Purpose of Laboratory Work

Laboratory work provides students with an opportunity to engage in the practice of science, resulting in improved academic success. According to Shana and Abulibdeh (2020), there is a positive correlation between students engaging in practical science work and their academic success. In their study investigating how practical work in science impacted student success, students who participated in laboratory work were more successful not only in their comprehension of scientific concepts, but also with questions that required evaluation and application of content. Daman et al. (2019) shared that meaningful learning is created through minds-on laboratory activities. Minds-on laboratory activities can take many forms, one of which is the use of demonstrations. Demonstrations, while able to create meaningful learning,

were found to be less effective than laboratory activities by Frago and Janer (2020). Finne et al. (2022) supported this, describing how participating in laboratory activities allows students to engage in the act of science, which results in students being able to identify the relationship between scientific phenomenon, experiment, and the resulting data more easily. Tempelman et al. (2023) found similar results in academic success in students who engaged in laboratory activities. Via a written knowledge test, they found students' success rates in performing calculations increased from 65% to 85% when students engaged in laboratory activities (Tempelman et al., 2023). Laboratories are a critical part of science education. They provide opportunities for students to act as scientists and make connections, which results in an improved understanding of scientific concepts. It is obvious that there are many academic benefits of laboratory activities, but the benefits extend beyond academics.

Socioemotional Benefits of Laboratory Activities

When students engage in laboratory activities, their attitude and confidence in science is positively impacted. Laboratories, whether virtual or in-person, positively impact student attitudes toward science (Kapici et al., 2020). Ural (2016) found a similar change in attitude with inquiry-style laboratory activities. By performing a laboratory hands-on and being required to think like a scientist, students realize that science may not be as scary as it seems. In fact, by participating in the act of science, students experience a decrease in laboratory-based anxiety (Ural, 2016) and an increase in confidence (Haase et al., 2022). A study performed by Haase et al. (2022) analyzed student confidence in laboratory skills, such as pipetting, after three laboratories completed in a biology course. They discovered that after each laboratory, student confidence increased significantly, by 27-48% (Haase et al., 2022). Laboratory activities are

such a keystone part of science classes that students who lost the opportunity to participate in laboratory activities due to the COVID-19 lockdown described feeling they were missing out on something (Finne et al., 2022). Laboratory work is foundational to science education, and benefits extend beyond academics. Laboratory work may decrease student anxiety, improve student perspectives on science, and increase student confidence. To ensure that all classrooms use laboratory work effectively, the Next Generation Science Standards were created. The aim of the Next Generation Science Standards is to integrate laboratory and scientific practices into nationwide education standards.

Importance of Laboratory Work

Nationwide science standards regulate what is being taught in the science classroom. The Next Generation Science Standards (NGSS) were developed to emphasize the importance of laboratory work and provide teachers with a comprehensive set of standards to ensure students are engaged in the critical act of doing science. These standards were based on a framework provided by the National Research Council (NRC). This framework aimed to create a vision where students "actively engage in scientific and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields" (National Academies of Sciences, Engineering, and Medicine, 2012, p. 10). To this end, they provided a three-dimensional approach to learning that incorporates (a) science and engineering practices, (b) cross-cutting concepts, and (c) disciplinary core ideas. The science and engineering practices dimension is designed to engage students in the act of science, because only by engaging in science can students truly learn it (National Academies of Sciences, Engineering, and Medicine, 2012). The goal of implementing the NGSS nationwide was to provide teachers

with guidelines on teaching science within its best practices. This has proven to be beneficial to students.

When given opportunities to engage in scientific practices, as outlined in the NGSS, students are more successful. One major method of engaging in scientific practices is through laboratory work. Tapia et al. (2020) describe the need for laboratory work to allow students not only to apply scientific concepts but also to explore. New approaches to laboratory work, like those encouraged by NGSS, should be provided. Laboratory activities should integrate the Science and Engineering Practices (SEPs) outlined in the NGSS (Rodriguez & Towns, 2018). Coursework that is aligned with NGSS results in increased student success. When using an NGSS-based assessment, Kelp (2024) found that students who were taught within NGSS guidelines had an increase in scores by 11%. Engaging in inquiry activities, which is also encouraged in the NGSS, has proven to improve student success (Abu, 2023).

With this shift in focus, McComas and Nori (2016) describe how the Nature of Science was overlooked. This makes sense, since the emphasis of the NGSS is on the act of doing science through laboratory activities rather than rote learning about how science works. However, the Nature of Science can often be discussed through the use of laboratory activities, which is encouraged by the NGSS. Laboratory activities, with their positive academic and socioemotional impact, are therefore critical to student success. However, students often struggle with laboratory work. Why is that the case if our standards are designed to emphasize the importance of laboratory activities?

Cognitive Foundations and Their Impact on Laboratory Activities

Cognitive Load

When performing laboratory activities, students often encounter a high cognitive load, which can prevent them from being able to successfully form connections. Cognitive load theory considers the relationship between (a) sensory memory, (b) working memory, and (c) long-term memory. Working memory is limited compared to sensory memory and long-term memory, and it can store around six pieces of information at a time. This information can then be transferred to long-term memory (Cognitive Load Theory, 2022; Iskander, 2018). Cognitive load describes how much a person can actively hold in their working memory. It is impacted by how difficult the information is, how it is presented, and the effort needed to commit it to long-term memory (Cognitive Load Theory, 2022). When too much information is provided, and the working memory exceeds its limits, a student can experience cognitive overload (Iskander, 2018). Laboratory activities can be challenging for students, due to the large quantity of unfamiliar information, skills, and equipment used. This results in a high cognitive load (Rayment et al., 2022), which may demotivate students (Phan et al., 2017). Laboratory work, by its nature, produces a high cognitive load by (a) use of unique equipment with specialized names, (b) using technical skills not used in everyday life, and (c) employing a different set of behavioral expectations for students. This not only takes up valuable space in students' working memory but can impact student motivation. To allow space in students' working memory, cognitive load needs to be decreased, which can be done by encouraging metacognitive skills within students, before, during, and after a laboratory activity.

Metacognitive Skills in a Laboratory Setting

Providing opportunities for students to use metacognitive skills before, during, or after laboratory work can decrease cognitive load, which in turn will provide students the opportunity to move more important concepts into long-term memory. Metacognition describes the processes that are used to monitor one's own thoughts and use them to make decisions (Rhodes, 2019). It is often referred to as thinking about your own thinking. Metacognition does not add to cognitive load, even when metacognitive strategies are applied in collaborative group settings (Zheng et al., 2019). In fact, metacognitive skills are required to guide what is being kept in working memory. In other words, metacognition directs attention (Iskander, 2018). Iskander (2018) posits that the development of metacognitive skills can allow for better management of cognitive load. This is supported by López-Vargas et al. (2017), who found that interaction with metacognitive scaffolding positively impacted student achievement. The scaffolding aided students in planning their activities and monitoring their learning process. This helped foster systemic and structured behavior in the students (López-Vargas et al., 2017). In laboratory activities, metacognition occurs when students identify the purpose of laboratory activities, the skills and knowledge gained, and the challenges they face (Sarıbaş & Bayram, 2016). Therefore, using metacognitive skills can positively impact conceptual understanding (Sarıbaş & Bayram, 2016) and provides students with tools to better manage their cognitive load. Within a laboratory setting, students experience a large cognitive load due to the quantity of information they are working with. Creating opportunities for students to use metacognitive skills allows them to make space in their working memory, so they can focus on broad concepts rather than small details which results in an improved understanding of concepts.

Pre-Laboratory Activities

Function of Pre-Laboratory Activities

Pre-laboratory activities can provide students with the opportunity to think metacognitively. By providing well-structured pre-laboratory activities, teachers can create environments in which students can focus on the application and understanding of scientific concepts. Students who engaged in pre-laboratory and post-laboratory discussions exhibited a positive impact on conceptual understanding (Sarıbaş & Bayram, 2016). The benefits of pre-laboratory activities are not limited to providing metacognitive opportunities and improving understanding. Pre-laboratory discussions increase (a) engagement, (b) understanding of core concepts, (c) ability to understand what happens during the laboratory, and (d) confidence in their ability to complete the lab (Agustian & Seery, 2017). The increased confidence and motivation can lead students to engage in more self-directed learning, resulting in deeper understanding (Costello, 2020). The form of the pre-laboratory activity needs to be considered, as not all pre-laboratory activities will reap the same benefits (Costello, 2020). When students engage with metacognitive pre-laboratory activities, their cognitive load will be reduced. When choosing a metacognitive pre-laboratory activity, teachers should consider what tools and approach will best suit their needs and classroom.

Use of Technology in Pre-Laboratory Activities

Pre-laboratory activities vary considerably, including (a) lectures, (b) discussions, (c) questions, (d), quizzes, (e) videos, and (f) more. Activities that require students to actively engage, rather than merely listen, are more effective in preparing students for a laboratory activity. One method used to engage students is using technology. In a study comparing pre-

laboratory lectures and videos, students who watched video presentations consistently scored higher on laboratory quizzes, after an assimilation period of the first two to three quizzes (Aronne et al., 2019). Sarmouk et al. (2019) found a similar result, in their study comparing the effects of a scripted lecture to use of an online resource which was composed of (a) quizzes, (b) videos, and (c) safety information. Students who engaged with the online resource were better prepared, more confident, and performed better (Sarmouk et al., 2019). Rodgers et al. (2019) also found that pre-laboratory videos improved student preparedness and assessment scores. Increasing student attentiveness and ensuring students understand the importance of the information is key to creating a successful pre-laboratory activity (Aronne et al., 2019). Engaging and instructional pre-laboratory activities that use technology and require students to actively participate will improve laboratory and academic performance. These activities assist students in preparing for the laboratory and in understanding critical safety information. In particular, pre-laboratory videos have been shown to successfully prepare students for laboratory activities. By providing purposefully designed pre-laboratory activities and scaffolding students to use metacognitive skills, students' cognitive loads will decrease while their confidence and academic achievement will increase.

Conclusion

The NGSS are written in a way to encourage the integration of laboratory activities in science classroom. When participating in laboratory activities, students experience a high cognitive load. This makes completion of the laboratory activity difficult and takes up valuable space in their working memory. Metacognitive skills can be employed to open more space and allow for better retention of concepts. One method of providing opportunities for interaction with

metacognitive scaffolding is by using pre-laboratory activities. Pre-laboratory activities that use technology are more likely to result in an increase in student success and confidence.

CHAPTER THREE

METHODOLOGY

Demographics

The focus question of this action research study is, How does the use of pre-laboratory videos impact students' academic success and laboratory performance? I compared the effectiveness of pre-laboratory videos against pre-laboratory questions. Effectiveness was examined in three different facets: (a) student ability to retain and apply content information, (b) student preparedness (how well students understand the material before starting the laboratory), and (c) student confidence (how confident/sure they felt while performing the lab). My sub-questions included the following:

1. Do pre-laboratory videos result in better retention and application of scientific concepts?
2. Do pre-laboratory videos better prepare students to perform a laboratory, compared to pre-laboratory questions?
3. Do pre-laboratory videos improve student confidence before performing a laboratory?

This study took place in an 11th grade (junior) chemistry class. The participants were comprised of seven males and four females (Figure 1). Most juniors take chemistry, so there is a wide range of academic abilities, although no participants had accommodations (e.g. 504, IEP, ELL). One participant was an ethnic minority (Figure 1). I have the benefit of being one of only two science teachers in the high school, which means I get students for sequential years. All

participants had me as a teacher last year in Biology; and one participant took both Chemistry and Anatomy and Physiology, resulting in attending my class two times a day. This extra year of relationship building provides a base of trust, so junior students feel comfortable in my classroom during one of their most challenging academic years.

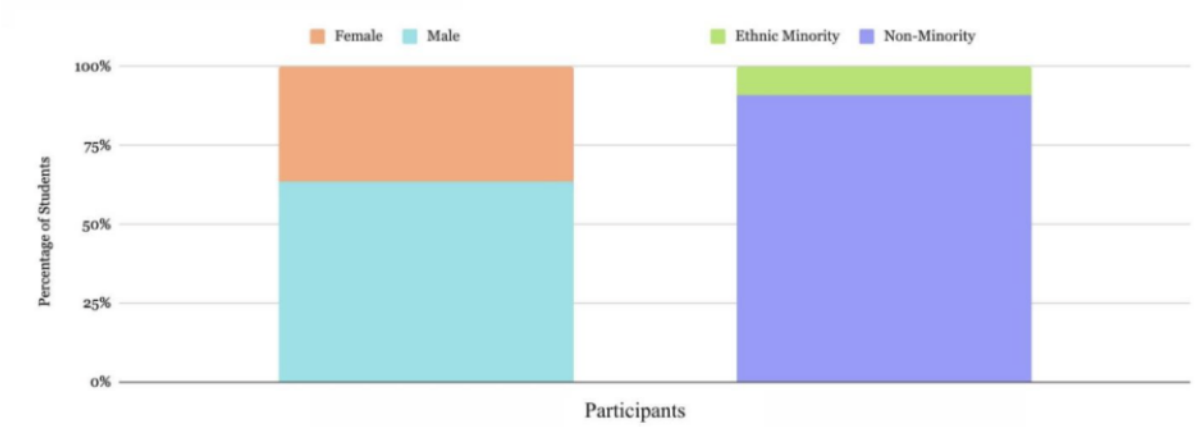


Figure 1. Participant demographics, by sex and ethnicity, (N=11).

To determine the effectiveness of pre-laboratory videos, students were divided into treatment and non-treatment groups. The 11 participants were spread across two sections. Each section's participants were divided roughly in half to form the treatment and non-treatment groups. When assigning students to treatment and non-treatment groups, it is important to assign groups at random, where each student has an equal chance of being assigned to either group (Chen et al., n.d.). The treatment and non-treatment groups were assigned randomly using stratification by section to minimize the impact classroom culture may have on the results. Randomization was used because "there is unlikely to be any substantial differences between the experimental and control groups at the outset of the experiment" (Chen et al., n.d., para. 3). This allows for the data collected to be as unbiased and evenly spread as possible. A mixed-methods approach was used to provide a holistic view of the data. Quantitative data, such

as test and assignment scores were supported by qualitative data, such as open-ended survey questions and interview responses.

Treatment

To answer the research question and sub-questions, a mixed-methods research design was implemented. Mixed-methods design aligns well with action research because using both forms of data (qualitative and quantitative) can provide a better understanding than simply using one form of data (Creswell, 2005, as cited in Mertler, 2019). Guest et al. (2013) describes qualitative data as data that "answer[s] the whys and hows of human behavior, opinion, and experience" (p. 16). Since qualitative data provides a unique perspective into human experiences, it helped me peer into my students' thoughts and provided information that cannot be described quantitatively. Within my study, I examined not only changes in graded work but perceived changes in the students' behavior. I looked for things such as how they approached laboratory work and actions they did during the laboratory. Going beyond my own perceptions, I wanted to know how my students perceived their ability to effectively complete the laboratory activities.

Quantitative data provides "evidence for decision-making and accountability" or for "investigating a research problem and/or generating the information used in policy-making and knowledge" (Gaciu, 2021, p. 4-5). Since quantitative data is widely known and important in decision making, it is a valuable tool. Quantitative data provided the basis for my claims, while qualitative data further supported and added color to those claims. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A). Along with student

assent to participate in the study, parental consent was obtained to meet Family Educational Rights and Privacy Act (FERPA) guidelines, since grades were gathered as data (Appendix B).

The purpose of this action research study is to determine if pre-laboratory videos are more effective at communicating laboratory information than pre-laboratory questions. Students' academic success, laboratory performance, and confidence were used as measures to determine the effectiveness of the pre-laboratory activity. After normal instruction on types of chemical reactions and balancing chemical equations, students completed a laboratory activity to apply what they had learned. Half of the students (n=5) completed the non-treatment pre-laboratory activity, which consisted of a series of pre-laboratory questions to be answered in their lab notebook. The pre-laboratory questions quickly reviewed the relevant scientific content covered in the laboratory. These pre-laboratory questions were chosen because they are the questions I have used for several years for this laboratory activity. Completing pre-laboratory questions in their lab notebook is familiar to students, as it is how they have completed pre-laboratory activities in the past. The other half of the students (n=6) completed the treatment pre-laboratory activity, which consisted of a video to watch. The video covered the same information as the pre-laboratory questions, in addition to a quick review of key safety information and skills/equipment that students will need for the laboratory activity. Several tools were used to gather data before, during, and after the laboratory activity. The original timeline for implementation of this study included all activities and assignments to happen sequentially across the course of about a week (Figure 2).

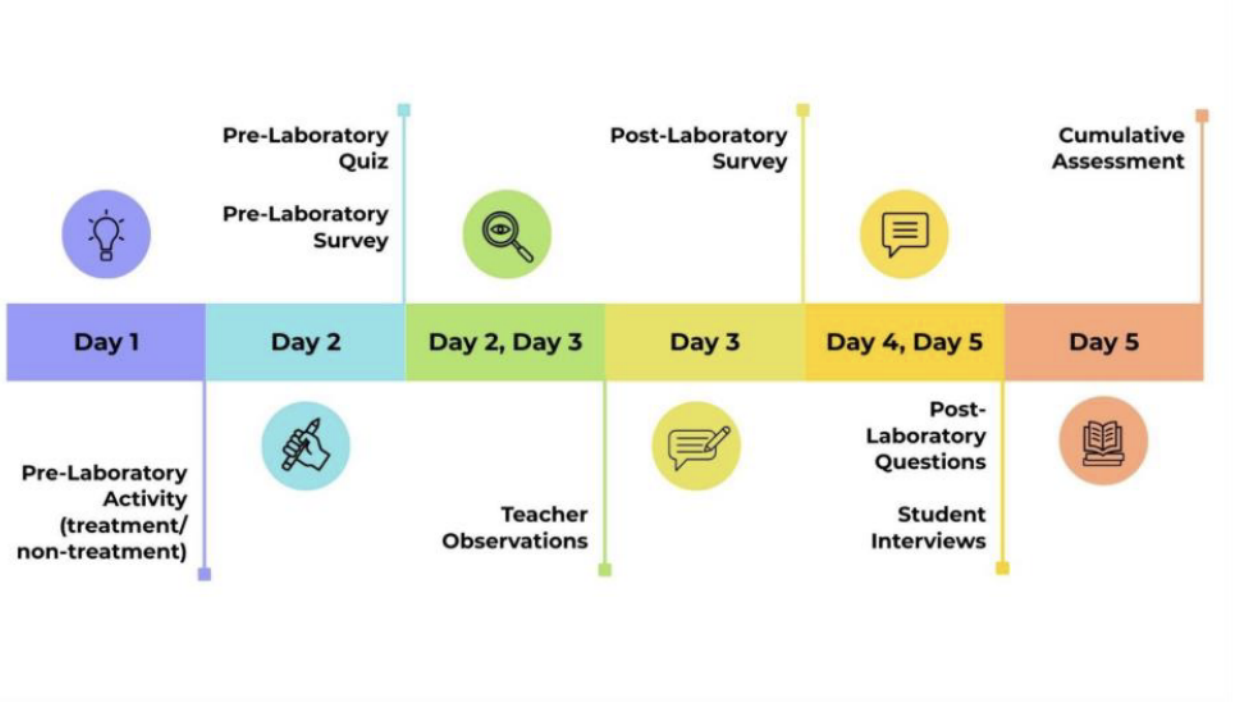


Figure 2. Original timeline for implementation of data collection instruments in the action research study.

Due to factors outside of my control, such as weather-related closures, there were unexpected days between the activities and assignments. These gaps resulted in the study taking nearly two weeks to complete all activities and assignments (Figure 3).

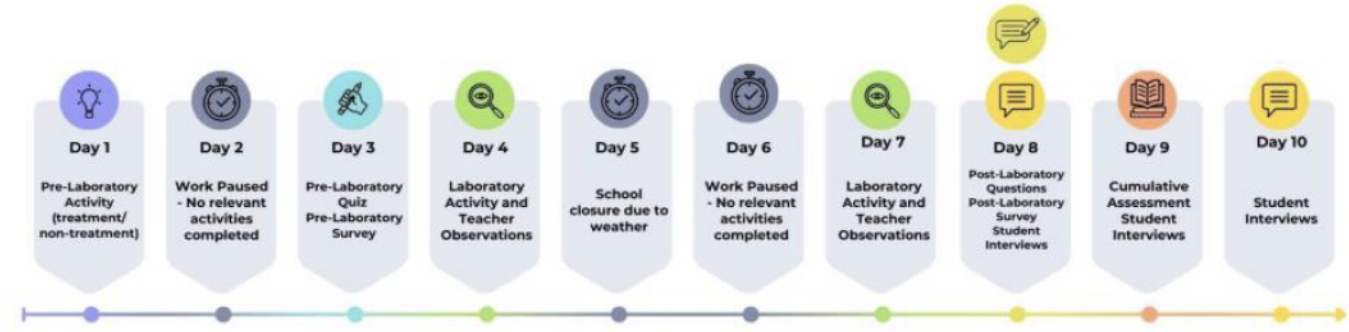


Figure 3. Actual timeline for implementation of data collection instruments, including unforeseen closures and pause days.

Data Collection and Analysis Strategies

Since the research question and sub-questions aimed to answer a wide variety of topics, a mixed-methods approach was employed. All students, treatment and non-treatment groups alike, participated in multiple means of data collection. Qualitative data was gathered using (a) Pre- and Post-Laboratory Surveys, (b) Student Interviews, and (c) Teacher Observations. Quantitative data was gathered using (a) Pre- and Post-Laboratory Surveys, (b) Pre-Laboratory Quiz, (c) Post-Laboratory Questions, (d) Teacher Observations, and (e) Cumulative Assessment. This provided a continuum of numerical data from before the laboratory activity to the Cumulative Assessment at the end of the unit. The Data Triangulation Matrix below (Table 1) represents the alignment between the research question and the data instrument used.

Table 1. Data Triangulation Matrix.

	Focus Questions		
Data Collection Instruments	Do pre-laboratory videos result in better retention and application of scientific concepts?	Do pre-laboratory videos better prepare students to perform a laboratory, compared to pre-laboratory questions?	Do pre-laboratory videos improve student confidence before performing a laboratory?
Pre-Laboratory Quiz		X	
Pre- and Post-Laboratory Survey		X	X
Post-Laboratory Questions	X		
Student Interviews	X	X	X
Teacher Observations		X	X
Cumulative Assessment Score	X		

Data Collection Methods

Pre-Laboratory Quiz. A Pre-Laboratory Quiz (Appendix C) was used to see what students retained from the completion of their assigned pre-laboratory activity (either video [treatment] or questions [non-treatment]). Quizzes, while classically viewed as summative assessments, can be used formatively by helping students to self-reflect (Black & Wiliam, 2018). This supports learning, rather than assessing learning. Therefore, the function of the pre-laboratory quiz is twofold: (1) to provide insight to student readiness in the form of quantitative data; and (2) give feedback to students on key details of the laboratory so they are better prepared. This instrument was implemented after the pre-laboratory activity, and before the laboratory itself.

Pre- and Post-Laboratory Surveys. Pre- and Post-Laboratory Surveys (Appendix D) were used to gauge student confidence and perceptions before and after the laboratory activity. Surveys provide valuable information about a participant's individual experiences. Gobo and Mauceri (2014) describe how surveys investigate "the existence and intensity of relations among variables in specific socially diffuse forms of action and attitude" (p. 20). Mertler (2019) explains how surveys provide a snapshot of student attitudes at a given point in time. The Pre-Laboratory Survey gauged student confidence in their ability to do the laboratory and the Post-Laboratory Survey allowed students to reflect on how the laboratory activity went. Using a Likert-style format for questions, the surveys have similar structure and questions, to allow for easy comparison of before to after. A six-point scale was used for questions, with no neutral option. When provided with a neutral option, students may not think as much about their actual opinions (Mertler, 2019). Artino et al. (2014) discusses how questionnaires, such as my survey, allow for the collection of information that is not directly observable. I was able to gather

information on the completion of each student's pre-laboratory activity, which may have been finished as homework and thus was unobservable. The Pre-Laboratory Survey was given after the Pre-Laboratory Quiz and before the laboratory. The Post-Laboratory Survey was given once students completed the laboratory, as they started to work on their Post-Laboratory Questions.

Teacher Observations. In addition to the details provided by interviews and surveys, Teacher Observations were taken during the laboratory activity. Observations are effective at gathering data "to provide specific incidents, behaviors, and so on that can be used as reference points for subsequent interviews" (Merriam, 2009, p. 139). Participant observations were performed, since my role as a teacher requires my active participation. The benefit to this mode of observation was the ability to see how behaviors and actions by participants correspond to their words (Mertler, 2019). These observations were focused on student behaviors that either exhibited or didn't exhibit student confidence and preparedness to do the laboratory. This is beneficial, since pre- and post-laboratory surveys and student interviews provide perspective to the students' experience but are colored by the fact that the students are self-reporting. Teacher observations provided a more unbiased perspective on what behaviors occurred during the laboratory activity. The use of structured tools in observations can help identify specific behaviors and skills. A list was used to help me identify what I was seeing and quickly record accurate observations (Clapp, 2025). Teacher Observations were made via tally marks on a grid (Appendix E). This grid allowed for easy collection of data and included examples of behaviors to be looking for. The opportunity to record open-ended observations was

on the grid as well. All participants were observed during the laboratory. Treatment and non-treatment observations were marked on separate grids.

Post-Laboratory Questions. While the Pre-Laboratory Quiz provided a view into initial preparedness, the Post-Laboratory Questions (Appendix F) helped students apply lecture content to the laboratory they performed. Students, continuing to work with their assigned lab partner, answered the questions in their lab notebooks. These questions acted as an assessment. Assessments can be considered summative and formative if it helps teachers make decisions about future planning and implementation, or if it helps the student reflect upon their own strengths or weaknesses in the topic (Black & William, 2018). The Post-Laboratory Questions filled both roles – they aided me in determining future use of the laboratory and helped students determine what they may need to focus their studying on before the Cumulative Assessment. This instrument was implemented after the laboratory activity was completed.

Student Interviews. In addition to the Pre- and Post-Laboratory Surveys, Student Interviews were used to gain more in-depth information about the students' perceptions and experiences while performing the laboratory activity. Interviews provide data on lived experiences of the interviewee, and in the process of providing a response the interviewee transforms the facts and details (Brinkmann, 2018; Holstein & Gubrium, 1995). The interview provided information about my students' experiences, which they interpreted themselves as they answered the questions. While some of the interview questions are similar to the survey questions, they are more in-depth and thus provide a different set of data. Follow up questions and additional questions not included in the survey are found in the interview as well. The script

for the student interviews, including potential follow-up questions, can be found in Appendix G. This instrument was implemented over the following several days after the laboratory activity (depending on the individual student's availability).

Cumulative Assessment. While all other instruments focus on student experiences and understanding before and during the laboratory, a Cumulative Assessment was given to determine overall content retention. Assessments are designed to support learning and are used by teachers to determine student progress and success (Harlen & Gardner, 2010). Data from the Cumulative Assessment provided a picture of how much the students learned within the unit and how successful the teaching activities were. Summative assessments, such as the Cumulative Assessment, can be used to judge the worth, merit, or success of a program based on its effectiveness in meeting goals (Jason, 2008) and give feedback to teachers about the effectiveness of their teaching (Black & Wiliam, 2018). The Cumulative Assessment provided data on the effectiveness of my treatment (pre-laboratory videos) and the success of the teaching tools. It effectively provided quantitative data on the students' ability to not only retain content information but also apply it in application questions on the assessment. This assessment was given after the laboratory activity and assessed the concepts covered in the laboratory activity and Post-Laboratory Questions. The Cumulative Assessment took the form of a test that students completed individually with no additional notes or materials beyond a periodic table, common polyatomic ion chart, and optional access to a calculator (Appendix H). There were three different versions, all that assess the same information at a similar level of difficulty. Most questions had a simple right/wrong answer, but some were open-ended. To ensure equality of

grading across all tests, a list of accepted right answers was determined before grading open-ended questions.

Analysis Strategies

Qualitative Measures. Inductive analysis aims to reduce the amount of data a researcher is working with and identify patterns and themes (Mertler, 2019), while thematic analysis focuses on identifying themes within qualitative data and forming conclusions based on those themes (Guest et al., 2012). Within this study, I used inductive thematic analysis to (a) reduce data, (b) form conclusions based on themes or patterns in the data, and (c) provide color and description to further support quantitative data. For each qualitative tool, I started by reading the data collected, then developing a coding scheme. A coding scheme, as defined by Mertler (2019), is a "system of categorization" (p. 174). For example, when creating my coding scheme, I considered themes such as confidence, laboratory equipment, content connection, etc. The themes varied by data collection tool and student responses. Once my coding scheme was created, I read through the data again and assigned my coding scheme to the student responses. From there, I identified patterns or opposing views. I searched for comparisons as well, including differences between treatment and non-treatment groups. In addition to these qualitative measures, calculating measures of central tendency were also used to determine the common or average response on survey questions.

Quantitative Measures. Quantitative data must be manipulated to be used to support conclusions, which require the use of statistics (Scherbaum & Shockley, 2015). One frequent focus in data analysis is how common or typical a data point is. This commonality can be described using measures of central tendency and spread. Weisberg (1992) describes how central

tendency can be measured in multiple ways, such as using mode, median, and mean. These measures provide a good picture of what the average student understands. To compare the treatment and non-treatment groups, a two-sample t-test was used to identify if the means are statistically different. A two-sample t-test helps to determine "whether the unknown population means of two groups are equal or not" (JMP, n.d., "What is the two-sample t-test?" section). Within this study, two groups (treatment and non-treatment) provided interval data in the form of grades on the Pre-Laboratory Quiz, Post-Laboratory Questions, and Cumulative Assessment. The two-sample t-test was performed using digital software. The goal alpha value was 0.05 (5%). If the p-value was less than the alpha value, then it was considered statistically significant. The use of measures of central tendency (mode, median, and mean) and the two-sample t-test identified the common score, and if there was a noticeable difference based on use of the treatment.

Numbers on their own often don't provide the whole picture, so visual representations of quantitative data are beneficial. Multiple visualizations were used, including stem-and-leaf displays and box-and-whisker plots. Hartwig and Dearling (1979) describe the benefits to a stem-and-leaf display, "The stem-and-leaf retains all of the observed values in rank order, but it also conveys well the shape of the distribution" (p. 18). The spread of the data provides a view on how typical the typical value is (Weisberg, 1992). A box-and-whisker plot provides a good picture of the entire spread of values and where most values fall. In a box-and-whisker plot, the upper quartile, lower quartile, median, and outliers are identified (Jones, 2020). Jones (2020) further describes the benefits to box-and-whisker plots, describing how they not only provide views of multiple data sets, but also show central tendency and spread. The use of stem-and-leaf

displays and box-and-whisker plots are both relevant, because the quantitative data that was gathered (assessment scores) results in a range of values. It is negligent to completely discount outliers, whether they are high or low. Using mean, median, and mode to represent central tendency helped mitigate this mathematically, and stem-and-leaf displays and box-and-whisker plots aided in the visualization of not only average scores but also the spread of scores. The use of this data helped me determine if, on average, the treatment resulted in students being able to draw connections between lecture and laboratory more effectively.

CHAPTER FOUR

DATA ANALYSIS: CLAIMS AND EVIDENCE

Results

The purpose of this study was to examine how pre-laboratory videos impact students' ability to perform a laboratory activity and make meaningful connections between scientific concepts and laboratory activities. To determine the impact, data was gathered through (a) Pre-Laboratory Quiz, (b) Pre- and Post-Laboratory Surveys, (c) Post-Laboratory Questions, (d) Student Interviews, (e) Teacher Observations, and (f) Cumulative Assessment. These data collection tools provided quantitative and qualitative data for each sub-question, with a minimum of three data collection tools per question. The data was analyzed by research sub-question topic: (a) retention and application of scientific concepts, (b) laboratory performance, and (c) student confidence. While there was no data to indicate that pre-laboratory videos impacted students' academic performance, the data does suggest that students' laboratory performance and confidence were positively impacted.

Retention and Application of Scientific Concepts

Students' ability to retain and apply scientific concepts was not influenced by the designated pre-laboratory activity (pre-laboratory video vs pre-laboratory questions). Retention and application of scientific concepts was analyzed using Post-Laboratory Questions, Student Interviews, and the Cumulative Assessment.

The Post-Laboratory Questions were scored out of a possible 9.75 points. Students assigned the pre-laboratory video (n=6) scored a mean of 9.125 and a median of 9.75;

while students assigned the pre-laboratory questions (n=5) scored a mean of 9 and a median of 9.25. The two-sample t-test resulted in an alpha score of 0.855, which shows no statistical significance between the samples. Students found their pre-laboratory activities beneficial, with one student (assigned the pre-laboratory questions) stating in the Student Interviews that they referenced the content information from the questions while doing the laboratory. With the exception of one outlier, students assigned the pre-laboratory video in general had less variation in score (Figure 4). This may be because, as one student stated, the video, "made me think a little more, so I got more out of it and it keeps me more engaged."

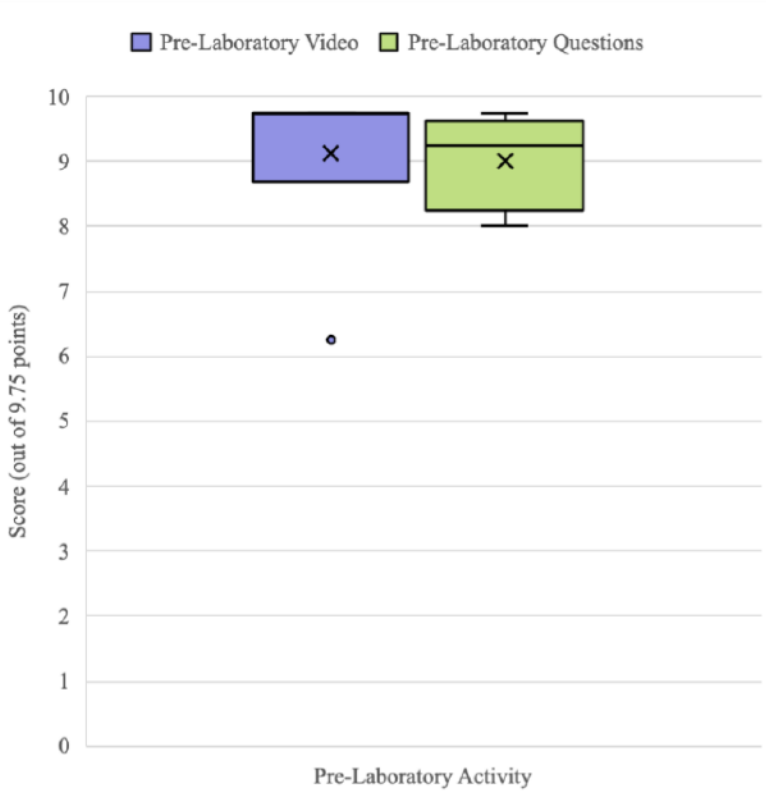


Figure 4. Student scores on Post-Laboratory Questions based on assigned pre-laboratory activity, (N=11).

Cumulative Assessment scores reflected the same trend. While there was variation in scores, the measures of central tendency were remarkably similar. Out of a possible 23 points, students assigned the pre-laboratory videos (n=6) scored a mean of 20 and a median of 21. Students assigned the pre-laboratory questions (n=5) scored a mean of 19.4 and a median of 20. The two-sample t-test alpha score was 0.453, indicating no statistical significance between scores. The distribution of scores leans towards the benefit of pre-laboratory videos, as seen in Figure 5 below.

Pre-Laboratory Videos

Stem	Leaf			
1	8	9		
2	1	1	2	3

Pre-Laboratory Questions

Stem	Leaf		
1	4	9	
2	0	0	3

Figure 5. Stem-and-leaf displays of Cumulative Assessment scores, (N=11). The stem represents the first digit of the score, while the leaf represents the second digit of the score.

Overall, the retention and application of scientific information was unaffected by the assigned pre-laboratory activity. There were some slight variations in graded classwork, with slightly higher scores in the treatment group (pre-laboratory video). However, these variations were not statistically significant. In addition, there were no patterns in the qualitative data that indicated that the pre-laboratory videos were more effective at aiding students in understanding and retaining the information.

Laboratory Performance

Pre-laboratory videos had a positive impact on student performance during the laboratory activity. Laboratory performance was evaluated using Pre-Laboratory Quiz, Pre- and Post-Laboratory Surveys, Student Interviews, and Teacher Observations. The Pre-Laboratory Quiz was designed to assess students' understanding of laboratory techniques before taking part in the laboratory. Out of a possible 13 points, students who were assigned pre-laboratory videos scored a mean of 7.6, and a median of 7. Students who were assigned pre-laboratory questions scored a mean of 5 and a median of 5. While these numbers appear to be similar, the two-sample t-test resulted in an alpha score of 0.010, indicating a statistical significance. Figure 6 represents this data well, showing how the highest quartile of the pre-laboratory questions is less than the lowest quartile of the pre-laboratory videos.

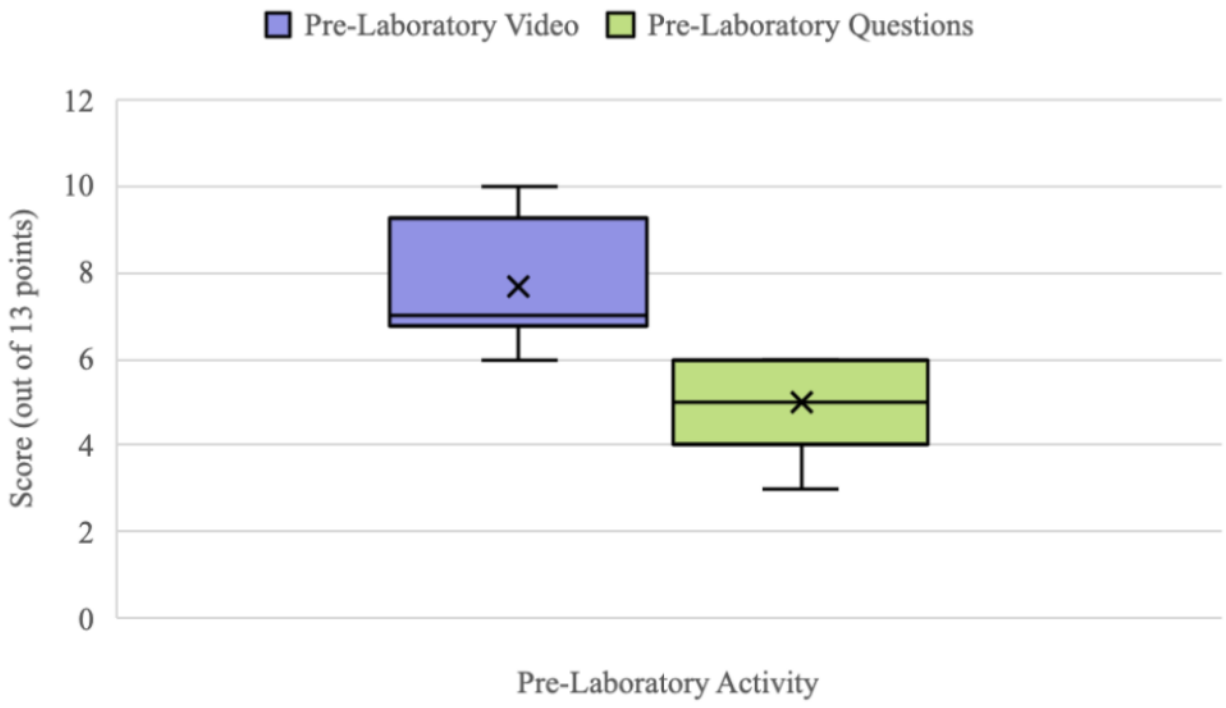


Figure 6. Student scores on Pre-Laboratory Quiz, based on assigned pre-laboratory activity, (*N*=11).

The pre-laboratory video was successful at preparing students to complete the laboratory. By being more prepared, students were able to perform the laboratory more successfully. This is evident in the responses to Likert-style questions in the Pre- and Post-Laboratory Survey. Each question was assigned a number to allow for mathematical analysis (Table 2).

Table 2. Likert-style question responses and their assigned numerical values.

Likert Response	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
Assigned Numerical Value	1	2	3	4	5	6

All students felt prepared for the laboratory, with students who did the pre-laboratory video feeling more prepared (Appendix I). On the Pre-Laboratory Survey, the average response to the statement "I can perform the lab effectively and efficiently" was 'Agree.' All students also 'Agreed' with several statements regarding safety and laboratory equipment. One student who was assigned the pre-laboratory video discussed in the Student Interview how the most useful part of the video was the "safety equipment, like gloves, and knowing how to safely complete the lab." Students assigned the pre-laboratory questions who participated in interviews did not discuss how their assigned activity prepared them to do the laboratory. Rather, they focused on the scientific content, "[the pre-laboratory questions] were good to have a refresher of the equations and helped me think about what physical traits could help identify the type of reaction." Those who watched the pre-laboratory video on average 'Agreed' that they knew which chemicals were required, while those who completed the pre-laboratory questions 'Slightly Disagreed.' This mean may be influenced by an outlier, however, as the median and mode were 'Slightly Agree.' Students who completed the pre-laboratory questions were not

confident in their ability to properly dispose of chemical waste, by 'Slightly Disagreeing' with that statement (Figure 7). All students, however, agreed that their assigned pre-laboratory activity made them feel prepared to complete the laboratory (Figure 8). This is likely one reason that students performed well in the laboratory. While all students felt prepared, the students who were assigned the pre-laboratory video felt more prepared before the laboratory in understanding how to handle and dispose of the chemicals.

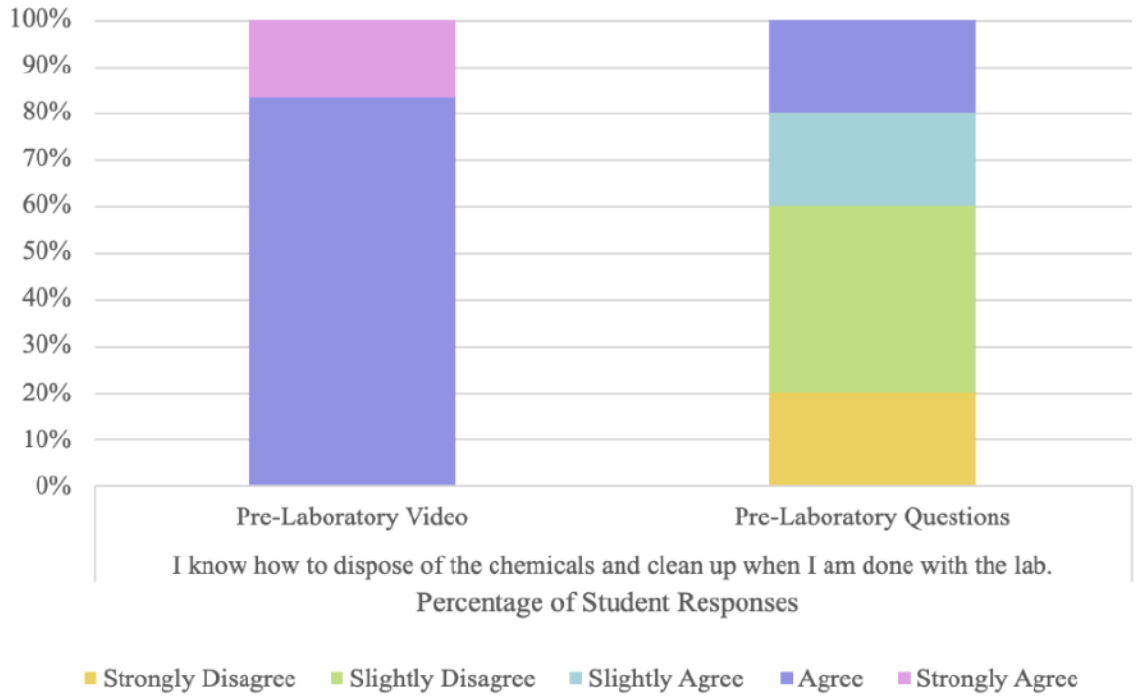


Figure 7. Student responses on the Pre-Laboratory Survey to the prompt "I know how to dispose of the chemicals and clean up when I am done with the lab," (*N*=11).

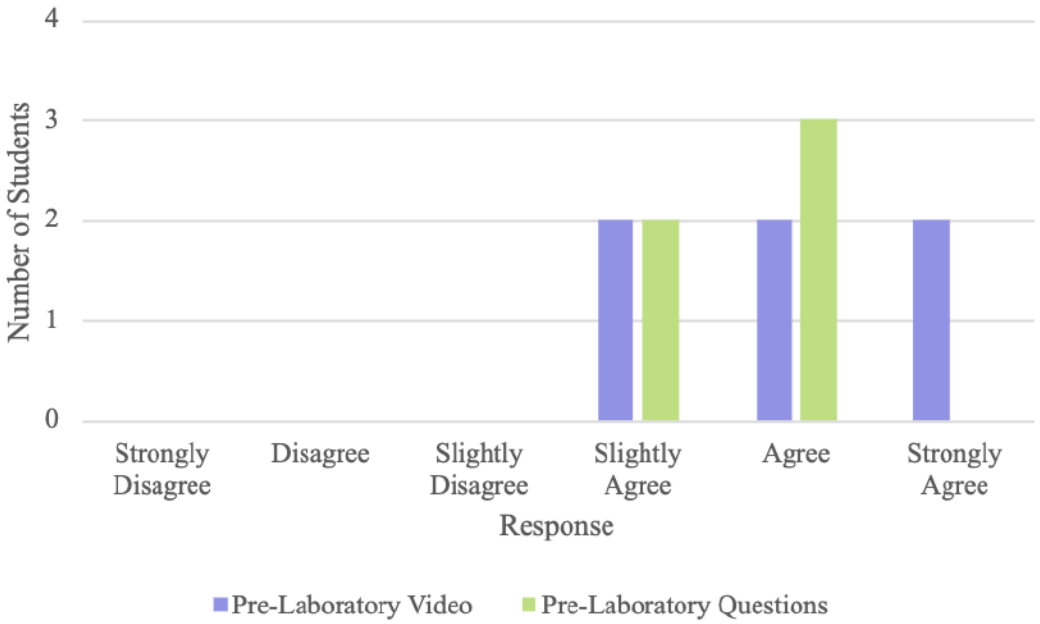


Figure 8. Student responses on the Pre-Laboratory Survey to the prompt "I believe that my pre-lab activity effectively prepared me to perform the lab," (*N*=11).

When considering their preparedness for the laboratory, student perceptions did not change much from the Pre-Laboratory Survey to the Post-Laboratory Survey. In the Post-Laboratory Survey, no prompts were given 'Strongly Disagree,' 'Disagree,' or 'Slightly Disagree' responses. The questions asked were the same as the Pre-Laboratory Survey, with changes in tense (e.g. "I can perform the lab safely" in the Pre-Laboratory Survey to "I performed the lab safely" in the Post-Laboratory Survey). The prompt "I knew how to dispose of the chemicals and clean up when I am done with the lab" received a range of responses in the Pre-Laboratory Survey and closer responses in the Post-Laboratory Survey. The students given the pre-laboratory video had a mean response of 'Strongly Agree,' while the students assigned the pre-laboratory questions had a mean response of 'Agree.' In the Student Interviews, one student who was assigned the pre-laboratory questions did discuss this

gap, stating that they would like a pre-laboratory activity to include, “something that would involve the chemicals we’re using and their properties.” All students, regardless of their assigned pre-laboratory activity, felt upon reflection that their pre-laboratory activity prepared them to perform the laboratory (Figure 9).

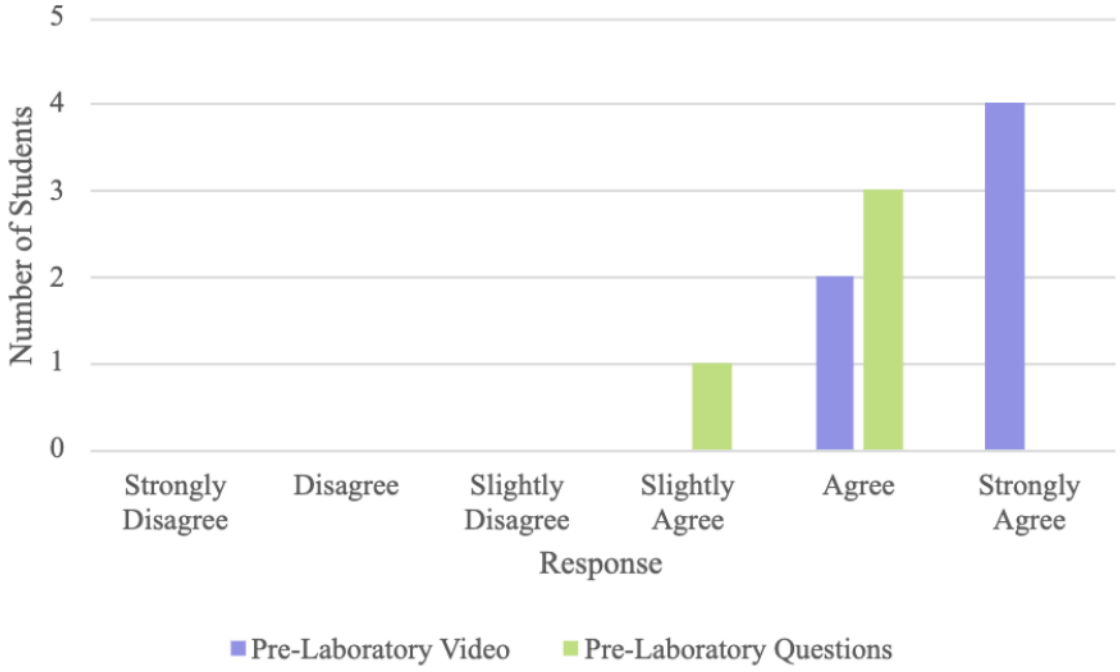


Figure 9. Student responses on the Post-Laboratory Survey to the prompt “My pre-lab activity effectively prepared me to perform the lab,” (*N*=10).

Open-ended responses on the Pre-Laboratory Survey and Post-Laboratory Survey indicate that the pre-laboratory video better prepared students to perform the laboratory. Students mentioned reasons relating to safety, laboratory techniques, and the visual component of the video (Figures 12). In the Pre-Laboratory Survey (*N*=11), two students (18%) discussed in the open-ended response a feeling of being able to safely perform the laboratory, while in the Post-Laboratory Survey (*N*=10), one student (10%) reported the same. All these responses were provided by students assigned the pre-laboratory video.

Similarly, students who were assigned the pre-laboratory video discussed how watching a demonstration on how to light the Bunsen burner in the video made it easier for them to perform that action in the laboratory. Upon reflecting in the Post-Laboratory Survey (N=10), four students (40%) identified the Bunsen burner as a skill they learned during their pre-laboratory activity. One student said, "I learned how to use a Bunsen burner which I didn't know how to use one, but the video demonstrated how to do it." Only students assigned the pre-laboratory video discussed the Bunsen burner in the Post-Laboratory Survey.

Many students discussed how the visual component of the pre-laboratory video made a big impact on their understanding. In fact, one student in their interview repeatedly praised the visual component of the activity, stating that, "the visual component really helped seeing it performed, it was the biggest thing I liked about the video." Within the Pre-Laboratory Survey (N=11), five students total (45%) identified how the visual component of showing what needed to be done in the laboratory helped them feel prepared (Figure 10). One student explained, "The pre-lab activity helped me prepare because it helped to give me a visual representation of what I would need to do. This gave me a better understanding of how the lab would work and what materials I would need." Out of the students who mentioned demonstration or visual components (n=5), one was assigned the pre-laboratory questions (20%) and four were assigned the pre-laboratory video (80%). Seventy-five percent of students interviewed (n=3) mentioned a video or demonstration when asked what type of laboratory activity would make them feel most prepared. This included one student who was assigned the pre-laboratory questions. This student pondered the benefit of a visual component, stating that, "I have always done questions and those

work because I have scored well on labs, but I wonder if I would be more prepared if I could see a demonstration."

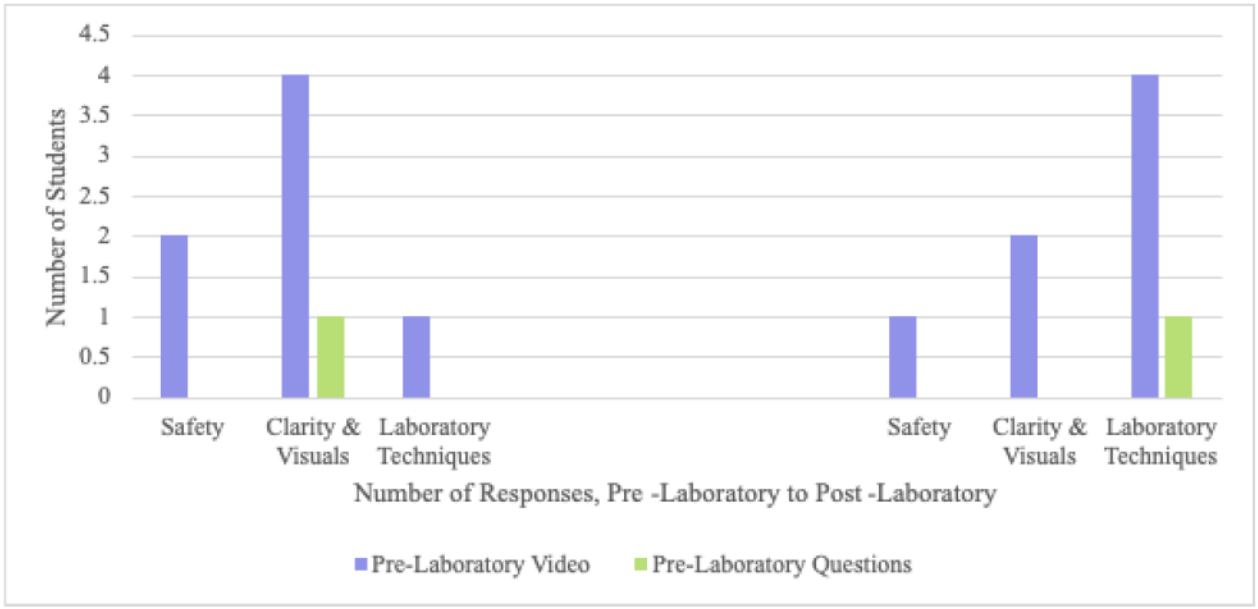


Figure 10. Breakdown of open-ended responses from the Pre-Laboratory Survey (*N*=11) and Post-Laboratory Survey (*N*=10) into categories. Pre-Laboratory Survey responses are on the left, while Post-Laboratory Survey responses are on the right.

While there is little quantitative data to support the use of pre-laboratory videos over pre-laboratory questions, the qualitative data suggests that students feel more prepared to perform in a laboratory after watching a video. The visual component, including the ability to demonstrate how to use specialized equipment, was particularly valuable to students. Having already been introduced to this information, students were able to perform the laboratory more effectively.

The increase in performance between students who were assigned pre-laboratory video and students who were assigned pre-laboratory questions was extremely evident while observing them perform the laboratory. When making observations, positive and negative marks were

recorded to identify specific behaviors within the laboratory that would indicate preparedness (Figure 11). All students observed (N=11) disposed of their chemical waste correctly. Seventy-four percent of marks from observing students who were assigned the pre-laboratory video (n=31) were positive marks – indicating that they showed the behavior correctly. In comparison, 62% of marks from observing students who were assigned the pre-laboratory questions (n=27) were positive marks.

In general, there was a similar distribution of marks between groups when considering the behavior 'Follows safety expectations." Students who were assigned the pre-laboratory video more frequently followed procedure and used the correct equipment than those assigned the pre-laboratory questions (Figure 11). Students who were assigned the pre-laboratory video were observed using the correct techniques more frequently – I observed one student squat down to measure using their graduated cylinder, multiple students light their Bunsen burner with confidence, and one student help another group light their Bunsen burner. Conversely, one group of students who were assigned the pre-laboratory questions mistakenly chose the wrong size of test tube, causing their test tube to overflow when they added the second chemical.

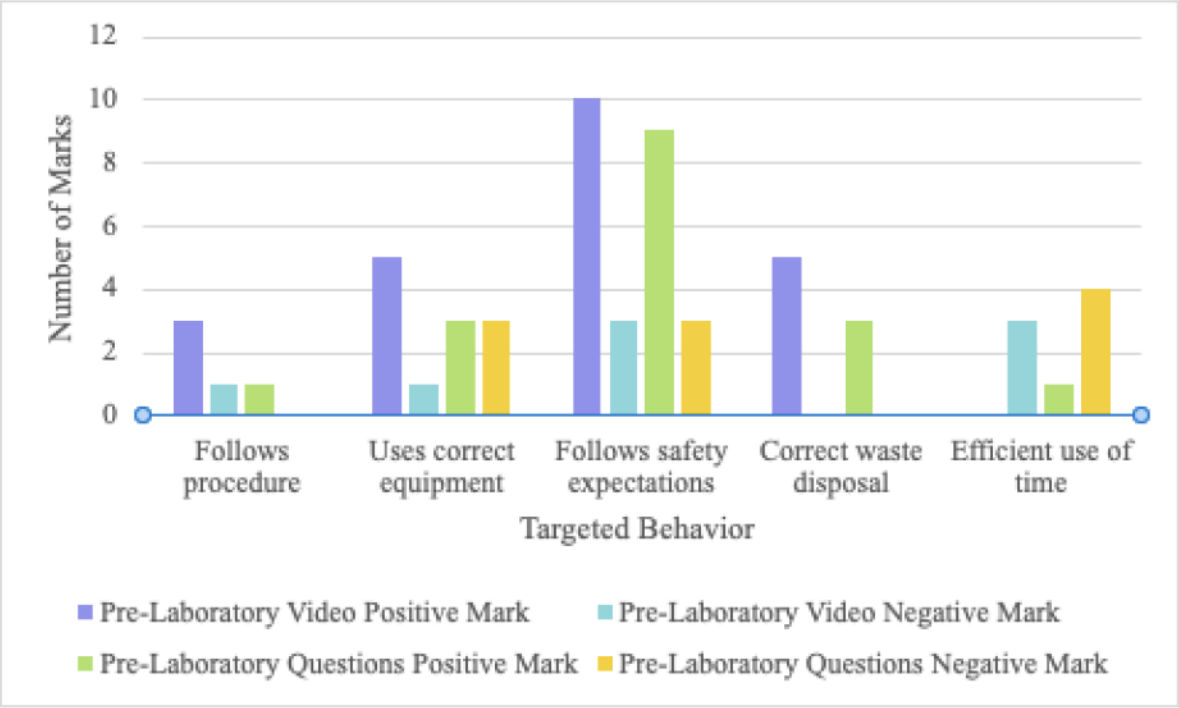


Figure 11. Number of marks for targeted behaviors that exhibit student preparedness, (*N*=58).

Overall, a pattern emerged showing that while all students felt prepared for the laboratory based on their pre-laboratory activity, the visual component of the pre-laboratory videos was invaluable. Students repeatedly discussed how the visual component helped them feel prepared to perform the laboratory safely, use equipment properly, and dispose of chemical waste. During the laboratory, students who were assigned the pre-laboratory video repeatedly used the correct equipment and used it correctly. Therefore, it appears that the visual component of the pre-laboratory video resulted in students being able to better perform the laboratory activity.

Student Confidence

Pre-laboratory videos had a positive impact on student confidence during the laboratory activity. Laboratory confidence was evaluated using Pre- and Post-Laboratory Surveys, Student Interviews, and Teacher Observations. In the Pre-Laboratory and Post-Laboratory Survey, student confidence was measured using the prompt "I can perform/performed the lab effectively and efficiently." Before the laboratory, 100% of students who were given the pre-laboratory video (n=6) felt confident in their ability to perform the laboratory (stated they 'Agree' or 'Strongly Agree' with the statement). While all students interviewed said they were confident before starting the laboratory, the two students who were assigned the pre-laboratory videos said they were "really confident" and "very confident," while those assigned the pre-laboratory questions simply said they were "confident" and "pretty confident." While the difference in wording seems minimal, the modifiers show that the students who were assigned the pre-laboratory videos were more confident than those assigned the pre-laboratory questions.

Confidence can be seen in a laboratory when students are actively engaged and communicating with their peers. While performing teacher observations, marks were recorded to track specific behaviors that would indicate student confidence: (a) begins lab immediately, (b) positive body language, (c) asks appropriate questions, (d) active participation, and (e) collaboration (Figure 12). In general, students actively participated no matter their pre-laboratory activity. Positive marks in 'active participation' accounted for 35% of all marks from students who were assigned the pre-laboratory video (n=39) and 32% of all marks from students who were assigned the pre-laboratory questions (n=40). However, negative marks in 'active participation' accounted for only 2% of the total marks for students assigned the pre-laboratory

video (*n*=39), compared to 12% for those assigned the pre-laboratory questions (*n*=40). In addition to active participation, students assigned the pre-laboratory video were observed several times as having positive body language while completing the laboratory. This body language indicates that they were confident in their ability to perform the laboratory. No students who were assigned the pre-laboratory questions exhibited positive body language while performing the laboratory, and one student showed negative body language. In addition, 20% of students who were given the pre-laboratory questions (*n*=5) said they were not as confident in their abilities on the Pre-Laboratory Survey, saying they 'Slightly Disagree' with the statement "I can perform the lab effectively and efficiently" (Figure 14).

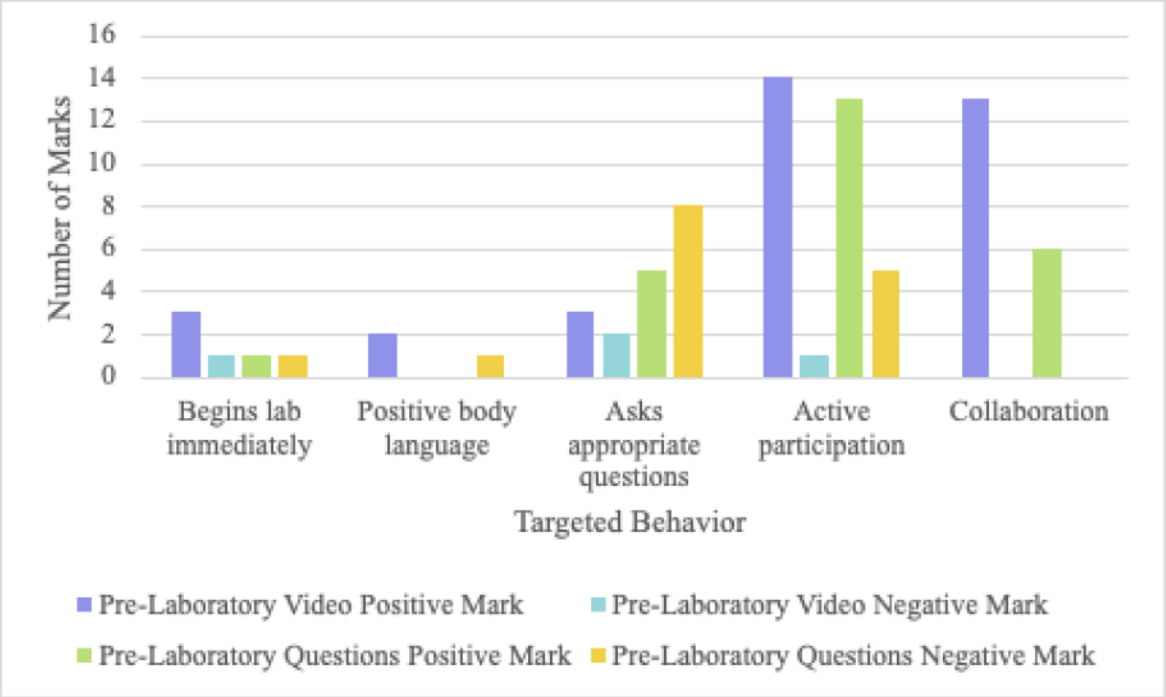


Figure 12. Number of marks for targeted behaviors that exhibit student confidence, (*N*=79).

In addition to their perceived confidence and positive body language, students who were assigned the pre-laboratory video were more collaborative with their peers. Those given pre-

laboratory videos received over twice as many positive marks in the 'collaboration' category in comparison to their peers who were given pre-laboratory questions. While performing the laboratory, students worked in their normal partner groups. This means that some students may have been working with a peer who was assigned a different pre-laboratory activity. One of the observations I made of the students who completed the pre-laboratory questions was that the student seemed to act more as a follower in their group. They did contribute to the discussions within their group but didn't initiate actions or heavily involve themselves in participating. In addition, when the students assigned the pre-laboratory questions asked questions of me (n=13), they were only relevant 38% of the time (Figure 13). In contrast, I observed students in the pre-laboratory group frequently proactively lead their group. One student in the pre-laboratory group was very active in participating in this laboratory when they are typically less involved. Another student from the pre-laboratory video group communicated effectively with the group they were sharing chemicals with, to limit the amount of time waiting between each group. Yet another student from the pre-laboratory video group was able to communicate effectively enough to aid another group in lighting their Bunsen burner. When students assigned the pre-laboratory video asked questions of me (n=5), they were relevant 60% of the time. While students appeared confident, their confidence changed throughout the laboratory (Figure 14). One hundred percent of participants (N=11) said they felt they had performed the laboratory effectively and accurately (stated they 'Agree' or 'Strongly Agree' with the statement) when reflecting in the Post-Laboratory Survey, in comparison to the 90% before the laboratory.

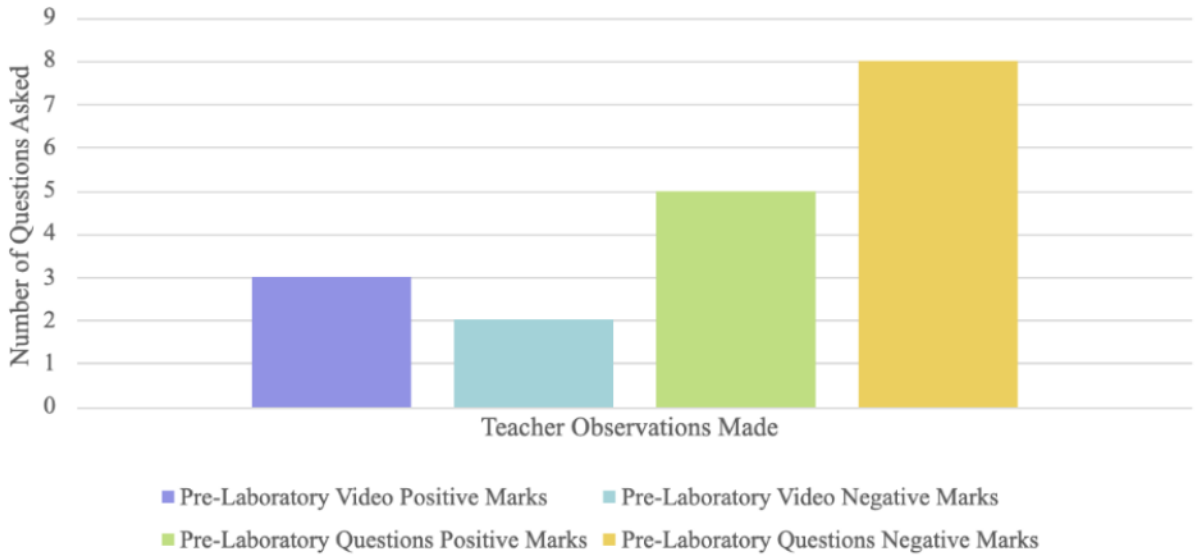


Figure 13. Total number of marks for the Teacher Observation "Asks appropriate questions" separated by type of pre-laboratory activity and positive (appropriate) or negative (irrelevant) question, (n=18).

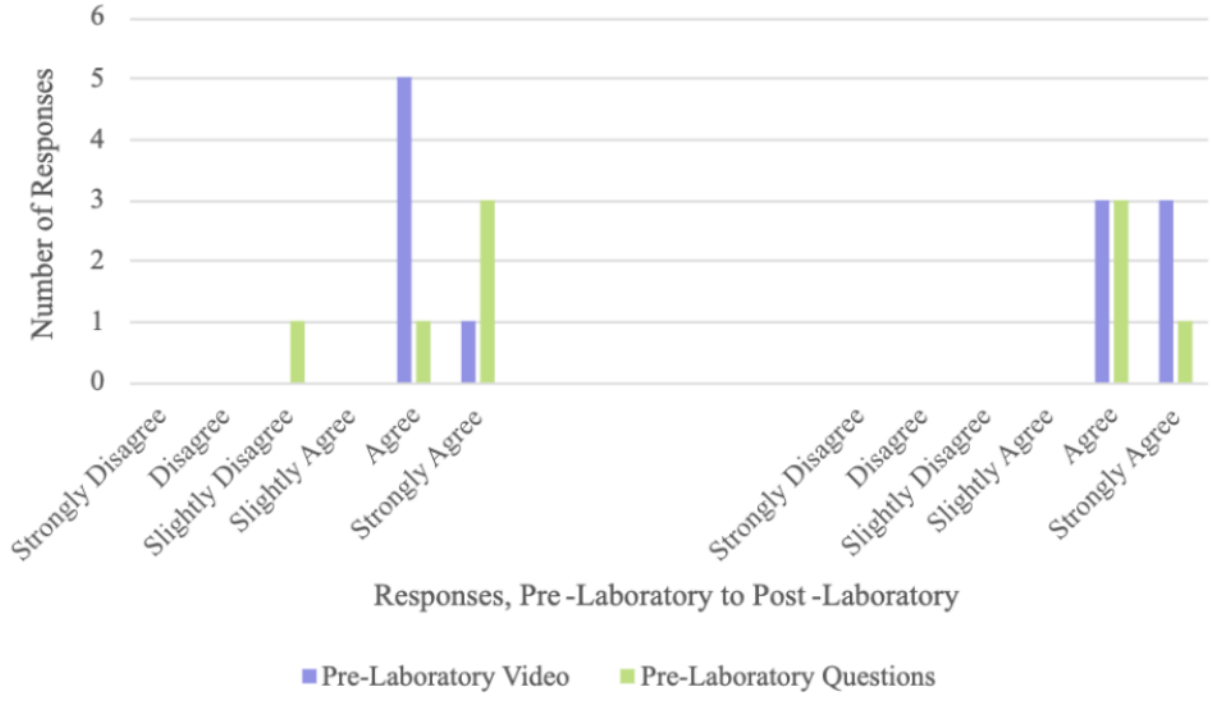


Figure 14. A comparison of student responses to the statement "I can perform/performed the laboratory effectively/correctly and efficiently." Pre-Laboratory Survey responses are on the left, while Post-Laboratory Survey responses are on the right.

Students felt confident in their ability to perform the laboratory, but those assigned the pre-laboratory video rated their agreement higher. This is supported by one student, who on their Pre-Laboratory Survey said, “I liked the video, it walked through everything we do and it let me understand the procedure better.” In addition, one student who was assigned the pre-laboratory video was able to cite specific things in the video (information about putting the caps back on the bottles and when gloves were required) that made them feel confident in their ability to perform the laboratory. Students assigned the pre-laboratory video also self-reported a higher confidence. Their behavior in the laboratory showed their confidence as well, in their ability to ask appropriate questions, communicate effectively with their peers, and actively participate in the laboratory.

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CHAPTER FIVE

VALUE: REASONING AND REFLECTION

Claims From the Study

Chemistry is a challenging subject for most students, and the strict behavior expectations and specialized equipment when performing a chemistry laboratory makes the subject even more challenging. I have noticed students struggle to draw connections between content and laboratory work, or struggle to meet safety expectations. These observations led to the research question this study aimed to answer: How does the use of pre-laboratory videos impact students' academic success and laboratory performance? My purpose was to find a more effective way of communicating laboratory information, to decrease the information students must carry in their working memory during a laboratory activity. This should allow students more space to focus not only on laboratory performance, but to also create meaningful connections between laboratory and lecture.

Impact on Retention and Application of Scientific Concepts

The use of pre-laboratory videos in lieu of pre-laboratory questions had no major impact on students' ability to retain and apply scientific information. When comparing scores on graded classwork (Pre-Laboratory Quiz, Post-Laboratory Questions, and Cumulative Assessment), only the Pre-Laboratory Quiz showed a statistically significant difference in score between treatment and non-treatment groups. This statistical difference could be due to the nature of the information covered in the pre-laboratory activity, rather than the format of the pre-laboratory activity. The majority of the data, qualitative and quantitative, did not indicate any pattern to

support the use of pre-laboratory videos to help students better retain and apply the information they learned in class. Laboratory activities, by their nature, have a high cognitive load (Rayment et al., 2022). The goal of an effective pre-laboratory activity is to decrease that cognitive load to allow for more space in the students' working memory. Based on the 2016 study by Sarıbaş and Bayram, the use of metacognitive scaffolding, such as pre-laboratory activities, should have a positive impact on conceptual understanding. In addition, Rodgers et al. (2019) found that pre-laboratory videos improved student assessment scores. Although there was no data in this study to support the use of pre-laboratory videos to help students retain and apply scientific information, there are other benefits to pre-laboratory activities, suggesting that further research is required.

Impact on Laboratory Performance and Student Confidence

Pre-laboratory videos had a positive impact on student confidence and their performance during the laboratory activity. Students who were assigned the pre-laboratory video were more confident and better prepared to do the laboratory activity. These students discussed how they felt as if they could better meet the safety expectations and use specialized scientific equipment (in particular, the Bunsen burner). This confidence was evident in my observations of the students during the laboratory. Students who watched the video discussed how the visual component was the critical difference that impacted their preparedness and confidence. Similarly, a student in the pre-laboratory questions group specifically mentioned the potential benefit of a visual component in their open-ended response. The benefit of engaging pre-laboratory activities on student confidence and performance has been well documented, by researchers such as Sarıbaş and Bayram (2016), Agustian and Seery (2017), Aronne et al. (2019),

Sarmouk et al. (2019), and Rodgers et al. (2019). But, as Costello (2020) describes, not all pre-laboratory activities reap the same benefit. The use of videos, sometimes in combination with other activities, has been found to engage and positively impact students by Aronne et al. (2019), Sarmouk et al. (2019), and Rodgers et al. (2019). Based on the literature and the significant impact of pre-laboratory videos on my students' confidence and performance, I intend to continue the use of pre-laboratory videos.

Value of the Study and Consideration for Future Research

Value of the Study

Laboratories are a keystone characteristic of science education. While they are critically important, how laboratories are used and performed varies by each teacher's individual classroom. Understanding how to use laboratories in a way to enhance student understanding, rather than to simply perform a laboratory, is beneficial to all science teachers. In my undergraduate science classes, I often saw no connection between the lecture class and the corresponding laboratory class. Now, as a science teacher myself, I strongly believe that that lecture and laboratory should support and strengthen each other. Students will benefit if teachers are able to find a way to improve laboratory performance.

Within my own classroom, I use laboratories as an opportunity to take what the students have learned and apply that information. I have noticed a disconnect, however, between my students' understanding of content and their ability to apply it. I hope that by changing my approach to laboratories I can bridge this disconnection. While my data doesn't support an academic benefit to pre-laboratory videos over pre-laboratory questions, it does support socioemotional benefits to my students. I also believe that, with further research

and modification, I can create a pre-laboratory activity that does have an academic benefit to my students. Even without an increase in scores on graded classwork, the socioemotional benefits alone are worth continuing to use a video component in pre-laboratory activities. Science is classically thought of as mysterious, challenging, and inaccessible. By providing my students with the opportunity to be better prepared for a laboratory, they can complete it easily with confidence, making science more accessible for all students.

Study Limitations

During the implementation of this study, several challenges arose that may have impacted the results. First, there was a small sample size of only 11 students who volunteered to participate in the study. The small sample size resulted in even smaller and uneven treatment and non-treatment groups. This means that the students who participated in the study may not accurately represent the average student population. In addition to the challenge of sample size, the flow of the study was interrupted. While the initial sequence of events intended for the study to take five school days to complete, it took ten school days to complete. There were multiple days when we were unable to continue in the sequence of events for the study; due to weather, illness, and pre-scheduled guest speakers. In addition, several of the students who participated in the study were absent for one or more days during the sequence of the study. This resulted in students needing additional time to complete the laboratory and the accompanying work, and one student not completing the Post-Laboratory Survey. I believe that both factors had an impact on the results of the study, and that if the sample size were larger and the sequence of events went uninterrupted, there may have been a positive impact on students' ability to retain and apply scientific information.

Future Research

From here, further research is required. I would suggest the potential to simply perform a similar study, with a larger sample size and fewer interruptions. However, based on the feedback provided by students in the Student Interviews, a pre-laboratory activity that incorporates questions and a video would be even more beneficial to students. Therefore, adjusting the pre-laboratory activity to include multiple components (e.g. video, questions, quiz) would be one avenue of study. Another option would be to allow students to choose the format of their pre-laboratory activity, if there are safeguards in place to ensure students completed their activity with integrity. Tailoring the pre-laboratory components (e.g. video, questions, quiz) based on content information could be studied as well. Many topics in chemistry are unequal in difficulty. In my experience types of chemical reactions and balancing equations are topics that are simple for students to understand, where topics such as predicting the products of a chemical equation and Le Chatelier's Principle are much more challenging. A pre-laboratory video for a laboratory focused on a more challenging concept could potentially demonstrate an impact on student's academic success.

Impact of Action Research on the Author

Throughout the process of my action research project, I was provided with many opportunities to practice being flexible. I normally consider myself a flexible teacher, but I found it difficult to adapt to the challenges presented, such as illnesses and snow days. This process reminded me how to focus on the most important parts first. It also allowed me to explore a topic that I have been discontented with for a long time. I have never been fully satisfied with my laboratory and pre-laboratory activity design, especially for chemistry. Recently, I have

worried that I fell into a trap where my chemistry laboratories were reminiscent of lecture and laboratory in my undergraduate classes. In these classes, I found the disconnect between the lecture and laboratory of the same class jarring. I don't want that to be my students' experience as well. This action research study provided me the opportunity to try and improve this connection between lecture and laboratory.

During Student Interviews, students discussed how relevant videos would be based on the type of laboratory performed. One student put it well, stating "Most of the time I think a demonstration would be good just because it shows how to use stuff, but if the lab is only combining [chemicals] then I don't need a demonstration." In other words, a simplistic laboratory doesn't require a demonstration nearly as much as a more complicated laboratory does. Another student agreed, stating that visual components wouldn't be required for easier labs. In addition, students discussed the benefits of using pre-laboratory questions, with one student saying that the questions make them think more than the video did. Going forward, I intend to keep pre-laboratory questions. I plan to add a video to the pre-laboratory activity for laboratories that are more challenging, complicated, or require special safety considerations or equipment. This will allow students to still be confident in their abilities going into the lab, while encouraging them to think about the scientific concepts related to the lab. This strategy would also limit the amount of time required to record videos. Including videos for only more challenging laboratories would also hopefully encourage students to watch required videos with integrity. Throughout the course of this study, I have felt a revitalized purpose to improve laboratory activities for my chemistry students. This study has provided me with the

background knowledge to guide me as I continue teaching, so that my laboratories are relevant and accessible to all students.

REFERENCES CITED

Abu, A. O. (2023). Effect of inquiry method on students' academic achievement in biology at senior secondary school in Idah Kogi State. *Journal of Science, Technology and Mathematics Pedagogy, 1*(1), 30-36. https://jostmpksu.com.ng/index.php/jostmp/article/view/37

Agustian, H. Y., & Seery, M. K. (2017). Reasserting the role of pre-laboratory activities in chemistry education: A proposed framework for their design. *Chemistry Education Research and Practice, 18*(4), 518–532. https://doi.org/10.1039/c7rp00140a

Aronne, L., Nagle, C., Styers, J. L., Combs, A., & George, J. A. (2019). The effects of video based pre-lab instruction on college students' attitudes and achievement in the digital era. *Electronic Journal of Science Education, 23*(5), 3–21.

Black, P., & Wiliam, D. (2018). Classroom assessment and pedagogy. *Assessment in Education: Principles, Policy & Practice, 25*(6), 551–575. https://doi.org/10.1080/0969594X.2018.1441807

Brinkmann, S. (2018). The interview. In N. K. Denzin & Y. S. Lincoln (Eds.), The SAGE handbook of qualitative research (5th ed., pp. 997–1038). SAGE Publications.

Chen, V. T., León-Pérez, G., & Honnold, J. (n.d.). *12.2. Randomized controlled designs: What you should do*. In *The craft of sociological research*. https://viva.pressbooks.pub/sociology-research-methods/chapter/12-2-randomized-controlled-designs-what-you-should-do/

Clapp, T. (2025, February 20). *A practical guide to observation checklists*. Coursebox AI. https://www.coursebox.ai/blog/observation-checklists

Costello, T. (2020). An evaluation of the effects of flipped classroom pre-laboratory activities on students' engagement with laboratory learning (Thesis). Atlantic Technological University (Galway-Mayo). http://research.thea.ie/handle/20.500.12065/3330

Cognitive Load Theory. (2022). A guide to applying cognitive load theory to your teaching.

Daman Huri, N. H., & Karpudewan, M. (2019). Evaluating the effectiveness of integrated STEM-lab activities in improving secondary school students' understanding of electrolysis. *Chemistry Education Research and Practice, 20*(3), 495–508. https://doi.org/10.1039/c9rp00021f

Finne, L. T., Gammelgaard, B., & Christiansen, F. V. (2022). When the lab work disappears: Students' perception of laboratory teaching for quality learning. *Journal of Chemical Education, 99*(4), 1766–1774. https://doi.org/10.1021/acs.jchemed.1c01113

Frago, R. L., & Janer, S. S. (2020). Effect of demonstration method and laboratory method in enhancing the conceptual understanding of grade ten (10) students in chemistry. *International Journal of Engineering Science and Computing, 10*(5), 25784–25790.

Gobo, G., & Mauceri, S. (2014). Constructing survey data: An interactional approach. SAGE Publications Ltd, https://doi.org/10.4135/9781446288481

Guest, G., MacQueen, K. M., & Namey, E. E. (2012). Applied thematic analysis. SAGE Publications, Inc., https://doi.org/10.4135/9781483384436

Guest, G., Namey, E., & Mitchell, M. (2013). Collecting qualitative data. (Vols. 1-0). SAGE Publications, Ltd, https://doi.org/10.4135/9781506374680

Haase, E., Furukawa, N., Hardesty, B., Patil, A., & Ruci, A. (2022). Impact of lab experiences on student knowledge and confidence. 2022 ASEE Annual Conference & Exposition Proceedings. https://doi.org/10.18260/1-2--40556

Harlen, W., & Gardner, J. (2010). Assessment to support learning. In J. Gardner, W. Harlen, L. Hayward, & G. Stobart (Eds.), *Developing teacher assessment* (pp. 15–28). McGraw-Hill/Open University Press.

Hartwig, F., & Dearling, B. E. (1979). Exploratory data analysis. SAGE Publications Inc. https://doi.org/10.4135/9781412984232

Holstein, J. A., & Gubrium, J. F. (1995). The active interview. SAGE Publications, Inc. https://doi.org/10.4135/9781412986120

Iowa Department of Education. (2024). *Hudson High School: Iowa school performance profile. Iowa School Performance Profiles*. https://www.iaschoolperformance.gov/ECP/StateDistrictSchool/SchoolSummary?k=17767&y=2024

Iskander, M. (2018). Burnout, cognitive overload, and metacognition in medicine. *Medical Science Educator, 29*(1), 325–328. https://doi.org/10.1007/s40670-018-00654-5

Jason, M. H. (2008). Evaluating programs to increase student achievement. SAGE Publications, Inc. https://doi.org/10.4135/9781412990264

JMP. (n.d.). *The two-sample t-test.* JMP Statistical Knowledge Portal. https://www.jmp.com/en/statistics-knowledge-portal/t-test/two-sample-t-test

Jones, R. (2020). Essential maths skills for exploring social data. (Vols. 1-0). SAGE Publications Ltd. https://doi.org/10.4135/9781036212865

Kapici, H. O., Akcay, H., & de Jong, T. (2020). How do different laboratory environments influence students' attitudes toward science courses and laboratories? *Journal of*

Research on Technology in Education, 52(4), 534-549. https://doi.org/10.1080/15391523.2020.1750075

Kelp, L. (2024). The efficacy of NGSS curricula in improving middle school student performance on science assessments [Doctoral dissertation, University of Findlay]. OhioLINK Electronic Theses and Dissertations Center. http://rave.ohiolink.edu/etdc/view?acc_num=findlay1722032365630349

López-Vargas, O., Ibáñez-Ibáñez, J., & Racines-Prada, O. (2017). Students' metacognition and cognitive style and their effect on cognitive load and learning achievement. *Journal of Educational Technology & Society, 20*(3), 145–157. http://www.jstor.org/stable/26196126

McComas, W. F., & Nouri, N. (2016). The nature of science and the next generation science standards: Analysis and critique. *Journal of Science Teacher Education, 27*(5), 555–576. https://doi.org/10.1007/s10972-016-9474-3

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation.* Jossey Bass.

Mertler, C. A. (2019). *Action research: Improving schools and empowering educators* (6th ed.). SAGE Publications, Inc. https://doi.org/10.4135/9781071879092

National Academies of Sciences, Engineering, and Medicine. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* The National Academies Press. https://doi.org/10.17226/13165

OpenAI. (2025). ChatGPT (Nov 2 version) [Large language model]. https://chat.openai.com/ Note: Used as a proofreading editor for this paper.

Phan, H. P., Ngu, B. H., & Yeung, A. S. (2017). Achieving optimal best: Instructional efficiency and the use of cognitive load theory in mathematical problem solving. *Educational Psychology Review*, 29, 667–692. https://doi.org/10.1007/s10648-016-9373-3

Rayment, S. J., Evans, J., Moss, K., Coffey, M., Kirk, S. H., & Sivasubramaniam, S. D. (2022). Using lessons from a comparative study of chemistry & bioscience pre-lab activities to design effective pre-lab interventions: A case study. *Journal of Biological Education, 57*(5), 1092–1111. https://doi.org/10.1080/00219266.2021.2011771

Rhodes, M. G. (2019). Metacognition. *Teaching of Psychology, 46*(2), 168–175. https://doi.org/10.1177/0098628319834381

Rodgers, T. L., Cheema, N., Vasanth, S., Jamshed, A., Alfutimie, A., & Scully, P. J. (2019). Developing pre-laboratory videos for enhancing student preparedness. *European Journal of Engineering Education, 45*(2), 292–304. https://doi.org/10.1080/03043797.2019.1593322

Rodriguez, J.-M. G., & Towns, M. H. (2018). Modifying laboratory experiments to promote engagement in critical thinking by reframing prelab and postlab questions. *Journal of Chemical Education, 95*(12), 2141–2147.

Sarıbaş, D., & Bayram, H. (2016). Investigation of the effects of using metacognitive activities in chemistry laboratory on the development of conceptual understanding. *Bogazici University Journal of Education, 33*(1), 27-49.

Sarmouk, C., Ingram, M. J., Read, C., Curdy, M. E., Spall, E., Farlow, A., Kristova, P., Quadir, A., Maatta, S., Stephens, J., Smith, C., Baker, C., & Patel, B. A. (2019). Pre-laboratory online learning resource improves preparedness and performance in pharmaceutical sciences practical classes. *Innovations in Education and Teaching International, 57*(4), 460–471. https://doi.org/10.1080/14703297.2019.1604247

Scherbaum, C., & Shockley, K. (2015). Analysing quantitative data for business and management students. SAGE Publications, Inc., https://doi.org/10.4135/9781529716719

Shana, Z., & Abulibdeh, E. S. (2020). Science practical work and its impact on students' science achievement. *Journal of Technology and Science Education, 10*(2), 199–215. https://doi.org/10.3926/jotse.888

Stafford, M. E. (2006). Testing and measurement. SAGE Publications, Inc. https://doi.org/10.4135/9781412986106

Tapia, J. L., Huacani, L. C., Mamni, D. C., de la Cruz Paredes, D., & Mamani, M. J. (2020). Importance of laboratory work on the teach and learn process in engineering. 2020 IEEE International Symposium on Accreditation of Engineering and Computing Education (ICACIT), 1–6. https://doi.org/10.1109/icacit50253.2020.9277674

Tempelman, C. H. L., Rijgersberg, A., & van der Eijk, M. (2023). Introducing theory in practice: The beneficiary effects of teaching chemistry in the laboratory on student success. *Journal of Chemical Education, 100*(2), 564–571. https://doi.org/10.1021/acs.jchemed.2c00655

Ural, E. (2016). The effect of guided-inquiry laboratory experiments on science education students' chemistry laboratory attitudes, anxiety and achievement. *Journal of Education and Training Studies, 4*(4), 217–227. https://doi.org/10.11114/jets.v4i4.1395

U.S. Census Bureau. (2023). *American community survey 5-year estimates.* Census Reporter. http://censusreporter.org/profiles/16000US1937470-hudson-ia/

U.S. News & World Report. (2022). *Hudson High School*. U.S. News & World Report. https://www.usnews.com/education/best-high-schools/iowa/districts/hudson-community-school-district/hudson-high-school-7658

Weisberg, H. F. (1992). Central tendency and variability. SAGE Publications, Inc. https://doi.org/10.4135/9781412983617

Zheng, L., Li, X., Zhang, X., & Sun, W. (2019). The effects of group metacognitive scaffolding on group metacognitive behaviors, group performance, and cognitive load in computer supported collaborative learning. *The Internet and Higher Education*, 42, 13–24. https://doi.org/10.1016/j.iheduc.2019.03.002

APPENDICES

APPENDIX A: INSTITUTIONAL REVIEW BOARD

COMPLIANCE FORM

Hello Sinnott, Madeline,
Your protocol was reviewed by the IRB and has been approved.
PI: Sinnott, Madeline
Approval Date: 12/8/2025
Title: Impact of Pre-Laboratory Videos on Concept Retention and Laboratory Performance
Protocol #: 2025-2394-EXEMPT
Review Type: Exemption
Expiration Date: 12/8/2030
Work described under this protocol may now commence. The PI is responsible for ensuring that the protocol accurately describes research practices being conducted.
> Review Category designation determined by the IRB can be found in the final section of your protocol.
> Any changes must be submitted via Amendment prior to implementation.
> Per the Common Rule, research only requires Interim (annual) Review by the IRB if 1) it was reviewed via Full Committee or 2) is regulated by the FDA.
> All research is subject to post approval monitoring.
> All protocol types must be renewed 5 years after approval.
> Inform the IRB once your research is complete so that the protocol may be inactivated.
Please contact your IRB Program Manager with any questions or if you are in need of assistance.
Thank you for your diligence in the care of human subjects research participants.

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

APPENDIX B: STUDENT ASSENT AND PARENTAL CONSENT (FERPA) FORMS

SUBJECT CONSENT FORM FOR PARTICIPATION IN HUMAN RESARCH AT MONTANA STATE UNIVERSITY

January 5, 2026

Impact of Pre-Laboratory Videos on Concept Retention and Laboratory Performance

IRB Reference Number: 2025-2397

Dear [Parent/Guardian Name],

I am writing to introduce an exciting opportunity for your child to participate in a research project within our educational community. As part of my commitment to advancing knowledge and improving education practices, I (Madeline Sinnott) am conducting a research study titled "Impact of Pre-Laboratory Videos on Concept Retention and Laboratory Performance" for completion of Master's of Science in Science Education at Montana State University. Research plays a pivotal role in shaping the educational landscape, providing invaluable insights that drive innovation and improvement while encouraging exploration and discovery for not only the researcher but also for your child.

What this study is about:

Your child is being asked to participate in this research study that aims to determine if a different method of presenting pre-laboratory information is more effective. Classically, pre-laboratory questions are used to present information about the laboratory and help students identify topics that will be relevant during the laboratory activity. However, in this technological age, I will be investigating if pre-laboratory videos, rather than pre-laboratory questions, are more effective at preparing students to complete the laboratory and better form connections between content information and the laboratory activity.

What I will be asking students to complete:

For this study, I will be collecting grades for three different assignments: Chemical Reactions Lab Pre-Lab Quiz, Chemical Reactions Lab Post-Lab Questions, and Chemical Reactions Test. The numerical score will be recorded. After grading the assignments, I will record the scores on a separate log. While names will be used during grading of normal classroom activities, all scores will be de-identified before analysis. The utilization of these records will allow me to determine if the pre-laboratory activity used impacts the student's ability to retain information and apply it to new situations. If a student is able to retain and apply the information effectively, that should be reflected in their grades. As part of my study, I will also be performing student interviews to better understand the students' perspectives. Students will be chosen at random, using a random name generator, to be invited to participate in the interview. If your student participates in the interviews, an audio recording will be taken of the interview. There are no other recordings that will take place during the study. These recordings will be analyzed, and data will be recorded without names. Those that will have access to the records will be myself and my advisor, Jessica Anderson. All digital data will be stored on a password-protected device, and identifiable information (e.g. audio recordings) will be deleted no more than 30 days after the study has been presented as part of the degree requirements. The only people who will be allowed access to any records will be myself and my advisor, Jessica Anderson. The rough data will include the following possible identifiers: class period and assigned pre-laboratory activity.

Your child's participation will aid me in the completion of my Masters of Science in Science Education degree through Montana State University. The results of the study will

be presented in a Capstone Symposium over the summer, and published on Montana State University's website.

Your child's participation is completely voluntary, and your child may withdraw from the study at any time without penalty. Your child's choice to participate, or opt out, will not impact their grades or class standing in any way at Hudson High School.

For any questions or concerns please reach out to:

Maddie Sinnott

maddiesinnott@hudschools.org / (319) 988-4226

Or

Montana State University Institutional Review Board at irb@montana.edu or (406) 994-4706. The MSU IRB's mission is the protection of the rights, welfare, and well-being of human subjects who participate in research.

By signing this consent form, you acknowledge that you have read the details of this research study, and you freely give consent for your child to participate as well as be recorded for this study. Also, as noted prior, participation is completely voluntary, and your child may withdraw from the study at any time without penalty. Your child's choice to participate, or opt out, will not impact their grades or class standing in any way at Hudson High School.

As part of this study, your child may be asked to participate in a short interview or survey, which may be audio recorded to ensure accuracy of data collection. These recordings will only be

used for research purposes, will not include your child's name, and will be stored securely until the end of the study. Please indicate your choice below:

☐ I consent to my child being audio recorded for this research study.

☐ I do NOT consent to my child being audio recorded for this research study.

I, _____ [Parent/Guardian Name], hereby give consent for my child, _____ [Child's Name], to participate in this research study conducted by Montana State University for the purpose of attaining a Master's of Science in Science Education degree. I have read and understand the information herein.

Parent/Guardian Signature: _____

Date:_____

Printed Name of Parent/Guardian:_____

Relationship to Student:_____

SUBJECT ASSENT FORM FOR PARTICIPATION IN HUMAN RESARCH AT MONTANA STATE UNIVERSITY

January 5, 2026

Impact of Pre-Laboratory Videos on Concept Retention and Laboratory Performance

IRB Reference Number: 2025-2397

As part of the requirements for my degree, I am doing a research project to learn whether using pre-lab videos or written pre-lab questions helps students better prepare for labs and retain science information. The study is called "Impact of Pre-Laboratory Videos on Concept Retention and Laboratory Performance"

What this study is about:

The goal is to see whether a different method of communicating information before a lab works better. Usually, you get pre-lab questions to help you learn what you need to know for the activity. But since we use more technology now, this study will look at whether short pre-lab videos do a better job of helping you understand the material and feel more prepared for the lab.

What I will be asking students to complete:

If you choose to take part, you will have the opportunity to complete a short survey before and after the lab, to provide perspective on your preparation and experience during the lab. Some participants will be chosen at random (using a random name generator) and invited to do a short interview with me to share your thoughts about the lab and the pre-lab activity. These are optional, and you don't have to participate if you don't want to. Observations will be made during the lab activity, and if you choose not to participate no observations of you will be recorded.

I will also be recording scores from three assignments — a Pre-Lab Quiz, Post-Lab Questions, and Chemical Reactions Test — to see if the type of pre-lab activity makes a difference. When the data is being compiled, your name will not be recorded - just your class period and which pre-lab activity you completed.

Participation in the study is completely voluntary. You can choose not to participate, skip any question, or stop at any time, and it will not affect your grade, your standing in class, or your relationship with me in any way.

Since you are under 18 and I will be recording grades, you must have a signed form in order to participate in the study. I will be sending those forms home with you on [date], and need them back no later than [date].

In addition to parental consent, you must assent to participating in the study. To provide assent, you musth sign this form, which I need back no later than [date]. You also must indicate below what parts of study you assent to participating in. You can opt-out of the study at any time, and it will not affect your grade, your standing in class, or your relationship with me in any way.

This study has been approved by the Montana State University Institutional Review Board (IRB Protocol #2025-2397).

I, _____, assent to the following activities within the research study outlined above. I realize that I can opt-out of participation in any of these activities at any time. I realize that choosing to not participate in the study does not exempt me from normal classroom activities, and opting out of participation will simply mean my scores are not recorded.

Data Sources	I give assent for this data to be collected and used:
Pre-Laboratory Survey	
Pre-Laboratory Quiz score	
Post-Laboratory Survey	
Post-Laboratory Questions score	
Teacher Observations	
Student interviews	
Cumulative Assessment (Chemical Reactions Test) score	

Student Signature: _____

Date:_____

APPENDIX C: PRE-LABORATORY QUIZ

Name: _____ Period: _____

Your score on this quiz won't affect your grade, but doing your best will help you be more prepared for the lab. Please take it seriously and do your best! All questions are multiple choice.

☐ Check this box if you do *not* want your score to be used in the study.

1. Mark the form of pre-laboratory activity you were assigned to complete:

☐ Pre-lab Questions ☐ Pre-lab Video

Reaction 1: Hydrogen Peroxide

2. What additional safety precautions are necessary for this reaction?
    a. Wear gloves
    b. Use caution – materials may stain
    c. No additional safety precautions
    d. Use caution when using a heat source
3. What is the role of iron (III) chloride do in this reaction?
    a. It is a reactant
    b. It is a product
    c. It is a catalyst to kick-start the reaction
4. Where do you dispose of the waste from this reaction?
    a. Down the drain
    b. Down the drain with excess water
    c. In the disposal container
    d. In the trash can

Reaction 2: Aluminum and Copper (II) Chloride

5. What additional safety precautions are necessary for this reaction?
    a. Wear gloves
    b. Use caution – materials may stain
    c. No additional safety precautions
    d. Use caution when using a heat source
6. What additional piece of equipment will you need for this reaction?
    a. Tongs
    b. Thermometer
    c. Ruler
    d. Scale
7. Where do you dispose of the waste from this reaction?
    a. Down the drain
    b. Down the drain with excess water
    c. In the disposal container
    d. In the trash can

Reaction 3: Copper (II) Chloride and Sodium Phosphate

8. What additional safety precautions are necessary for this reaction?
    a. Wear gloves
    b. Use caution – materials may stain
    c. No additional safety precautions
    d. Use caution when using a heat source

9. What order do you add the materials together?
    a. Add water to Copper (II) Chloride and separately add water to Sodium Phosphate. Then add the Copper (II) Chloride to the Sodium Phosphate
    b. Add Copper (II) Chloride to the Sodium Phosphate, then add water.
10. Where do you dispose of the waste from this reaction?
    a. Down the drain
    b. Down the drain with excess water
    c. In the disposal container
    d. In the trash can

Reaction 4: Copper and Oxygen

11. What additional safety precautions are necessary for this reaction?
    a. Wear gloves
    b. Use caution – materials may stain
    c. No additional safety precautions
    d. Use caution when using a heat source
12. What additional piece of equipment will you need for this reaction?
    a. Tongs
    b. Thermometer
    c. Ruler
    d. Scale

13. Where do you dispose of the waste from this reaction?

    a. Down the drain

    b. Down the drain with excess water

    c. In the disposal container

    d. In the trash can

KEY

1. Answer varied by student
2. A
3. C
4. C
5. C
6. B
7. C
8. C
9. A
10. C
11. D
12. A
13. C

APPENDIX D: PRE- AND POST-LABORATORY SURVEYS

PRE-LABORATORY SURVEY

Answer honestly! Your responses are private and won't change your grade or how your teacher treats you. You may choose not to respond to the survey or stop at any point.

1. Which class period are you in?

   ☐ Period 4 ☐ Period 6 ☐ Period 7

2. Which pre-lab activity did you complete?

   ☐ Pre-lab Questions ☐ Pre-lab Video

<u>Please indicate how strongly you agree or disagree with each of the following statements.</u>

3. I completed my pre-lab activity with integrity.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

4. The pre-lab activity was effective at communicating pre-lab information.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

5. I can perform the lab safely.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

6. I can perform the lab correctly and efficiently.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

7. I know what equipment is needed for the lab.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

8. I know where to find the equipment needed for the lab.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

9. I know what chemicals are needed for the lab.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

10. I know how to dispose of the chemicals and clean up when I am done with the lab.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

11. I believe that my pre-lab activity effectively prepared me to perform the lab.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

12. I understand the types of chemical reactions.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

13. I understand how to balance an equation.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

14. Please describe how your pre-lab activity helped you prepare for the lab, or what could have helped you feel more prepared.

_____

_____

_____

POST-LABORATORY SURVEY

Answer honestly! Your responses are private and won't change your grade or how your teacher treats you. You may choose not to respond to the survey or stop at any point.

1. Which class period are you in?

☐ Period 4 ☐ Period 6 ☐ Period 7

2. Which pre-lab activity did you complete?

☐ Pre-lab Questions ☐ Pre-lab Video

<u>Please indicate how strongly you agree or disagree with each of the following statements.</u>

3. I performed the lab safely.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

4. I performed the lab correctly and efficiently.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

5. I knew what equipment was needed for the lab.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

6. I knew where to find the equipment needed for the lab.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

7. I knew what chemicals are needed for the lab.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

8. I knew how to dispose of the chemicals and clean up when I was done with the lab.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

9. My pre-lab activity effectively prepared me to perform the lab.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

10. I saw a connection to the types of chemical reactions in the lab.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

11. I saw a connection to balancing equations in the lab.

Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree

12. Please describe how your pre-lab activity helped you prepare for the lab, or what could have helped you feel more prepared.

_____

_____

_____

_____

_____

_____

_____

APPENDIX E: POST-LABORATORY QUESTIONS

1. Write the chemical formulas for the following compounds:
    a. Copper (II) chloride
    b. Iron (III) chloride
    c. Sodium Phosphate
    d. Copper (II) oxide
    e. Dihydrogen dioxide
2. The unbalanced chemical equation for Reaction 1 is as follows:

$H_2O_2(aq) \rightarrow H_2O(l) + O_2(g)$

    a. How did you know that a chemical reaction had occurred? Explain, using specific observable evidence (think back to LG 3-E).
    b. Balance the equation. Show your work, or you will not receive credit for this question!
    c. What type of reaction is it? Explain how you determined this.
3. The unbalanced chemical equation for Reaction 2 is as follows:

$Al(s) + CuCl_2(aq) \rightarrow AlCl_3(aq) + Cu(s)$

    a. How did you know that a chemical reaction had occurred? Explain, using specific observable evidence (think back to LG 3-E).
    b. Balance the equation. Show your work, or you will not receive credit for this question!
    c. What type of reaction is it? Explain how you determined this.
4. The unbalanced chemical equation for Reaction 3 is as follows:

$CuCl_2(aq) + Na_3PO_4(aq) \rightarrow Cu_3(PO_4)_2(s) + NaCl(aq)$

a. How did you know that a chemical reaction had occurred? Explain, using specific observable evidence (think back to LG 3-E).

b. Balance the equation. Show your work, or you will not receive credit for this question!

c. What type of reaction is it? Explain how you determined this.

5. The unbalanced chemical equation for Reaction 4 is as follows:

$Cu(s) + O_2(g) \rightarrow CuO(s)$

a. How did you know that a chemical reaction had occurred? Explain, using specific observable evidence (think back to LG 3-E).

b. Balance the equation. Show your work, or you will not receive credit for this question!

c. What type of reaction is it? Explain how you determined this.

6. The unbalanced chemical equation for Reaction 5 is as follows:

$C_{25}H_{52}\ (s) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

a. How did you know that a chemical reaction had occurred? Explain, using specific observable evidence (think back to LG 3-E).

b. Balance the equation. Show your work, or you will not receive credit for this question!

c. What type of reaction is it? Explain how you determined this.

7. Choose two reactions from the list below. For each of your chosen reactions, list the chemical equation and describe it using words. Be sure to include the phase of each substance.

See the example below:

$C_{25}H_{52}$ (s) + O_2(g) → CO_2(g) + H_2O(g)

Paraffin wax in the form of a solid reacted with oxygen gas. This reaction resulted in carbon dioxide gas and water vapor (water as a gas) being formed.

a. H_2O_2(aq) → H_2O(l) + O_2(g)

b. Al(s) + $CuCl_2$(aq) → $AlCl_3$(aq) + Cu(s)

c. $CuCl_2$(aq) + Na_3PO_4(aq) → $Cu_3(PO_4)_2$(s) + NaCl(aq)

d. Cu(s) + O_2(g) → CuO(s)

KEY

1. a. $CuCl_2$

b. $FeCl_3$

c. Na_3PO_4

d. CuO

e. H_2O_2

2. a. Varied by student – they should mention the production of a gas (bubbles)

b. $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

c. Decomposition – one thing breaks down into more than one thing

3. a. Varied by student – they should mention one or all of the following: production of heat (change in temperature), change in color, formation of a precipitate

b. $2Al(s) + 3CuCl_2(aq) \rightarrow 2AlCl_3 + 3Cu(s)$

c. Single Displacement – one element takes the place of another, leaving one element on its own

4. a. Varied by student – they should mention one or all of the following: change in color, formation of a precipitate

b. $3CuCl_2(aq) + 2Na_3PO_4(aq) \rightarrow Cu_3(PO_4)_2(s) + 6NaCl(aq)$

c. Double Displacement – two elements or polyatomic ions switch places

5. a. Varied by student – they should mention a color change

b. $2Cu(s) + O_2(g) \text{ --> } 2CuO(s)$

c. Synthesis – one thing is made from more than one thing

6. a. Varied by student – they should mention one or all of the following: production of

light, production of a smell, production of heat (change in temperature)

b. $C_{25}H_{52}(s) + 38O_2(g) \rightarrow 25CO_2(g) + 26H_2O(g)$

c. Combustion – something reacts with oxygen, forming carbon dioxide and water

7. **Only two are required**

a. Aqueous hydrogen peroxide breaks down into liquid water and oxygen gas.

b. Solid aluminum combined with aqueous copper (II) chloride. Aqueous aluminum (III) chloride formed, along with solid copper.

c. Aqueous copper (II) chloride combined with sodium phosphate. Solid copper (II) phosphate and aqueous salt solution was formed.

d. Solid copper reacted with oxygen gas, forming solid copper oxide.

APPENDIX F: STUDENT INTERVIEWS

Below are the list of questions (and possible follow up questions) students were asked during the Student Interview after the laboratory activity.

Before starting the interview, students were told: "Participation in this interview is completely voluntary. Your responses will help me better understand students' perspectives on the pre-lab activity and how it may have affected your lab experience. You don't have to answer any question you don't want to, and you can stop the interview at any time."

1. How do you normally feel before starting a lab in chemistry?
    a. Is there anything that helps or would help you feel ready for a lab?

Pre-Laboratory Activity Experience

2. You completed a [pre-lab video / pre-lab questions] before the lab. What did that activity involve?
    a. What parts felt most useful?
    b. What felt unnecessary?
    c. What was confusing or unclear?
3. Think back to pre-lab activities you have done before in chemistry. Did this one feel more or less effective for getting you ready to do the lab?

Preparedness and Confidence

4. Before starting the lab, how prepared did you feel to perform the experiment?
    a. What helped you feel that way?
    b. Was there anything you were unsure about before starting?
    c. Do you think your [pre-lab video / pre-lab questions] influenced your confidence? How?

5. How confident did you feel handling the equipment and chemicals?
    a. Do you think your [pre-lab video / pre-lab questions] influenced your confidence? How?
6. Let's say you were getting ready to do another lab with similar expectations, chemicals, and safety. What type of pre-lab activity would help you feel most prepared or confident?
7. While you were doing the lab, did you remember or use anything from your pre-lab activity?
    a. Can you give me an example?

Reflection and Comparison

8. [Pre-Lab Video] If you had the choice between pre-lab videos and pre-lab questions, which would you prefer, and why?
    a. Do you think your choice would change depending on the type of lab?

[Pre-Lab Questions] If you had the opportunity to choose a pre-lab activity, what type of activity would you prefer and why?

    b. Do you think your choice would change depending on the type of lab?

9. What would make pre-lab activities more helpful or engaging for you?
10. Is there anything else you'd like to share about how the pre-lab activity affected your learning, preparation, or confidence in this lab?

APPENDIX G: TEACHER OBSERVATIONS

Teacher Observations will be made while students complete the laboratory activity. Specific behaviors will be searched for and marked with a tally. A separate sheet will be used based on pre-laboratory activity assigned, and one or two partner groups per class period were observed. Additional notes were made as needed.

Observations to Target Student Preparedness				
Behavior	Positive Examples	Positive Tally	Negative Examples	Negative Tally
Follows Procedure	Begins with minimal teacher intervention Makes little to no mistakes while doing the laboratory		Requires multiple prompts to begin Makes several mistakes while doing the laboratory	
Uses correct equipment	Gathers correct materials on the first try		Does not gather correct materials on the first try	
Follows Safety Expectations	Puts on goggles without prompting Follows additional safety rules without prompting		Requires prompting to put on goggles Requires prompting to follow additional safety rules	
Correct Waste Disposal	Disposes of waste correctly without teacher intervention		Disposes of waste correctly only with teacher intervention	
Efficient Use of Time	Uses time effectively Not easily distracted by peers		Does not use time effectively Easily distracted by peers	

Observations to Target Student Confidence				
Behavior	Positive Examples	Positive Tally	Negative Examples	Negative Tally
Begins Lab Immediately	Student sets up and starts without waiting for peers to start first		Waits for others to get started before getting up Waits for peer or teacher to tell them to get started	
Positive Body Language	Good posture Focused facial expressions Calm and engaged demeanor No visible signs of anxiety		Poor posture Gazing off into the distance/spacing out Boisterous (behavior not appropriate for a lab) Visible signs of anxiety (e.g. picking, fidgeting, etc)	
Asks Appropriate Questions	Asks clarifying questions relevant to lab (questions that are not answered in the procedure)		Ask questions that are clearly answered in the procedure Doesn't ask questions when it is evident the student needs help	
Active Participation	Takes an active role in participating in the lab		Sits back and watches partner do the work Simply records notes – does not take initiative	

	Delegates jobs to partner Takes initiative		for an active role in the lab Only participates when prompted by partner or teacher	
Collaboration	Collaborates well with partner Doesn't get distracted by other nearby groups Answers peers' questions		Doesn't speak to partner or interact without partner prompting Easily distracted by nearby groups	

APPENDIX H: CUMULATIVE ASSESSMENT

CHEMICAL REACTIONS TEST – VERSION A

Name _____ Period _____ _____/23

Learning Goal 4-A:: I can identify the parts and the types of chemical reactions.

1. Use the chemical equation below to answer the questions. (2 points)

$CH_4 + 4Cl_2 \rightarrow CCl_4 + 4HCl$

   a. List the reactants.

   b. List the products.

   c. How many hydrogen are in the reactants?

   d. How many chlorine are in the products?

2. Match the definition to the type of reaction. (2.5 points)

a. _____ Synthesis	1. One element taking the place of another, leaving one element on its own
b. _____Decomposition	2. Something reacts with oxygen, creating carbon dioxide and water
c. _____ Single Displacement	3. Two or more things come together to make one
d. _____ Double Displacement	4. Two elements or polyatomic ions switch places
e. _____ Combustion	5. One thing breaks down into more than one thing

3. Use the chemical equation below to answer the questions. (1.5 points)

$Ca_3(PO_4)_2 + 3H_2SO_4 \rightarrow 3CaSO_4 + 2H_3PO_4$

   a. How many phosphorus are in the reactants?

   b. How many oxygen are in the reactants?

c. What is one of the polyatomic ions in this equation?

4. Match the definition to the type of reaction. (2.5 points)

a. _____	Synthesis	1. $A + B \rightarrow AB$
b. _____	Decomposition	2. $AB + O_2 \rightarrow CO_2 + H_2O$
c. _____	Single Displacement	3. $AB + CD \rightarrow AD + CB$
d. _____	Double Displacement	4. $AB \rightarrow A + B$
e. _____	Combustion	5. $A + BC \rightarrow AC + B$

5. How many oxygen would there be in this compound? (1 points)

$8Fe(H_2O)_4(OH)_2$

6. Identify the type of the reactions below. (2.5 points)

a. $2AgI + Na_2S \rightarrow Ag_2S + 2NaI$

b. $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$

c. $SnO_2 + 2H_2 \rightarrow Sn + 2H_2O$

d. $2Ni_2O_3 \rightarrow 4Ni + 3O_2$

e. $2Mg + O_2 \rightarrow 2MgO$

Learning Goal 4-B:: I can balance an equation, and explain why equations must be balanced using the Law of Conservation of Mass.

7. What does the Law of Conservation of Mass state? (1 points)

8. Describe a specific example of when we saw evidence of the Law of Conservation of Mass in class. Explain the example, and how it showed the Law of Conservation of Mass. (2 points)

9. Explain how balancing equations makes it so that reactions are following the Law of Conservation of Mass. (2 points)

10. Balance the equation. You MUST show your work in order to receive credit. (2 points)

___$NaHCO_3$ → ___Na_2CO_3 + ___CO_2 + ___H_2O

11. Balance the equation. You MUST show your work in order to receive credit. (2 points)

___Al + ___H_2SO_4 → ___$Al_2(SO_4)_3$ + ___H_2

12. Balance the equation. You MUST show your work in order to receive credit. (2 points)

___C_5H_{12} + ___O_2 → ___CO_2 + ___H_2O

CHEMICAL REACTIONS TEST – VERSION B

Name _____ Period _____ _____/23

Learning Goal 4-A:: I can identify the parts and the types of chemical reactions.

1. Use the chemical equation below to answer the questions. (2 points)

$2ClO_2 + H_2O \rightarrow HClO_2 + HClO_3$

   a. List the reactants.

   b. List the products.

   c. How many hydrogen are in the reactants?

   d. How many oxygen are in the products?

2. Match the definition to the type of reaction. (2.5 points)

a. _____ Synthesis	1. Something reacts with oxygen, creating carbon dioxide and water
b. _____ Decomposition	2. One element taking the place of another, leaving one element on its own
c. _____ Single Displacement	3. Two elements or polyatomic ions switch places
d. _____ Double Displacement	4. Two or more things come together to make one
e. _____ Combustion	5. One thing breaks down into more than one thing

3. Use the chemical equation below to answer the questions. (1.5 points)

$2H_3PO_4 + 3Ca(OH)_2 \rightarrow Ca_3(PO_4)_2 + 6H_2O$

   a. How many hydrogen are in the reactants?

   b. How many phosphorus are in the reactants?

c. What is one of the polyatomic ions in this equation?

4. Match the definition to the type of reaction. (2.5 points)

a. _____	Synthesis	1. $AB + CD \rightarrow AD + CB$
b. _____	Decomposition	2. $A + B \rightarrow AB$
c. _____	Single Displacement	3. $A + BC \rightarrow AC + B$
d. _____	Double Displacement	4. $AB + O_2 \rightarrow CO_2 + H_2O$
e. _____	Combustion	5. $AB \rightarrow A + B$

5. How many oxygen would there be in this compound? (1 points)

$5Fe(H_2O)_4(OH)_2$

6. Identify the type of the reactions below. (2.5 points)

a. $C_2H_6O + 3O_2 \rightarrow 2CO_2 + 3H_2O$

b. $2CaO + 2H_2O \rightarrow 2Ca(OH)_2$

c. $3CaCl_2 + 2Na_3PO_4 \rightarrow Ca_3(PO_4)_2 + 6NaCl$

d. $2Fe + 6HC_2H_3O_2 \rightarrow 2Fe(C_2H_3O_2)_3 + 3H_2$

e. $2Ni_2O_3 \rightarrow 4Ni + 3O_2$

Learning Goal 4-B:: I can balance an equation, and explain why equations must be balanced using the Law of Conservation of Mass.

7. What does the Law of Conservation of Mass state? (1 points)

8. Describe a specific example of when we saw evidence of the Law of Conservation of Mass in class. Explain the example, and how it showed the Law of Conservation of Mass. (2 points)

9. Explain how balancing equations makes it so that reactions are following the Law of Conservation of Mass. (2 points)

10. Balance the equation. You MUST show your work in order to receive credit. (2 points)

___$BaCO_3$ + ___HNO_3 → ___$Ba(NO_3)_2$ + ___CO_2 + ___H_2O

11. Balance the equation. You MUST show your work in order to receive credit. (2 points)

___Na_3PO_4 + ___$MgCl_2$ → ___NaCl + ___$Mg_3(PO_4)_2$

12. Balance the equation. You MUST show your work in order to receive credit. (2 points)

___C_2H_2 + ___O_2 → ___CO_2 + ___H_2O

CHEMICAL REACTIONS TEST – VERSION C

Name _____ Period _____ _____/23

Learning Goal 4-A:: I can identify the parts and the types of chemical reactions.

1. Use the chemical equation below to answer the questions. (2 points)

$2ClO_2 + H_2O \rightarrow HClO_2 + HClO_3$

   a. List the reactants.

   b. List the products.

   c. How many hydrogen are in the reactants?

   d. How many oxygen are in the products?

2. Match the definition to the type of reaction. (2.5 points)

a. _____ Synthesis	1. One element taking the place of another, leaving one element on its own
b. _____ Decomposition	2. Something reacts with oxygen, creating carbon dioxide and water
c. _____ Single Displacement	3. Two or more things come together to make one
d. _____ Double Displacement	4. Two elements or polyatomic ions switch places
e. _____ Combustion	5. One thing breaks down into more than one thing

3. Use the chemical equation below to answer the questions. (1.5 points)

$Ca_3(PO_4)_2 + 3H_2SO_4 \rightarrow 3CaSO_4 + 2H_3PO_4$

   a. How many phosphorus are in the reactants?

   b. How many oxygen are in the reactants?

c. What is one of the polyatomic ions in this equation?

4. Match the definition to the type of reaction. (2.5 points)

a. _____	Synthesis	1. $AB + CD \rightarrow AD + CB$
b. _____	Decomposition	2. $A + B \rightarrow AB$
c. _____	Single Displacement	3. $A + BC \rightarrow AC + B$
d. _____	Double Displacement	4. $AB + O2 \rightarrow CO2 + H2O$
e. _____	Combustion	5. $AB \rightarrow A + B$

5. How many oxygen would there be in this compound? (1 points)

$7Fe(H_2O)_4(OH)_2$

6. Identify the type of the reactions below. (2.5 points)

a. $2Ni_2O_3 \rightarrow 4Ni + 3O_2$

b. $2AgNO_3 + FeCl_2 \rightarrow Fe(NO_3)_2 + 2AgCl$

c. $2Mg + O_2 \rightarrow 2MgO$

d. $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$

e. $Al + 6HCl \rightarrow 3H_2 + 2AlCl_3$

Learning Goal 4-B:: I can balance an equation, and explain why equations must be balanced using the Law of Conservation of Mass.

7. What does the Law of Conservation of Mass state? (1 points)

8. Describe a specific example of when we saw evidence of the Law of Conservation of Mass in class. Explain the example, and how it showed the Law of Conservation of Mass. (2 points)

9. Explain how balancing equations makes it so that reactions are following the Law of Conservation of Mass. (2 points)

10. Balance the equation. You MUST show your work in order to receive credit. (2 points)

___$NaNO_3$ + ___PbO → ___$Pb(NO_3)_2$ + ___Na_2O

11. Balance the equation. You MUST show your work in order to receive credit. (2 points)

___$CaCl_2$ + ___Na_3PO_4 → ___$Ca_3(PO_4)_2$ + ___NaCl

12. Balance the equation. You MUST show your work in order to receive credit. (2 points)

___C_6H_6 + ___O_2 → ___CO_2 + ___H_2O

KEY – VERSION A

1. a. Full Credit: CH_4 and $4Cl_2$ or CH_4 and Cl_2

Half Credit: C, H, Cl

b. Full Credit: CCl_4 and 4HCl or CCl_4 and HCl

Half Credit: C, H, Cl

c. 4

d. 8

2. a. 3

b. 5

c. 1

d. 4

e. 2

3. a. 2

b. 20

c. PO_4 or SO_4 (either answer is considered correct)

4. a. 1

b. 4

c. 5

d. 3

e. 2

5. Full Credit = 48

Half Credit = 64

6. a. Double displacement

b. Combustion

c. Single displacement

d. Decomposition

e. Synthesis

7. Mass cannot be created or destroyed or Mass cannot magically appear or disappear

The addition of information is acceptable (if it is correct), but the phrase above must be included.

8. Varied by student:

Full Credit answers will discuss the PhET simulation students completed or the Mass Exploration Lab (where students completed a vinegar and baking soda reaction in a closed system, gathering mass before and after the reaction)

Half Credit answers will reference another lab or activity done during the unit, but one that didn't gather mass or refer to mass

9. Varied by student – Example:

Mass cannot appear or disappear, so balancing equations makes this true (by balancing the equation we are ensuring that elements are not appearing or disappearing)

10. $\underline{2}NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

Half Credit = balanced but not simplified

No Credit given if there is no work shown

11. **2**Al + **3**H_2SO_4 → $Al_2(SO_4)_3$ + **3**H_2

Half Credit = balanced but not simplified

No Credit given if there is no work shown

12. C_5H_{12} + **8**O_2 → **5**CO_2 + **6**H_2O

Half Credit = balanced but not simplified

No Credit given if there is no work shown

KEY – VERSION B

1. a. Full Credit: $2ClO_2$ and H_2O or ClO_2 and H_2O

   Half Credit: Cl, O, H

b. Full Credit: $HClO_2$ and $HClO_3$

   Half Credit: Cl, O, H

c. 2

d. 5

2. a. 4

b. 5

c. 2

d. 3

e. 1

3. a. 12

b. 2

c. PO_4 or OH (either answer is considered correct)

4. a. 2

b. 5

c. 3

d. 1

e. 4

5. Full Credit = 30

Half Credit = 40

6. a. Combustion

b. Synthesis

c. Double displacement

d. Single displacement

e. Decomposition

7. Mass cannot be created or destroyed or Mass cannot magically appear or disappear

The addition of information is acceptable (if it is correct), but the phrase above must be included.

8. Varied by student:

Full Credit answers will discuss the PhET simulation students completed or the Mass Exploration Lab (where students completed a vinegar and baking soda reaction in a closed system, gathering mass before and after the reaction)

Half Credit answers will reference another lab or activity done during the unit, but one that didn't gather mass or refer to mass

9. Varied by student – Example:

Mass cannot appear or disappear, so balancing equations makes this true (by balancing the equation we are ensuring that elements are not appearing or disappearing)

10. $BaCO_3 + \underline{2}HNO_3 \rightarrow Ba(NO_3)_2 + CO_2 + H_2O$

Half Credit = balanced but not simplified

No Credit given if there is no work shown

11. $\underline{2}Na_3PO_4 + \underline{3}MgCl_2 \rightarrow \underline{6}NaCl + Mg_3(PO_4)_2$

Half Credit = balanced but not simplified

No Credit given if there is no work shown

12. $\underline{2}C_2H_2 + \underline{5}O_2 \rightarrow \underline{4}CO_2 + \underline{2}H_2O$

Half Credit = balanced but not simplified

No Credit given if there is no work shown

KEY – VERSION C

1. a. Full Credit: $2ClO_2$ and H_2O or ClO_2 and H_2O

   Half Credit: Cl, O, H

b. Full Credit: $HClO_2$ and $HClO_3$

   Half Credit: Cl, O, H

c. 2

d. 5

2. a. 3

b. 5

c. 1

d. 4

e. 2

3. a. 2

b. 20

c. PO_4 or SO_4 (either answer is considered correct)

4. a. 2

b. 5

c. 3

d. 1

e. 4

5. Full Credit = 42

Half Credit = 56

6. a. Decomposition

b. Double displacement

c. Synthesis

d. Combustion

e. Single displacement

7. Mass cannot be created or destroyed or Mass cannot magically appear or disappear

The addition of information is acceptable (if it is correct), but the phrase above must be included.

8. Varied by student:

Full Credit answers will discuss the PhET simulation students completed or the Mass Exploration Lab (where students completed a vinegar and baking soda reaction in a closed system, gathering mass before and after the reaction)

Half Credit answers will reference another lab or activity done during the unit, but one that didn't gather mass or refer to mass

9. Varied by student – Example:

Mass cannot appear or disappear, so balancing equations makes this true (by balancing the equation we are ensuring that elements are not appearing or disappearing)

10. $\underline{2}NaNO_3 + PbO \rightarrow Pb(NO_3)_2 + Na_2O$

Half Credit = balanced but not simplified

No Credit given if there is no work shown

11. **3**$CaCl_2$ + **2**Na_3PO_4 → $Ca_3(PO_4)_2$ + **6**NaCl

Half Credit = balanced but not simplified

No Credit given if there is no work shown

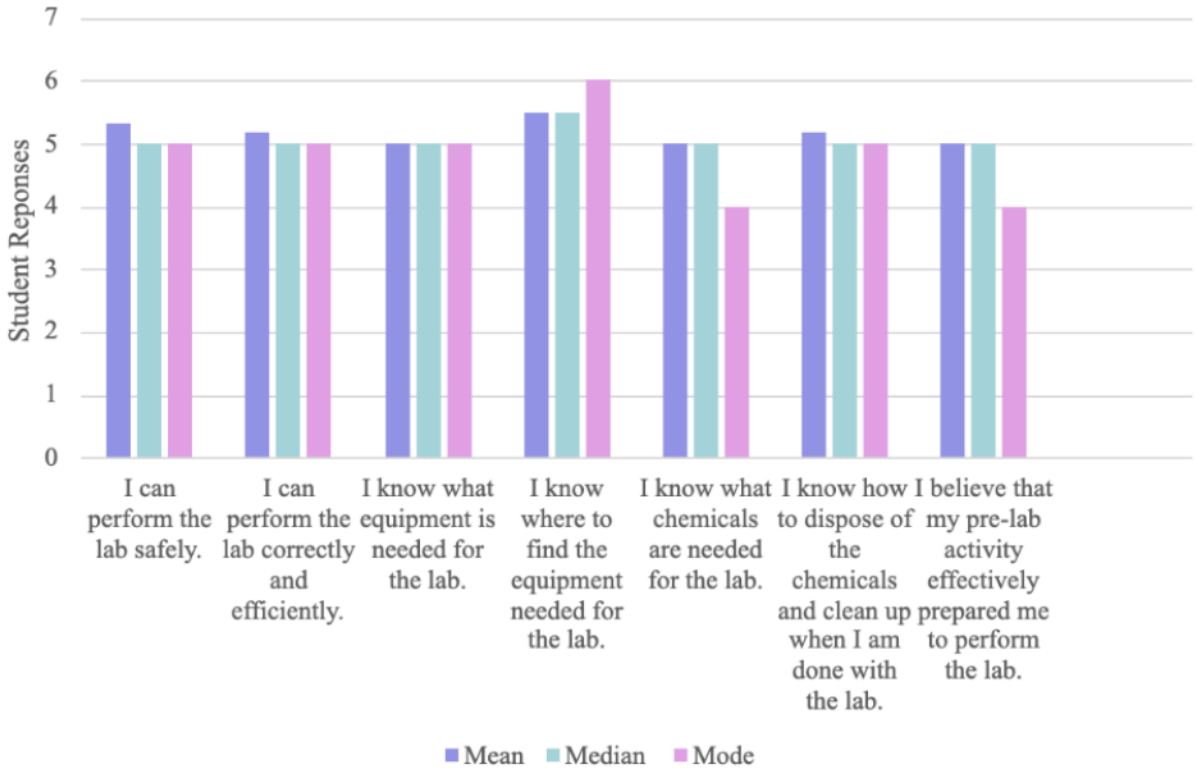
12. **2**C_6H_6 +**15**O_2 → **12**CO_2 + **6**H_2O

Half Credit = balanced but not simplified

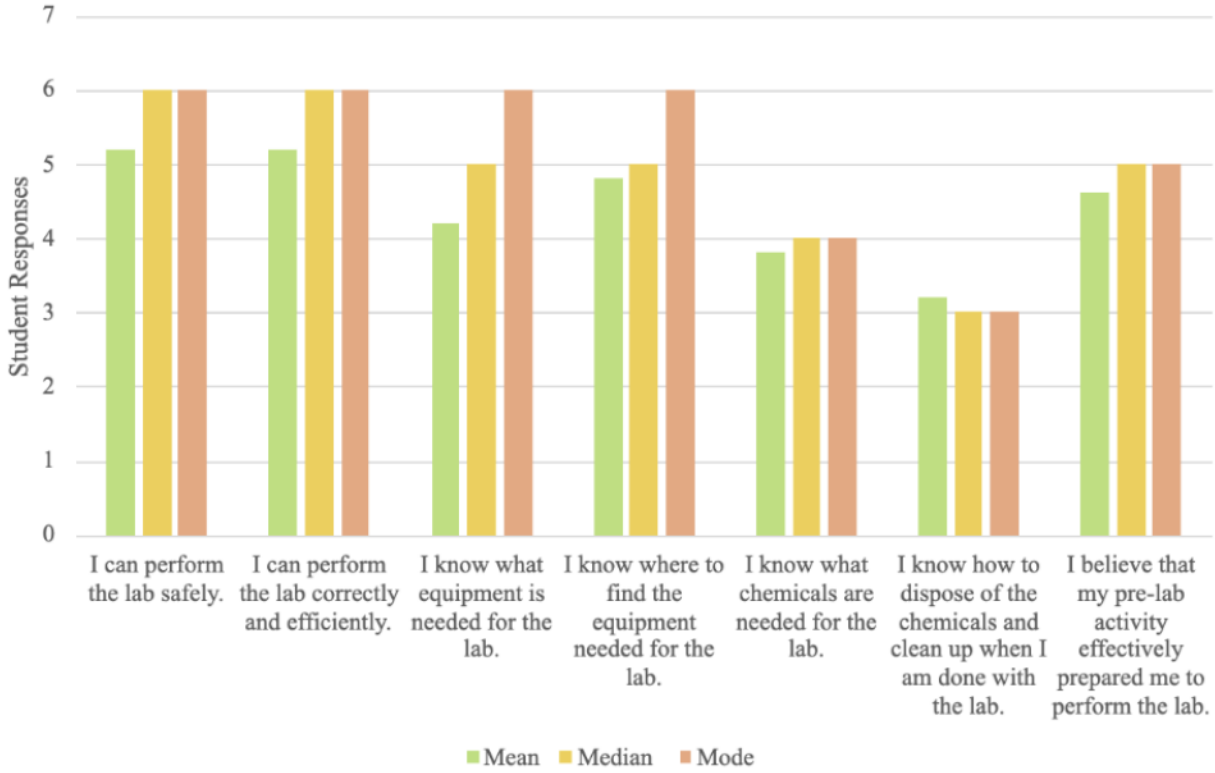
No Credit given if there is no work shown

APPENDIX I: PRE-LABORATORY SURVEY RESPONSES:

MEASURES OF CENTRAL TENDANCY



Mean, median, and mode values for Pre-Laboratory Survey prompts relating to student preparedness for the laboratory activity, as reported by students who were assigned the pre-laboratory video, (n=6). Refer to Table 2 for the meaning of numbers.



Mean, median, and mode values for Pre-Laboratory Survey prompts relating to student preparedness for the laboratory activity, as reported by students who were assigned the pre-laboratory questions, (n=5). Refer to Table 2 for the meaning of numbers.