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The Difference in High School Chemistry Students' Ability to Retain Science Concepts when Performing Virtual Versus Hands-on Labs

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The Difference in High School Chemistry Students' Ability to Retain Science Concepts when Performing Virtual Versus Hands-on Labs

by

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Abstract

This research evaluated high school chemistry students' science lab quiz scores after they performed multiple chemical reactions labs in two different formats: virtual and hands-on approaches. Virtual labs were performed by the researcher using a video format where the lab was set up and performed with no student contribution, and hands-on labs were performed by students in their lab groups with little teacher contribution. Minor teacher-led safety measures were taken to ensure student safety. Students who performed a virtual lab for the first lab were required to perform the second lab using the hands-on lab to accurately evaluate data when students perform each type of lab format. During each lab, students identified observations and results of the lab and participants were assessed using a lab quiz within a week and at the end of the trimester to identify short-term and long-term retention of material.
Independent T-Tests indicated 95% confidence that the variance (means) between lab formats were not equal. Test of Between-Subjects (ANOVA) tested differences in gender, race, hour of class, and teacher of the class indicated a 95% confidence that the mean scores were equal across groups when tested with both lab formats. Regarding short term retention, mixed data was observed. The hands-on lab mean score was 9.7% higher than the virtual lab in the first chemical reaction lab and the virtual mean score was 1.3% higher than the hands-on lab in the second chemical reaction lab. Long-term retention appeared to drop most significantly in the hands-on lab groups with a mean decrease of 21.25% compared to a decrease of 14.22% for students who performed virtual labs. Qualitative data suggests that students prefer hands-on labs and feel that they learn more with a deeper understanding; however, the results do not clearly show the validity from the students surveys and in fact show the opposite regarding long-term retention attrition rates. The results of the study provide arguments for both formats of lab and ultimately requires more data, more labs, and more participants to confidently answer the research questions.

Keywords: virtual, in-person, hands-on labs, VARK

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Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

With the 2020 and 2021 pandemic school years in the rearview mirror, it is evident that students learn in different ways. Long-term retention of science concepts vary significantly when students were in an actual classroom versus at home watching online lessons and labs. The rise of the digital era has contributed to the increasing amounts of online resources and school classes for students. The question remains whether digital learning can completely replace in-person learning and hands-on labs.

It has been shown that when courses are primarily online, there is roughly a 10-20% higher failed retention rate compared to students who are in a physical classroom setting (Herbert, 2006). The past year and a half has shown anecdotal evidence that students can have difficulties identifying and grasping main connections between science concepts taught in class and real-life applications when primarily utilizing online or virtual labs and resources. Despite anecdotal evidence, statewide science test scores have decreased since the start of the COVID-19 pandemic.

In Minnesota, science test scores in the high school have changed in regard to percentages of students not meeting, partially meeting, meeting, or exceeding standards. According to the Minnesota Department of Education, MCA scores were obtained from 2019 and 2021: pre-pandemic and post-pandemic. Scores were not obtained in 2020 due to the MCA test not being administered. The following scores are listed in Table 1.1.

Table 1.1

MN MCA Science Scores

	Year		
MN Science Test Scores	2019 (%)	2021 (%)	Difference (%)
Did not meet	23.9	25.8	1.9
Partially met	21.8	25.9	4.1
Met	38.5	36.0	-2.5
Exceeded	15.9	12.4	-3.5

Despite statewide test scores decreasing, educators have tried to provide material that is beneficial to their students.

K-12 schools have adapted to the growing pandemic, and educators produced virtual resources for their students to facilitate and continue education when the student's physical school buildings were closed. Similarly, universities around the United States have made online classes more accessible for non-traditional students who have full-time jobs or long commutes to be able to eliminate in-person meetings for worry of the continued spread of the COVID-19 virus. One major problem with online courses is the attrition rate. In 2006, Tyler-Smith identified in a literature review that upwards of 40-80% of students drop out of online courses at some point in their educational career. Four broad categories have been determined to affect online drop-outs the most: personal reasons, job-related reasons, program-related and technology-related reasons. Subsections of each of these reasons included family problems, difficulty of working a full-time job and completing an online course, lack of interest, and the learning environment was too de-personalized (Willging & Johnson, 2009). De-personalizing classes often reduces the need for students to work with other individuals in a physical setting and gain different learning experiences.

With the utilization and development of virtual resources and classes, materials have greatly increased in the past twenty years; however, there is an argument to be made that learning and experimenting with peers at a lab bench is irreplaceable. Fleming and Mills developed the VARK model, a model of identifying a person's preference for visual, aural/auditory, read/write, or kinesthetic modes of learning (Fleming & Mills, 1992). Fleming and Mills outline that individuals learn differently and typically have a specific preference between the four categories but can benefit when multiple modes of learning are presented. The purpose of this Master's study is to research and identify retention of science concepts between different lab formats. Students were given instruction on chemical reactions and labs were used to reinforce this concept to further their understanding. The initial research question ultimately was driven from teaching high school science during the pandemic is the following: *Will students who participate in a hands-on science lab retain the science concept more, less, or equal to students who participate in the same lab virtually?* A second question arose from the first: *Will gender, race, class section, or course teacher affect a student's ability to retain the science concept when paired with a different type of lab formats?*

Literature Review

The American Chemical Society (ACS), a foremost supporter and leader of science inquiry and research investigations issued their public policy statement for 2020 which recognizes that virtual resources and labs can increase exposure, reduce costs associated with lab materials, and eliminate hazardous waste and concerns with safety. The ACS also states that these practices cannot be considered to have the same equivalence as a hands-on laboratory and in class hands-on labs should not be fully replaced with virtual equivalents (ACS, 2020-2023). Similar claims have been made by the National Science Teaching Association (NSTA) regarding the inability to substitute computer simulations and teacher demonstrations for actual hands-on labs for students (NRC, 2006, p. 3). Inquiry based labs are valuable at every level from preschool through college if they follow the four specific declarations of the NSTA: Labs have a definite purpose clearly communicated to students, focus on processes of science to convey content, incorporate ongoing reflection and discussion and enable students to develop safe lab practices and procedures (NRC, 2006 p. 101-102). When labs incorporate the four declarations, students benefit from hands-on inquiry labs, along with gaining experience communicating and listening with lab partners and physically building lab setups.

In the general population, individuals tend to lean toward a specific learning model in the VARK system and prefer a primary mode of instruction; however, learning is not as black and white as picking a singular mode to learn. Fleming, one of the two researchers who developed the VARK model, identified that the majority of learners are multimodal, meaning that it is common to mix and match the different types of learning. Two thirds of learners tend to be multimodal and learn best when they combine at least two of the modes (Fleming, 2012). This would suggest that in a science classroom, hands-on activities such as labs will be beneficial to at least 66% of students if they can learn visually or with an auditory component. Regardless of the mode of learning students prefer, educators must be able to build upon prior knowledge and facilitate learning by utilizing scaffolding, a method where teachers offer support when students are learning a new skill.

From the beginning of the school year, scaffolding of science material and lab preparation is detrimental. With the difficulty and complexity of a science lab, the importance for the instructor to facilitate learning by assisting students early on is key. According to Dickson et al. (1993), students need to be given specific prompts regarding content, materials, and tasks to optimize learning. Students in their K-12 years receive different training from their counterparts across the country because teachers do not teach identical methods and material across the United States. Depending on the school, science departments may start this training at an elementary, middle school, or high school level, creating an unequal playing field for students. Regardless of when students experience scientific lab, skills such as making observations, inquiry, and the ability to understand results should be taught at the beginning of a school year. When scaffolding and support are applied early, students are able to independently apply new skills and strategies to maneuver themselves through a specific task or problem. (Rosenshine & Meister, 1992). Learning models, lab techniques and scaffolding all play a significant role in a student's ability to understand a learned concept. It is important to identify the positive and negative aspects of both hands-on and virtual labs.

Hands-on Labs

Labs in a classroom setting have been a staple for K-12 students as long as schools have been functioning and teaching science. In general, labs are meant to serve multiple purposes: provide deeper understanding of a concept taught in lecture, increase student's ability to follow directions, and to analyze information regardless of the outcome. There tends to be a more intimate relationship between the student and the science concept when taught through multiple methods. A study dating back to 1924 reported that when labs are coupled with textbook and memory work, students typically provide better recall than from just textbook/memory work alone (Bowers, 1924). Although the small study indicated results justifying science labs, other researchers have identified a lack of complete evidence proving the importance of labs on a large scale. Bowers data is minimalistic in that his exams consisted of few questions and only utilized first year university students.

Despite Bowers' argument of the importance of laboratory work, other researchers have made claims that prior studies lack significant data to make the complete claim that hands-on labs are beneficial to students' learning (Hofstein & Lunetta, 1982). A chemistry professor at Miami University in Ohio identified that there is not strong enough evidence to determine that students in general chemistry classes benefit from labs (Bretz, 2019). Bretz identified that educators do not use sufficient information for their utilization of labs in the classroom and instead carry on with labs that may not be reinforcing the science concepts that are being taught. Contrary to this information, at an undergraduate level, a bachelor’s degree in chemistry needs to utilize up to 400 hours of laboratory experience that must not be virtual or simulated labs (ACS, 2015).

Bretz has made valid claims that teachers and professors need to take a look at the evidence from their own data to assess the validity of performing certain labs (Bretz, 2019). As stated earlier in the brief literature review in Chapter 1, the NSTA outlines four specific recommendations that all teachers should follow before implementing a lab to their students. Educators who are not constantly looking at data from their schools and using labs that are redundant may be losing large sums of money paying for chemicals plus the time and resources spent disposing of harmful chemicals. Regardless if science teachers were using data or not to utilize science labs that encourage and facilitate deeper learning in the past few years, teachers were still forced to adapt to a digital and virtual format to continue educating students during the COVID-19 pandemic.

Virtual Labs

Virtual labs are relatively new to many parts of the United States or individuals in the world due to multiple reasons. First, recent adaptation and usage of the internet has brought more opportunities to provide students with a deeper knowledge of topics that were unavailable in typical classroom textbooks. The vast majority of the United States of America has the capability to access high speed internet; however, this is not always accessible for individuals of color and low income families. In 2015, 15% of all Americans did not have access to high speed internet, but this number greatly increased when accounting for Hispanics and African-Americans. 25% of Hispanics and 23% of African Americans throughout all income levels did not have high speed internet. To make this matter worse, 41% of African American and 38% of Hispanic families earning less than $30,000 per year did not have high speed internet (Anderson & Perrin, 2018).

Second and most recently, students were required to stay at home due to school closures. Since the start of the pandemic, nearly 1.5 billion students around the world dealt with school closures including students enrolled in pre-primary, primary, lower-secondary, and upper-secondary levels of education (United Nations Educational Scientific and Cultural Organization (UNESCO), n.d). Educators who previously did not utilize digital and virtual resources had the opportunity to learn new educational technologies to improve their students' ability to continue learning. When polled, 87 percent of educators believed that they had improved their ability to utilize educational technologies during the time when their schools were forcefully closed by the government or based on area COVID-19 cases (Bushweller, 2020). For most school districts, the use of virtual resources or online classes do show clear benefits.

Science teachers spend hours setting up and tearing down hands-on labs and spending the majority of science department budgets on chemicals and supplies. When schools were preparing to teach their students via virtual setup during the pandemic, students were unable to take chemicals, equipment, and other materials home which allowed schools to reduce spending on science materials and paper copies for each student. Davenport et al. (2018) performed a study that used virtual labs in different scenarios including using them in place of in-person labs, in addition to in-person labs or as a review. Regardless of the scenario, students learned and made gains on the test scores; however, the largest increase was from students who used the virtual labs as a review. Virtual labs can be initially difficult to find or difficult to justify effectiveness. Companies and universities are constantly developing more resources such as the Phet Interactive Simulations through the University of Colorado Boulder.

The University of Colorado Boulder has simulations for physics, math, chemistry, biology and earth science, and according to the university, there have been 1.1 billion uses/downloads of the simulations (University of Colorado Boulder, 2022). Simulations offered through the University of Colorado Boulder are free and provide a simple and clear purpose. They are easily understandable and acceptable for educators to utilize in a 50 minute class period where time for lab setups can be hindered. Online simulations have been proven to be beneficial as was indicated when physics students were analyzed after performing a lab using simulations, students using hands-on lab equipment, and students who did not perform the lab. The students who used simulations were able to outperform the other two groups using a conceptual survey, coordinated task of building a circuit and understanding how the circuit worked (Finkelstein et al. 2004). Similar to research performed on hands-on labs, simulations can succeed or falter based on the setup. Extensive initial setup can ensure that simulations are a productive education tool (Adams et al. 2008).

Despite previous studies to show the effectiveness of virtual labs, not all are comparable. In 2018, Miller and colleagues performed a study on a group of non-science major undergraduate students that had taken an introductory science class to evaluate and compare in-person labs and virtual labs. The data obtained identified that when given a pretest and posttest regarding contents from the labs, the group of students who scored higher was from the group without the virtual component. Because Miller et al. (2018) had given a pretest and posttest, conclusions were made regarding the fact that both groups, virtual and in-person, did have gains from the pretest to the posttest.

The literature review provides both positive and negative examples of using in-person and virtual labs without a clear indication as to which is more effective when utilizing high school chemistry students throughout multiple labs. Many educators, including the author, have preferences to in-person labs, but as education continues to develop, educators should also be able to evolve their teaching styles and methods. Scheckler (2003) concluded that both lab formats should be used but each cannot always replace the other (Scheckler, 2003). Besides virtual labs being an effective tool if performed correctly, material costs can be reduced short and long term. The science budget at the school where this research takes place has been reduced to one third within the last ten years and continues to be decreased every year. Administrations that are aware that in-person labs have little benefit to their students may reduce science department budgets even further as to save the district money or employ more support staff with these funds.

This study evaluates major differences between student's scores when performing virtual versus hands-on labs to better inform the researcher and other science educators.

Definition of Variables

Independent variables: Lab format, lab quiz questions, gender, race, class section/hour, and teacher.

Dependent variable: Student's lab quiz scores.

Significance of the Study

During the end of the 2019 year and entire 2020-21 school year, digital learning and virtual lessons were necessary to continue the schools' ability to stay open. Students were still able to learn different standards; however, in a virtual setting usually at home. Prior to the COVID-19 pandemic, the use of virtual resources had not been adopted by all educators. Before the pandemic, science educators have believed that hands-on learning is better for all students regardless of their preference in the VARK learning model. During the pandemic, it became clear that certain students who previously struggled during in-person school excelled at home and preferred to watch labs provided by their teacher. One of the common comments that came up from students was that when they were able to watch the teacher perform the lab, they knew that it would be done correctly, efficiently, and at a pace where they could understand. For some students, the speed of a lab in a 45 minute class period is too accelerated. Given this fact, students who preferred to do things more slowly and carefully could rewind and watch the teacher multiple times if they did not understand the information the first time. With nearly 49.4 million students attending public schools and 4.7 million attending private schools in 2019-2020, there could be a substantial amount of learners who prefer the different methods of teaching that the pandemic has brought about (NCES, 2020).

According to the National Center for Education Statistics, there were roughly 130,930 schools (public and private) and 6,500 postsecondary institutions in 2017-2018. The NES also provided information showing that every state in the United States requires at least one science credit which translates to one year to graduate. At most, many states choose to require four years of science in order to graduate. Students will spend countless hours performing labs that may or may not increase their ability to maintain understanding of the science concept that is taught. At the end of the study, the results will help educators decide whether or not to use virtual/digital labs, hands-on labs, or a combination of both for students who have different preferences.

Chapter 2: Methods

The research study is to identify if students who participate in hands-on lab activities will score higher, similar, or lower on an assessment that tests for the specific science concept taught in class compared to students who perform the same lab virtually. Students performing the lab via a virtual setup will watch the teacher setup and perform the lab through a video format on a computer provided to them through the technology department.

Measurements were recorded using quantitative and qualitative analysis. Lab quiz scores were obtained from students within one week after they performed each lab. Two labs were used for students to have the opportunity to work on a virtual lab and hands-on lab for the chemical reactions unit. Qualitatively, the survey at the end of the study identified preferences, likes and dislikes and future preferences, and if the lab format was able to increase knowledge of chemical reactions. The data was collected in the second trimester of the 2021-2022 school year in a high school chemistry classroom that consists mainly of students who are in 11th grade.

Research Ethics

To conduct research on human subjects, SCSU’s Institutional Review Board (IRB) approved this research to move forward and be conducted. Authorization was obtained through the district office at the local school, and parent/guardian permission slips were sent home with students. A copy of the letter is found in Appendix A.

Informed Consent

Assurance was given regarding the protection of human subjects' information that participated in the research study. The majority of participants were minors, which required a signed permission form from parents or guardians. The researcher read through the letter to the students, identifying that their names would not be used in the study. Participants were aware that the research was to be conducted to satisfy the researcher's Master Degree. Parents were advised to read through the permission slip and to sign to allow their child to participate and have scores recorded for the study. At any point, students could choose to not have their information used in the study without penalty. They were given the option of withdrawing at any point. This research was conducted only after students and parents had been informed of the study and consent was received. Students and parents were able to decline involvement in the study and informed them that they could leave the study at any time. The use of a virtual lab does not create any concerns for student safety or concerns for negative effects on student learning progress. All survey responses and interview questions were coded to create anonymous data with no information that could identify individual students in the study.

Students were given the option to participate in the study with parental permission slips sent home. 59 students returned their parental consent forms that gave approval for the researcher to use their data in the study. 10 students never returned their parental consent form so their data was omitted from the study. Participants with signed parental consent forms were given a qualitative survey regarding the lab format and names were not collected or could be optionally omitted.

Context of Study and Setting

The school is in a rural area in the Midwest serving multiple communities and towns. The school district allows open enrollment which may bring in students from other nearby towns with different backgrounds and socioeconomic statuses. On average, each grade has 100-125 students totaling roughly 500 students in the high school. Individual class sizes range from 10-24 students. 75.4% of the high school students are white with a minority percentage of 24.6%. The majority of students who are from a minority group are Hispanic or Latin American and 6% of students are English Learners (EL). Students come from families with differing economic status and family structures. Participants of the study are all in the senior high school.

Participants

The participants of the study were enrolled in the general chemistry course at the researcher's school. The course consists of three trimesters within an entire school year. At the beginning of the second trimester, there were 69 students enrolled throughout four chemistry classes. Students in the study were 49% male and 51% female. 77% of participants identified as white, 13% identified as Hispanic/Latino/Spanish origin, and 9% identified as being two or more races. Ages of students ranged from 16-18 years of age.

Data Collection

Instrumentation and Technology

Students performing the hands-on labs did not utilize specific technologies during the lab. Students who performed the lab virtually were given school owned HP Chromebooks or had the option of using their own computer to watch the video of the researcher performing the lab. Students were not permitted to utilize cell phones to watch the video. This restriction was utilized to eliminate the possibility of students using a smaller screen when compared to others who had a large computer screen to view the video.

Data collection was obtained through the use of google forms and spreadsheets. Students took each lab quiz on a device that could be placed into locked mode. Locked mode is used so that students can only view the quiz on their device and eliminates the possibility for students to look up answers on the internet or communicate with other students for answers. Once students submit their quiz, the score is logged with all of their answers. Data from students who were unable to obtain a parent/guardian consent form was deleted along with all participating student's identifying information. The SCSU statistics department analyzed and ran the collected data through their specific programming. Independent T-tests, Tests of Between-Subjects ANOVA, and Levene's test were used to identify differences and confidence intervals.

Quantitative Data Procedure

Within the study, there were four classes that were to be observed containing 17, 24, 18, and 10 students totaling 69 students. First hour contained 17 students, the 3rd hour contained 24 students, the 6th hour contained 10 students and the 7th hour contained 18 students. The classes had a similar composition of individuals identifying as male and female. The majority of individuals in the class were juniors in high school ages 16 to 17 years old; however, there were a few seniors who were 18 at the time of the study. The school operates on a schedule that has 50 minute class periods. The students taking chemistry had either hour 1 (8:10-9:00AM), hour 3 (9:58-10:47), hour 6 (1:16-2:06PM) and hour 7 (2:10-3:00PM).

During the 2nd trimester (November 29th-March 4th), the same chemical reaction labs were chosen for all four classes to complete. Each student completed the same pre-lab where they identified the purpose of the lab, materials used, and a set of procedures that were summarized into their own words. Chemistry labs took two days to complete. Each section had the exact same amount of time to complete the lab and post-lab questions. To eliminate class section bias between the virtual and in-person lab classes, multiple labs were performed: chemical reaction lab 1 and chemical reaction lab 2. The 1st and 3rd hour sections performed the hands-on lab for chemical reaction lab 1 and watched the virtual lab for chemical reactions lab 2. The 6th and 7th hour sections watched the virtual lab for chemical reaction lab 1 and the hands on lab for chemical reaction lab 2.

The classes that performed the lab in class were placed in groups of 3-4 students and worked together to complete the lab. The group members obtained all of the materials including equipment and chemicals to bring to their lab station. Once groups obtained all of the correct materials, they set up and performed the lab using the lab procedures from their summaries they made in their prelab. The groups were able to ask clarifying questions about the lab to the teacher; however, the teacher/researcher was unable to help them set up the lab. Each student recorded observations individually. Qualitative data that students recorded were the physical properties before the reaction, changes during and after the reaction and identifying if the changes were chemical or physical. Once the groups completed the lab on day 1, they had to clean up, dispose of materials in a safe manner and break down their lab stations. On day 2, the lab groups worked together and went through post-lab questions which included writing balanced chemical equations for each reaction and identifying the type of reaction that took place.

The students that watched the teacher/researcher perform the lab via digital/virtual/video platform had the same amount of time to complete the lab. On the first day, students used a computer or tablet and watched the lab being performed by the researcher. The researcher set up the lab and went through all of the materials and chemicals being used in the video. Students in this lab filled out the same lab results, data charts and observation section that the hands-on sections had.

When both groups completed the lab and post lab questions, a lab quiz was given within a week to assess for understanding of the science concepts taught in the lab. The lab quiz was presented via a google form quiz and had multiple choice questions. The questions focused on the purpose of the lab, observations and the overall results. Questions were used to assess a student's ability to balance a chemical equation and effectively identify the products and reactants of each part of the lab. At the end of the trimester which occurred 77 days after the students took their first lab quiz, the same quizzes were given to assess long term retention of the science concepts. These included the same exact questions. Through the 77 days, a Christmas break occurred along with two more chemistry units.

Qualitative Data

Once both of the labs and quizzes were finished, the author of the study provided an end of lab survey that identified preferences to the type of lab, likes and dislikes and future preferences. This was performed after both labs to allow students the opportunity to make comparisons between both lab formats they participated in. The qualitative survey was given shortly after the labs and quizzes to allow recent recall of lab format. Questions can be found in Appendix C.

Data Analysis

At the end of each lab and the end of the trimester, the researcher analyzed the data collected from the google form quizzes, comparing the scores from the students who performed the lab in-person and the students who watched it via virtual platform. The data output was analyzed using different statistical tests.

Independent Samples T-Tests were used to compare the mean scores of the independent groups to determine if there was statistical evidence that the populations were significantly different. This test was used to determine statistical differences between the delivery of the lab and the score. The null hypothesis was that equal variances are assumed and the alternative hypothesis would conclude that equal variances are not assumed. To identify if the variances are not equal, a $p\text{-value} < 0.05$ would indicate a 95% confidence to reject the null hypothesis.

Independent Samples T-tests were run on each lab: chemical reactions lab 1, chemical reactions lab 1 post-trimester, chemical reactions lab 2, and chemical reactions lab 2 post trimester. Tests of Between Subjects and Levene's test were used as an ANOVA test to determine a significant difference in multiple independent variables including race, gender, hour/section, and teacher.

Chapter 3: Results

Through Quantitative and Qualitative analysis, differences in students' quiz scores comparing in-person hands on labs and virtual video format labs were assessed. The following chapter provides a summary of the results obtained via quantitative quizzes and qualitative surveys. Quantitative data is presented in tabular and graphical format to highlight major differences in quiz scores between lab types.

Retention and Participation

Table 4.1

Total Number of Chemistry Students & Number of Students Who Participated in Each Lab Quiz

Description	Number of students
Students enrolled in High School Chemistry	69
Students who completed Chemical Reaction Lab 1 Quiz	53
Students who completed Chemical Reaction Lab 2 Quiz	52
Students who completed Chemical Reaction Post-Trimester Lab 1 Quiz	54
Students who completed Chemical Reaction Post-Trimester Lab 2 Quiz	53

Table 4.1 presents the number of participants enrolled in high school chemistry, students that participated in chemical reaction lab 1, chemical reaction lab 2, and chemical reaction lab 1 post-trimester and chemical reaction lab 2 post-trimester quizzes. Due to consistent student absences in attendance and student's choice not to participate in the data collection portion, there was a reduction in student participation. 53 students completed chemical reaction lab 1 quiz, 52

students completed chemical reaction lab 2, 54 students completed chemical reaction lab 1 post-trimester and 53 students completed chemical reaction lab 2 post-trimester.

Table 4.2 highlights the mean scores for the in-person and virtual lab experience for both chemical reaction lab 1 and 2, mean scores for both post-trimester quizzes and the difference between the scores from the quizzes at the beginning and end of the trimester. Students who performed the hands-on lab for chemical reaction lab 1 had a mean score of 70.47% compared to the students who performed the lab virtually with a mean score of 60.79%. Students who performed the hands-on lab scored 9.68% higher than those who watched the lab virtually. Despite these results, the same did not occur for chemical reaction lab 2. The mean scores were higher in the virtual group with a mean of 83% which was 1.28% higher than the group who performed the hands-on lab (81.72%).

Although scores were lower for the virtual format in chemical reactions lab 1, the post trimester lab quizzes showed that the difference in mean scores when comparing hands-on to virtual decreased post trimester. During chemical reaction lab 1, hands-on lab students had a mean score 9.68% higher than virtual lab students, but this difference decreased to 5.74% at the end of the trimester. The students placed in the hands-on lab had higher mean scores (53.37%) compared to the virtual lab format (47.63%); however, the difference between groups decreased 3.94%. The gap between students' scores for chemical reaction lab 2 ended up increasing from 1.28% to 11.39% at the end of the trimester between students who performed the hands-on lab (56.33%) and the students who watched the virtual lab (67.72%).

For both chemical reaction lab 1 and 2, scores decreased in all post-trimester quizzes regardless of the format but with varying percent decreases. According to the data, students who performed the virtual lab had scores decrease in both chemical reaction lab 1 and 2 13.16% and

15.28% providing a mean decrease of 14.22%. This was contrasted by the students who performed the hands-on labs for chemical reaction lab 1 and 2 where their scores decreased at the end of the trimester by 17.11% and 25.39%, with a mean decrease of 21.25%. Regarding long-term retention, the virtual lab attrition rate for scores decreased less than the hands-on lab mean scores by 7.03% after 77 days. Graph 4.1 reflects the mean scores taken from each type of lab format throughout the study. Results would indicate that there is a difference between mean scores and the lab format but for the data to be considered significant, several statistical tests were utilized to analyze the data further.

Table 4.2

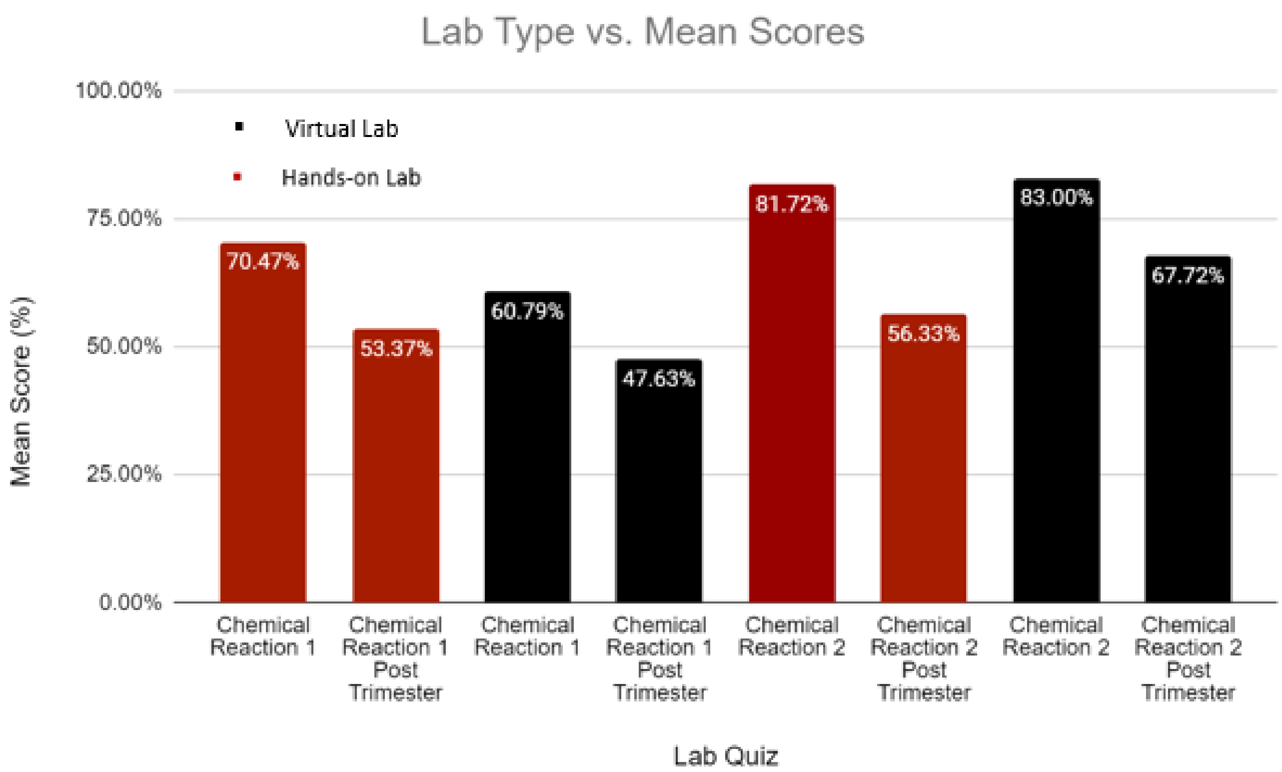
Mean Lab Quiz Scores and Differences

Lab	Format	Mean (%)	Change in Mean (%) (Chemical Reaction quiz - Chemical Reaction Post-Trimester quiz)
Chemical Reaction 1	In Person Hands on	70.47 (16.8)	-17.11%
Chemical Reaction 1 Post-Trimester	In Person Hands on	53.37(19.7)	
Chemical Reaction 1	Virtual	60.79 (19.3)	-13.16%
Chemical Reaction 1 Post-Trimester	Virtual	47.63 (18.8)	
Chemical Reaction 2	In Person Hands on	81.72(12.4)	-25.39%
Chemical Reaction 2 Post-Trimester	In Person Hands on	56.33(12.7)	
Chemical Reaction 2	Virtual	83.00(13.1)	-15.28%
Chemical Reaction 2 Post-Trimester	Virtual	67.72(16.4)	

Note. Standard deviations are presented in parentheses.

Figure 4.1

Mean Percentage Lab Scores for All Lab Quizzes and Formats



Tables 4.3-4.6 indicate the results. Three out of the four labs indicated a p-value < 0.05, rendering the data statistically significant. Data supports a 95% confidence that there is enough evidence to reject the null hypothesis that there are equal variances and accept the alternative hypothesis that variances between the type of lab and score are not equal for chemical reactions lab, chemical reactions lab 2, and chemical reactions lab 2 post trimester. A 95% confidence that chemical reaction post lab post lab mean scores cannot be assumed. The p-value was greater than 0.05 (0.297 and 0.295), indicating that the null hypothesis cannot be rejected and there is not enough evidence to claim that the variances are statistically different. After testing the independent t-test, a Test of Between Subjects (Analysis of Variance) evaluated whether the

mean of a numerical variable (lab quiz scores) changed according to the means of multiple categorical variables.

Table 4.3

Chemical Reaction Lab 1 Independent T-Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence ... Lower
Score (%)	Equal variances assumed	.000	-86.30190%	19.42800%	-125.30525%
	Equal variances not assumed	.000	-86.30190%	19.49100%	-125.56233%

Table 4.4

Chemical Reaction Post-Trimester Lab 1 Independent T-Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence ... Lower
Score (%)	Equal variances assumed	.297	5.73803%	5.45234%	-5.20289%
	Equal variances not assumed	.295	5.73803%	5.40481%	-5.20335%

Table 4.5

Chemical Reaction Lab 2 Independent T-Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence ... Lower
Score (%)	Equal variances assumed	.000	-136.84211%	13.87832%	-164.71754%
	Equal variances not assumed	.000	-136.84211%	11.16484%	-159.26781%

Table 4.6

Chemical Reaction Post-Trimester Lab 2 Independent T-Test

		t-test for Equality of Means			
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence ... Lower
Score (%)	Equal variances assumed	.010	-11.35913%	4.25570%	-19.90280%
	Equal variances not assumed	.007	-11.35913%	4.06091%	-19.52015%

The variables that were tested in accordance with lab format were gender, race, hour the lab occurred in, and teacher of the class. Tests of Between Subjects and Levene's Test of Equality of Error Variance analyzed statistical differences between the scores. The null hypothesis identified that one mean is not significantly different from the other indicating that the means across the groups would be equal. The alternative hypothesis was that one mean is different from the other. Both of these ANOVA tests were used because it cannot be assumed to rely on one piece of information. In all of the results from the Tests of Between Subjects and Levene's Test of Equality of Error Variance, there was never a p-value < 0.05. The null hypothesis was rejected and assumed that the means across the groups tested were equal. The research shows that there were not major statistical differences between race, gender, hour the lab occurred in, and the teacher of the class for any of the lab formats despite minor occurrences.

Three instances occurred in the Tests of Between Subjects where the p-value was below 0.05, but this only occurred with one variable. During chemical reaction lab 1, the p-value = 0.000, indicating a statistical significance that the hour had an effect on the mean scores but when paired with the lab format, the p-value = 0.158, rejecting the alternative hypothesis and concluding that there is not a correlation between what hour the student performed the lab and with which specific lab format. Out of all four lab quizzes, chemical reaction lab 1 was the only showing that the hour had an impact on the mean scores. This same phenomenon occurred during chemical reaction lab 2 for gender and race; however, when paired with the lab format, data was insignificant. These two phenomena also occurred one time out of the possible four lab quizzes. Although it is important to note that hour, gender, and race did show statistical significance with p-values < 0.05 indicating that the null hypothesis could be rejected, it is impossible to say with complete confidence that race, gender, and hour has a legitimate effect on mean scores for future labs due to inconsistencies throughout all labs.

Qualitative Surveys

Students were given surveys to complete to highlight current lab preferences, likes and dislikes and future preferences. The following brings attention to the most common statements regarding the hands on and virtual labs. Surveys were broken up according to student's first trimester final grades to identify how high success (A to B grade), mid success (B- to C-), low success (D-F), and EL/Minority students felt about both lab formats. Each grouping was utilized to have four possible grades: (A, A-, B+, and B), (B-, C+, C, and C-), and (D+, D, D-, and F).

High Success (A-B grade)

Students receiving these grades during the first trimester overwhelmingly identified that they prefer hands-on labs currently and would continue to perform them in the future. Regarding chemical reaction lab 1 and 2, there were multiple reasons for students to be optimistic. Students commented that "you're able to physically see and touch what you are working with, making it a big difference", "it was easier to see the observations, compared to watching it virtually", and "I like being kept busy and thinking the entire time". Several reasons for disliking hands-on labs were “stuff could go wrong and mess up the lab”, “cleaning up labs can take a while at the end”, and “it stresses me out when teammates are not helpful and don’t know what to do".

Students identified that the virtual labs were helpful and beneficial for the following reasons: “The lab was faster because we didn’t have to wait for the reaction to proceed”, “you can go back and review the video if you missed something/pause to catch up”, and “it was correct, there wasn’t any errors in the reaction”. Overwhelmingly, students in this group identified more dislikes regarding the lab. Major concerns were that it wasn’t as enjoyable to sit and watch the lab virtually, whereas, preferences were shown in the ability to move around and get out of their chairs as seen in hands-on labs. Comments that stood out to describe the downfalls of the virtual lab specifically were “the inability to get hands-on experience”, “it's kind of easy to zone out while watching the lab”, and “it feels far away and isn’t as memorable as the hands-on lab”.

Mid Success (B- - C- grade)

Similar to the students in the A - B group, preferences for future labs were hands-on; however, there were roughly 15% of students who wanted to see more virtual labs. Students preferred hands-on labs because “they were more fun to do and I got to work with other people”, “we get to mess around and learn”, and “I was able to focus on what was in front of me”. Students in this group had issues with the time constraints, worrying about not performing the lab correctly, and “not being able to go back later and watch like you can with the virtual lab”. The benefits of virtual labs seemed to be more prevalent in this group as they mentioned that they can work at their own pace and by themselves. Other students were concerned that “it was done correctly”, “the teacher explained the information about what was going on”, and a student who had been previously absent appreciated it being online to watch. Dislikes for the virtual lab in this group were similar to the high success group in that many addressed that the virtual lab was “really boring and it is easier to learn when you’re having fun”.

Low Success (D+ - F grade)

From anecdotal experience as a teacher, students who commonly receive low grades throughout the first trimester exhibit low leadership qualities in the lab, expecting other partners to carry the load and perform the majority of the work. This group contained the lowest number of students (4) but were split on future preferences for lab format. The individuals who selected a virtual preference were due to not wanting to work with other people and that they could work alone. On the other hand, one of the students mentioned that it “isn’t fun” to perform virtual labs but they could learn by themselves. The two students who identified their preference for hands-on lab made comments like “you got to see the reactions in person”, and “I’m actually doing the lab so I can understand it more”.

EL/Minority Students

Grades from the first trimester were not utilized for students placed into this category as not all EL/minority students had the same grade. Their perspective was taken to identify any differences in preferences due to their difficulty with the English language and cultural differences. EL students showed a preference toward the virtual labs as they could rewind to increase understanding of a lab and go at their own pace instead of having to rush to finish the lab in a 50 minute setting. Minority students appeared to be 50/50 with virtual lab preference compared to the hands-on lab. Similar to the other groups, students identified that “the virtual lab was boring” and “that the teacher walked us through the lab”.

Chapter 4: Conclusion

The first research question explores whether there is a difference in high school chemistry students' ability to retain science concepts when performing virtual versus hands-on labs. Results from this study shows that there is a definitive difference between virtual and in-person labs. The Independent T-tests rejected the null hypothesis with a 95% confidence that there was no difference between the groups and accepted the alternate hypothesis in three of the four lab quizzes. The data does not show a clear indication that students mean scores were significantly higher in the hands-on lab or vice versa with the virtual lab due to differing outcomes in chemical reactions lab 1 and lab 2.

The second research question explores whether there is a difference in high school chemistry students' ability to retain science concepts when performing virtual versus hands-on labs when combined with race, gender, class section hour, or teacher who taught the course. Results from this study show a clear but not absolute definitive answer. P-values < 0.05 were seen in three of the sixteen possible scenarios (chemical reaction lab 1: hour), (chemical reaction lab 2: gender & race) to show that there was a minor difference between the mean scores and hour, gender, and race but this occurred only once for each of the scenarios. In all other possible labs and variables, the p-values > 0.05 proving that there is not a confidence of 95% that these variables have a notable effect on quiz score outcomes.

Other notable values appeared in the post-trimester quizzes where the students mean scores in the hands-on lab groups fell 7.03% more than the students' mean scores in the virtual labs, indicating a higher attrition rate in the hands-on labs. Both post-lab quizzes identified higher rates of attrition in the hands-on labs compared to the virtual labs. This did not mean that virtual lab scores were always higher than hands-on lab scores since the students who were in the hands-on group had higher mean scores for chemical reactions lab 1 and chemical reactions lab 1 post-trimester quiz. The data is not necessarily indicative of which format is going to produce higher scores but the qualitative data does show preferences to hands-on labs.

It was common for students to identify that they felt like they had learned more or at a deeper level with the in person hands-on lab; however, this does not necessarily match up with what the quantitative data shows. The majority of students, regardless of their grade from the previous trimester, noted that hands-on labs were better for them for many different reasons which were outlined in the above sections. Qualitative data shows that not every student has the exact same feelings about both types of labs and most noted positives and negatives that they took away after performing the labs. It was more common for students with previous high success grades to prefer hands-on labs and for EL/minority students and low success students to prefer virtual labs.

Limitations

A major limitation to the study is a high school student's drive to perform well in a situation that is not a major test. Due to the nature of laboratories, the assessments are scored in a lower percentage category than a summative unit test. When particular students knew the category of the lab quiz/survey, some choose to put less effort as they knew if they scored poorly, it would not affect their end grade significantly. Another limitation to the study is only utilizing two labs in a singular unit. For future research, this could be applied to all units that include more labs to get a larger data set. The results of this study could reflect students' ability to score higher or lower depending on the lab format; however, it is impossible to assume that all schools with all different types of populations of students score in similar ways.

Regardless of possible limitations, the results obtained gave preliminary results and details about students' preferences regarding virtual labs performed by their teacher or labs performed with their peers in a classroom setting. This study used a small sample size at a small school with a diverse population, thereby creating legitimate data. This study can be a framework for future science classrooms utilization of both types of labs as there are clear benefits to both.

Future Implications

After analyzing both qualitative and quantitative data, it is unclear to definitively state whether hands-on labs are more beneficial to a learner in a science class. Anecdotally and qualitatively, it is evident that students prefer to perform hands-on labs, but this is due to multiple reasons, which don't always include deeper understanding of the content. As this research only focused on two labs, future research would be beneficial to see if other chemistry units' labs mimicked the data presented in this research. The data does show a high likelihood to suggest there is a difference in mean scores between students who perform each type of lab but does not show any significant difference in mean scores when linked with other factors including gender, race, hour, or teacher of the class. As the pandemic has brought to attention, there are definitive benefits and downfalls to virtual classes, and teachers need to be able to evolve and accept that there may be new ways of teaching subject matter. Specifically for the researcher, the data has shown that options should be given to students as everyone learns differently and at a different pace. Students found that they benefited greatly from the virtual lab option and would prefer this in the future over being placed in a lab group where they don't feel like they learn as well.

As school budgets for science continue to decrease, hands-on chemistry labs might turn into a thing of the past. Science teachers who are able to perform the lab themselves, record it, and show it to multiple classes could save significant amounts of money that is spent yearly to provide materials. Hands-on lab mean scores did not conclusively show that students learn better and are able to retain the science concept when compared to watching the lab virtually. As the primary researcher and science teacher, I can conclude that I have utilized few virtual labs prior to the COVID-19 pandemic because of the notion that hands-on labs in science are indispensable for everyone, a statement that the research does not support.

Plans for Sharing

Science teachers can benefit from data regarding labs because it is a tool that is used commonly to supplement other forms of instruction. Being in a relatively small school district, there are five other teachers in the science department at the 7-12 level that can benefit from the data that was obtained in this study. As a science team, regular Professional Learning Communities (PLC's) meetings occur to discuss better and more efficient ways to increase learning in the science field, making subjects more applicable to students and their real lives. In our smaller school, each teacher has slightly different teaching methods and attitudes about hands-on and virtual labs.

In the future, specifically in the next two years, it would be beneficial for our science staff to perform virtual labs in accordance with hands-on labs for students who did have preferences toward each type of lab. Students had two years where they were either in a digital or hybrid setting, so both formats should be available to help them transition from what they became accustomed to. At a minimum, a virtual recording of the labs should be available for all students who didn't understand the lab, missed key data and observations, or for absent students who need to catch up and are unable to come in for a lab regardless of the COVID-19 pandemic situation. The ultimate and final goal would be to have the data reviewed and published in a scholarly journal such as *The Chemical Educator, The Science Educator, Journal of Chemical Education* or a similar journal. The researcher wanted to perform research that would help guide other educators to improve the way they teach science and will share my data at education conferences in the state.

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Appendix A: Informed Consent Letter

Title: Student Evaluation of Online vs. In-Person Instruction

Primary Investigator: Felicia Leammukda

Email: STSresearch1@gmail.com

Introduction

Since the beginning of the pandemic, a very well-known concept to students today at St. Cloud State University is distance learning. There have been many ways in which this has been accomplished. Every student has an opinion or preference of what they prefer for their learning. COVID-19 has helped many students across the world better understand what works best for their own education.

Purpose

The purpose of this study is to analyze and collect student impressions on the effectiveness of online versus in-person science instruction.

Study Procedures

A Qualtrics 5 - question survey will be sent out to you. We are intending to analyze the impacts of online learning during the COVID-19 pandemic on science instruction at St. Cloud State University. Responses for this survey, other than one question on page three, will not be utilized for identification purposes in any way, shape, or form. This form will also not be tied to any names or emails unless you specifically input that data on the interview page. All responses are anonymous. If you have further questions or feedback, please email STSresearch1@gmail.com and we will get back to you as soon as we can.

After collecting all responses our research team will conduct interviews with select students who stated they wanted to be interviewed and also analyze the data numerically between sophomores in college and seniors in college.

Risks and Discomforts

The potential risks of this study include the following: Participants may have adverse reactions to the survey questions that are difficult to anticipate. The pandemic impacted people in different ways, and some of those ways could have been traumatic to certain individuals. Because of this, the survey may result in some participants recalling traumatizing times. Should you feel uncomfortable at any point during the study you are free to stop your participation with no consequences. Researchers are able to provide appropriate resources should you feel the need for them.

Benefits

The anticipated benefits associated with this study include the following: Participants in the study will be able to analyze their own learning styles and beliefs, which would improve their overall learning from a metacognitive standpoint. This study would help people in the St. Cloud Area learn more about the impact that the COVID19 pandemic had on students. Along with this, professors and teachers would be able to better learn what worked well in an online educational environment.

Compensation

There will be no compensation for the completion of this study.

Confidentiality

The confidentiality of the information gathered during your participation in this study will be maintained. Your personal identity will remain confidential. You will not be identified by your name in any published material. The interview recordings will only be used for the purposes of analyzing data.

Voluntary Participation/Withdrawal

Your participation in this study is voluntary. You may decide to not participate or to withdraw your consent to participate in this study at any time, for any reason, without penalty. If you would like to withdraw, just email the principal investigator, Felica Leammukda, and let her know. Her email address: felicia.leammukda@stcloudstate.edu

Your decision whether or not to participate will not affect your current or future relations with current or future relationships with St. Cloud State University, researchers or program.

Acceptance to Participate in the Student Evaluation of Online vs. In-Person Instruction Survey via Qualtrics

Your digital signature indicates that you are at least 18 years of age, you have read the information provided above, and you give consent to participate in a Qualtrics survey about your experiences with online learning. The results of the study can be obtained from the principal investigator.

Name (Printed) ____

Signature____Date_____

ST. CLOUD STATE UNIVERSITY
EDUCATION FOR LIFE.

Institutional Review Board (IRB)

720 4th Avenue South AS 210, St. Cloud, MN 56301-4498

Name: Shane McConkey
Felicia Leammukda

Email: cO6464uq@go.minnstate.edu
felicia.leammukda@stcloudstate.edu

IRB PROTOCOL DETERMINATION: Exempt Review

Project Title The difference in high school chemistry student's ability to retain science concepts when performing virtual versus hands-on labs

The Institutional Review Board has reviewed your protocol to conduct research involving human subjects. Your project has been: **APPROVED**

The modified consent form is to be used as sent by IRB reviewer Mili Mathew.

Please note the following important information concerning IRB projects:
- The principal investigator assumes the responsibilities for the protection of participants in this project. Any adverse events must be reported to the IRB as soon as possible (ex. research related injuries, harmful outcomes, significant withdrawal of subject population, etc.).

- For expedited or full board review, the principal investigator must submit a Continuing Review/Final Report form in advance of the expiration date indicated on this letter to report conclusion of the research or request an extension.

-Exempt review only requires the submission of a Continuing Review/Final Report form in advance of the expiration date indicated in this letter if an extension of time is needed.

- Approved consent forms display the official IRB stamp which documents approval and expiration dates. If a renewal is requested and approved, new consent forms will be officially stamped and reflect the new approval and expiration dates.

- The principal investigator must seek approval for any changes to the study (ex. research design, consent process, survey/interview instruments, funding source, etc.). The IRB reserves the right to review the research at any time.

If we can be of further assistance, feel free to contact the IRB at 320-308-4932 or email ResearchNow@stcloudstate.edu and please reference the SCSU IRB number when corresponding.

IRB Chair:

Dr. Mili Mathew
Chair and Graduate Director
Assistant Professor
Communication Sciences and Disorders

IRB Institutional Official:

María-Claudia Tomany

Dr. Claudia Tomany
Associate Provost for Research
Dean of Graduate Studies

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SCSU IRB#: 2058 - 2683	**Type:** Exempt Review	**Today's Date:** 12/3/2021
1st Year Approval Date: 12/3/2021	**2nd Year Approval Date:**	**3rd Year Approval Date:**
1st Year Expiration Date:	**2nd Year Expiration Date:**	**3rd Year Expiration Date:**

Appendix B: Quiz Questions

Chemical Reactions 1 Post Lab Quiz

1. All of the following are important to know why two reactants are being mixed together for a reaction EXCEPT?
   a. To identify if the two reactants will react
   b. To identify if there are safety concerns with mixing the two
   c. To identify the toxicity of waste products formed
   d. To identify a third reactant to mix in to form a reaction
2. What type of changes occurred during the lab?
   a. Chemical
   b. Physical
3. Identify the type of reactions that occurred during lab (single replacement, double replacement, decomposition, synthesis/combination, or combustion).
   a. Hydrochloric acid mixed with zinc
   b. Burning copper wire
   c. Hydrogen peroxide with a potato/catalase catalyst
   d. Burning calcium carbonate
   e. Magnesium with copper (II) chloride
4. During Reaction A1, copper (II) chloride was mixed with magnesium metal. What observation did you identify?
   a. Magnesium metal started on fire and glowed a bright yellow light
   b. The solution turned a bright purple color
   c. The magnesium broke down and a reddish solid formed
   d. Nothing happened
5. During Reaction A2, hydrochloric acid was mixed with a piece of zinc. What observation did you identify?
   a. Zinc turned red once in contact with the acid.
   b. Bubbles formed from the zinc contacting the acid
   c. Smoke formed in the test tube
   d. The mixture produced a rotten egg smell
6. During Reaction C1, what did you observe when the potato/catalase was added to the hydrogen peroxide?
   a. The potato/catalase triggered the hydrogen peroxide to produce bubbles
   b. The potato/catalase triggered the hydrogen peroxide to form a gel-like liquid.
   c. The potato started to break down and disintegrate.
   d. The potato absorbed the hydrogen peroxide.
7. During Reaction C2, what did you observe when calcium carbonate was heated in a Bunsen burner?
   a. The product becomes more brittle and crumbles when cooled
   b. The product turns a black color
   c. The product appears more shiny and clear

   d. The product is immediately flammable and nothing is left over after a few seconds

8. During Reaction D2, what did you observe when copper was heated in the Bunsen burner?
   a. The copper wire turned a black color
   b. The copper wire started to melt
   c. The copper wire emitted a bright green light
   d. The copper wire became brittle and broke when bent.
9. When magnesium metal is added to copper (II) chloride, what element replaces which element?
   a. Magnesium replaces copper
   b. Magnesium replaces chloride
   c. Copper replaces chloride
   d. Chloride replaces magnesium
10. What elements/metals WOULD NOT react with copper chloride? (Check all that apply)
    a. Sodium
    b. Gold
    c. Nickel
    d. Mercury
    e. Aluminum
11. Identify the correct balanced equation for Reaction A2
    a. $Zn + HCl \rightarrow H_2 + ZnCl_2$
    b. $Zn + 3HCl \rightarrow 3H_2ZnCl_2$
    c. $Zn + 2HCl \rightarrow H_2 + ZnCl_2$
    d. $Zn + 2HCl \rightarrow ZnH_2 + Cl_2$
12. Identify the correct balanced equation for Reaction C1
    a. $H_2O_2 \rightarrow 2H + 2O$
    b. $H_2O_2 \rightarrow H_2 + O_2$
    c. $H_2O_2 \rightarrow 2HO$
    d. $2H_2O \rightarrow 2H_2 + O_2$
13. Identify the correct balanced equation for Reaction C2
    a. $CaCO_3 \rightarrow CO_2 + O_2$
    b. $CaCO_3 \rightarrow CO_2 + H_2O$
    c. $CaCO \rightarrow CO_2 + Ca$
    d. $CaCO_3 \rightarrow CO_2 + CaO$
14. Identify the correct balanced equation for Reaction D2
    a. $Cu + H_2 \rightarrow CuH_2O$
    b. $2Cu + O_2 \rightarrow 2CuO$
    c. $Co + O_2 \rightarrow CoO$
    d. $2Cu + CO_2 \rightarrow 2CuC + O_2$

Chemical Reactions 2 Post-Lab Quiz

1. If two compounds are mixed together and there are no changes, this shows what about the reaction:
    a. The changes could be invisible
    b. You didn't put enough of the compound in
    c. the two compounds are not reactive together
    d. the two compounds are not reactive together
2. What type of changes occurred during the lab?
    a. Chemical
    b. Physical
3. During Reaction B1, what observations can you make when copper (II) sulfate is mixed with potassium carbonate?
    a. The solution turns a cloudy light blue color with small solid chunks.
    b. The solution starts to smoke and the solution is hot to the touch
    c. No reaction occurred
    d. The solution turned a light yellow color that bubbled.
4. During Reaction B2, when Barium chloride and sodium carbonate were mixed, what did you observe?
    a. The solution did not react and remained a clear color throughout.
    b. The solution produced gas bubbles
    c. The solution became a gray thick gel/syrup substance
    d. The solution became a cloudy white color
5. During Reaction B3, what did you observe when the Sodium phosphate and potassium chloride were mixed?
    a. A brownish solid formed at the bottom of the test tube
    b. The solution did not react and remained a clear color throughout.
    c. The reaction formed a cloudy white solid
    d. Once mixed, the reaction started to produce a smoke
6. During Reaction E1, what did you observe when hexane was lit with butane lighter?
    a. Hexane was not flammable
    b. Hexane was flammable
    c. Hexane turned to a black ash
    d. Hexane formed a crystalline like substance
7. During Reaction E1, what did you observe when hexane was covered with a beaker?
    a. The flame increased in size
    b. The black solid got smaller
    c. Nothing changed
    d. The flame went out after a short time
8. All show a reaction took place except:
    a. Bubbles form
    b. Mixture boils
    c. Clear liquids turn cloudy
    d. Change in color
9. Determine the reason for your observation in reaction E1 when the beaker was placed over hexane.

a. This reaction needs oxygen to continue
b. The reaction needs carbon dioxide to continue
c. The reaction does not need any air/gas to react
d. The reaction needs to be covered so the wind around doesn't inhibit the reaction.

10. Identify the correct balanced equation for Reaction B1
    a. $CuSO_4 + K_2CO_3 \rightarrow CuK + CO_3SO_4$
    b. $CuSO_4 + K_2CO_3 \rightarrow CuCO_3 + K_2SO_4$
    c. $2CuSO_4 + 3K_2CO_3 \rightarrow 2CuCO_3 + K_2SO_4$
    d. $CuSO_4 + K_2CO_3 \rightarrow CuKCO_3SO_4$
11. Identify the correct balanced equation for Reaction B2
    a. $BaCl_2 + Na_2CO_3 \rightarrow$ No Reaction
    b. $BaCl_2 + Na_2CO_3 \rightarrow BaCO_3 + NaCl$
    c. $2BaCl_2 + Na_2CO_3 \rightarrow 2BaNa + 2ClCO_3$
    d. $BaCl_2 + Na_2CO_3 \rightarrow BaCO_3 + 2NaCl$
12. Identify the correct balanced equation for Reaction B3
    a. $Na_3PO_4 + 3KCl \rightarrow 3NaCl + K_3PO_4$
    b. $Na_3PO_4 + KCl \rightarrow NaCl + K_3PO_4$
    c. $Na_3PO_4 + KCl \rightarrow$ No Reaction
    d. $Na_3PO_4 + 3KCl \rightarrow Na_3K_3 + PO_4Cl_3$
13. Identify the correct balanced equation for Reaction E1
    a. $C_6H_{14} + O_2 \rightarrow H_2O + CO_2$
    b. $C_6H_{14} + CO_2 \rightarrow 7H_2O + CO_2$
    c. $C_6H_{14} + CO_2 \rightarrow H_2O + CO_2$
    d. $2C_6H_{14} + 19O_2 \rightarrow 14H_2O + 12CO_2$

Appendix C: Qualitative Interview Questions

1. Did you prefer watching me perform the virtual lab or did you prefer doing hands-on labs with groups? Why?

2. Based on your previous answer, did that type of lab help increase your knowledge of chemical reactions?

3. In the future, what type of lab would you prefer to perform: virtual or hands on?

4. What did you like about the virtual lab?

5. What did you dislike about the virtual lab?

6. What did you like about the hands-on in person lab?

7. What did you dislike about the hands-on in person lab?