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Cassidy Javner
St. Catherine University

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The Effects of Learner-Generated Multimodal Video on Student Laboratory Reflections in a High School Chemistry Classroom

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In fulfillment of final requirements for the MAED degree

Cassidy H. Javner
Saint Catherine University
St. Paul, MN
Abstract

This action research project looked at the effect of implementing learner-generated multimodal video projects on students’ laboratory reflections in a high school chemistry class at a suburban high school. Fifty students in a 10th-11th-grade chemistry class completed digital video projects in the form of an iMovie or multimodal Google Slides presentation in place of a traditional written laboratory report. Data was collected in the form of a common rubric, unit exam scores, pre- and post-survey data, and teacher observations over the course of two units of study. The analysis of the rubric and survey data showed that the use of a multimodal digital video project improved students’ overall quality and depth of laboratory reflections compared to the traditional written report. However, the results were inconclusive on whether the implementation of the digital video project led to increased understanding, as evidenced by unit exam scores. Further analysis of survey data and teacher observations showed that each form of multimodal video project had its unique benefits and drawbacks. Therefore, further research will continue to be conducted related to the best practices for implementing various forms of multimodal projects in the classroom. Learner-generated multimodal video will continue to be utilized to provide students with more creative and reflective methods to express their knowledge and understanding of chemistry concepts and laboratory experiments.

Keywords: digital video, multimodal, reflection, chemistry
Science and technology play a central role in today’s society. Some of the greatest innovations in the world are the result of advancements in science, such as the harnessing of solar and wind energy, the development of antibiotics and vaccinations, and space exploration. Further, many issues facing society today involve science concepts, including climate change, land and ocean pollution, and genetically modified organisms. Regardless of whether students pursue a profession in science or technology, they will be required to continually participate and engage in political and social conversations surrounding these disciplines. The National Research Council (1996) outlines what it means for someone to be scientifically literate:

A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (p. 22).

Therefore, as a part of science education, it is important to teach students to be scientifically literate. That is, we need to teach students how to critically think and question, explore their curiosity, evaluate the validity of ideas, create meaning from the world, and communicate scientific explanations using a variety of digital tools. Specifically, incorporating the use of digital video in the classroom has the potential to enhance students’ science education experience.

Currently, in K-12 education students are continually learning how to craft a short story, a professional letter, an argumentative essay, or a written laboratory report. However, by the time current high school students graduate, video communication will comprise over 80% of all internet communication (Smith, 2016). “These students have grown up surrounded and shaped by literacy practices related to computers, the Internet, mobile phones, and other ubiquitous
computing devices...these everyday tools bind children and adolescents in a social culture” (Miller & McVee, 2012, p. 2). Therefore, to prepare students to be 21st-century learners, it is important that schools teach students how to effectively communicate and collaborate on these various technology platforms, including digital video. This involves providing meaningful opportunities for students to develop the skills necessary to create, analyze, and evaluate a variety of modes of communication throughout the content areas. When successfully incorporated, digital video “requires students to deepen their understanding of content while increasing visual, sound, oral language, creativity, and thinking skills” (Porter, 2017). The creation of videos in a classroom has the opportunity for students to engage in the material and apply the content to their everyday lives.

Students learn science by asking questions, conducting investigations, making observations, developing models, analyzing data, and explaining ideas (National Research Council, 2012). Traditionally, laboratory investigations are intended to teach students these concepts and skills. However, there is a disconnect between scientific practice, experiments, and the concepts learned in class. These traditional, cookbook style labs provide students with a question, a procedure to follow, and instructions on how to analyze the data and what the data should mean, thereby failing to engage students in developing meaningful conceptual understandings. Students have become “accustomed to a non-reflective, action-oriented mode of work” (Schauble, Glaser, Duschl, Schulze, & John as cited in Loh et al., 2001, p. 282). If students are to fully engage and create meaning from scientific investigations they must be able to learn and reflect on their processes and ideas (Loh et al., 2001). This can be accomplished by providing more opportunities for students to reflect on laboratory investigations. This can be done through the creation of multimodal representations to conceptualize the material (M.
Jarvinen, L. Jarvinen, & Sheehan, 2012). Through multimodal representations, students are required to synthesize information, create connections between concepts, and reflect upon their knowledge (Jarvinen et al., 2012). Digital video provides an ideal platform for multimodal learning because it provides students with the opportunity to combine narration, images, animations, and music to create their videos (Jarvinen et al., 2012). The incorporation of video in a science classroom has the opportunity to not only prepare students for the communication modes of the future but also to provide students will the skills necessary to participate in scientific conversations.

To prepare students to be 21st-century learners, we need to teach students how to collaborate and communicate using a variety of digital tools. Specifically, as part of science education, students should have opportunities to engage in scientific practices including: constructing explanations; engaging in argument from evidence; and obtaining, evaluating, and communicating information. Most of these practices are taught through laboratory investigations. However, high school chemistry students often have a difficult time constructing meaning from laboratory investigations, perhaps due to the result of inauthentic experiments, infrequent opportunities to reflect on laboratory investigations, and lack of opportunities to create multimodal representations of concepts. The purpose of this action research study is to explore how learner-generated video could be used as a strategy to increase both student reflection and the construction of knowledge from laboratory investigations in a secondary chemistry classroom. This action research project specifically addresses two questions: 1) How does the use of an iMovie or multimodal Google Slides presentation affect students’ understanding and application of chemistry concepts in a laboratory experiment compared to the use of a traditional written laboratory report in a 10th-11th-grade chemistry classroom? 2) In what ways does the use
of an iMovie or multimodal Google Slides presentation affect the quality of student’s laboratory reflections compared to a traditional written report in a 10th-11th grade chemistry classroom?

**Review of Literature**

Several studies and literature reviews note the lack of contextualization of concepts from laboratory experiences, such as *America’s Lab Report: Investigations in High School Science* (Hofstein & Lunetta, 2003; Singer, Hilton, & Schweingruber, 2006). For example, Clough (2002) states that:

> For decades, hands-on experiences have been promoted as the solution to helping students learn science. That direct experience will improve students’ understanding seems intuitively obvious, but evidence indicates that such experiences, by themselves, do not lead to scientific understanding of the natural world. (p. 87)

The current move in the science education community is to shift towards implementing more authentic and inquiry-based experiments to engage students’ minds instead of just their hands (Bross, 2008). Clough (2002) noted that it would be unreasonable for teachers to completely shift their laboratory curriculum to all inquiry-based labs and that instead, teachers should modify current experiments to focus more on engaging students critical thinking skills throughout the experiment. This could be accomplished by providing more authentic opportunities for students to reflect on laboratory investigations and create multimodal representations to conceptualize the material (Loh et al., 2001; Tytler, Prain, Hubber, & Waldrip, 2013; Veal, Taylor, & Rogers, 2009). One of these authentic methods is incorporating learner-generated video as a strategy to increase student reflection and the construction of knowledge from laboratory investigations in a secondary science classroom.
Reflective Practices in Science Laboratories

Loh et al. (2001) defined reflection as “the act of stepping back from one’s activity to view actions, objects, system states, or emerging understandings from a different perspective” (p. 283). This could include reflecting on prior knowledge, the goals of the investigation, or the meaning of the results (Loh et al., 2001). Further, the process of reflection involves connecting prior knowledge with new ideas to engage deep thinking (Hung et al., 2013). To consider the importance of reflection in laboratory investigations, the work of Veal et al. (2009) and Hung, Yang, Fang, Hwang, and Chen (2013) should be considered. In general, they found that for students to learn scientific processes and create knowledge, students need opportunities to reflect on their investigative experiences.

Veal et al. (2009) found that when students were asked to perform laboratory skills and verbally explain what they were doing, how they completed the task, and what might have gone right or wrong, their understanding of scientific process skills increased. The self-reflection process allowed students to “observe, critically analyze, interpret, and make decisions” about their actions in the lab and had a positive effect on their overall lab experience (Veal et al., 2009, p. 393). An important part of encouraging successful reflective practices with students is to provide prompts during the reflection process. Hung et al. (2013) noted that initially, learners do not know how to reflect without some guidance and scaffolds provided by the instructor. In their study, students scanned QR codes that provided specific video, text, and picture prompts related to that portion of the experiment. Students were required to answer a variety of open-ended reflection questions based on the video, text, and pictures. The results showed that when provided prompts, students engaged in deeper reflection and for longer periods of time (Hung et
al., 2013). These studies demonstrate how providing students with appropriately scaffolded opportunities for reflection can lead to increased understanding of science content and skills.

**Learner-Generated Multimodal Representations**

Several studies note that one method of fostering reflective practices is through the use of multimodal content. “The objective of multimedia learning is to link visual and verbal representations in a meaningful way to promote knowledge construction” (Mayer as cited in Diamond, 2011, p. 6). This can include combining different types of representations such as text, images, narration, animations, photography, video, or music. Through multimodal representations, students are required to synthesize information, create connections between concepts, and reflect upon their knowledge (Jarvinen et al., 2012). In general, studies showed that by incorporating technology, creative processes, and different forms of communication, students internalized deeper meanings of the content material and scientific methods.

**Implementation of Digital Video Projects.** Digital video is an ideal platform for multimodal learning because it provides students with the opportunity to combine narration, images, animations, and music to create their videos (Jarvinen et al., 2012). One study implemented a video project where students had to create a short, three- to five-minute video to explain and apply a science concept to a real-world situation of their choice (Jarvinen et al., 2012). After the project, students completed a survey, and 83.5% of students reported that “breaking the concept down helped in their understanding” and 93% of students reported that “they better understood their concept” as a result of the video (Jarvinen et al., 2012, p. 19). Further, students achieved higher scores on questions related to their video concept on the final assessment, thereby demonstrating increased content understanding. The researchers found that students quickly became comfortable using the video technology, valued the flexibility and
choice in the assignment, and became engaged with the content of the course. Furthermore, the results show that students gained a greater understanding of science content through a video project that involved researching a topic, organizing ideas, applying knowledge to a real situation, and communicating the information both orally and visually (Jarvinen et al., 2012).

Other Types of Multimodal Representations: Podcasts, Animations, and Art. Hoban, Nielsen, and Shepherd (2013) compared the purposes and benefits of incorporating different forms of multimodal representations such as student-generated podcasts, digital stories, animations, and videos. They identified the simplest option as being a podcast where students create a short audio recording to summarize or explain information. In this representative form, students can turn their podcast into a digital story by adding images to their narration (Hoban et al., 2013). One type of representation the authors identified that could be particularly useful in chemistry is to have students create an animation where they can connect what is happening on the microscopic level with macroscopic observations in the lab (Hoban et al., 2013). “The design process in creating such a blended form encourages students to think about the concept and how best to represent it in multiple and connected ways” (Hoban et al., 2013, p. 34).

Bartle, Longnecker, and Pegrum (2011) incorporated podcasting into the chemistry classroom and required students to choose and explain a topic in their own words through analogies and real-world applications. Another study used art-based activities, such as drawings and paintings, as a way to improve conceptual understanding (Danipog & Ferido, 2011). These illustrations required students to show meaning through colors, textures, and shapes. Once students create these multimodal projects, they could be shared with a more authentic audience on the internet or compiled to create a learning resource for the class. Students can engage in the content in new ways, take ownership of their learning, and share knowledge with their peers. In
general, these studies found that through using technology and learner-generated multimodal representations, students were able to create, apply, and extend their content knowledge.

**Strategies for Successful Implementation.** Today’s generation of students is exposed to technology at an early age and constantly accesses technology tools through laptop computers and mobile devices. In addition, “57% of teens who use the internet could be considered content creators...and 33% of teens (12–17 years old) who go online share content they have created, such as artwork, photos, stories, or videos” (Lenhart & Madden as cited in Benedict & Pence, 2012, p. 492). The incorporation of learner-generated video can readily be incorporated into a classroom because students are familiar with technology and often have access to a variety of technology tools, either through mobile devices or one-to-one devices provided by the school. Researchers noted that it was important to keep the length of the video short and give students time to develop a script and storyboard to increase the success of a digital video project (Green, Inan, & Maushak, 2014). In the process of writing a script or storyboard, Schuck and Kearney (2006) found that the role of the teacher should be that of a facilitator, focused on encouraging student ideas and helping students continually assess and enhance their video project. Further, while incorporating aspects of technology it is important to avoid letting the technology get in the way of the purpose of the project. “Teaching and learning through technology is more of an art — more about movement, creation, expression, and interpretation than about software and hardware” (Miller & McVee, 2012, p. 30). Therefore, Green et al. (2014) suggest pre-teaching some of the technical skills to avoid overemphasizing the technical and editing side of the process. Also, M. Jarvinen et al. (2012) found that students appreciate more guidance and instruction in the initial planning phase of the project. Therefore, clear, concise, and reasonable
expectations are required to successfully implement a digital video project as a part of a laboratory reflection.

One common theme among the studies was the implementation of digital video projects as small group assignments (Bartle et al., 2011; Green et al., 2014; Tytler et al., 2013; Doubleday & Wille, 2014). To effectively facilitate the project in a small group setting, Doubleday and Wille (2014) implemented group roles such as technical director, supervisor, as well as lead and assistant experimenter. This allowed for the delegation of responsibilities which led to increased accountability and functionality of small groups. In a post-project survey, students responded with both positive and negative comments regarding the group work (Bartle et al., 2011). For example, students appreciated being able to talk to their team members about ideas and gain different perspectives, but also found it difficult to coordinate group members’ schedules and ensure equal contributions to the project. Incorporating video as a collaborative task comes with advantages and disadvantages, but due to the participatory nature of science labs, completing a video reflection seems to lend itself better to a small group setting. Furthermore, if structured appropriately, group work can actively lead to increased collaboration, communication, and peer learning among students (Bartle et al., 2011).

Research on the problem of ineffective laboratory investigations indicates that by trying to incorporate more authentic laboratory experiences and opportunities for reflection and application through learner-generated media, a teacher can expect to see significant improvements in students’ overall understanding of the experiment. “Students engage with science content when they are asked to explain and communicate their knowledge to others” (Hoban, Nielsen, & Shepherd, 2013, p. 32). Further, instead of using traditional monomodal representations, such as writing, students are required to make connections between concepts and
reflect upon their knowledge in the creation of a digital video project. By filming experiments in action and synthesizing the information in a video, students are required to go beyond the surface knowledge often gained from an experiment.

**Methodology**

This research will be conducted as an action research project to investigate the laboratory reflection processes in a high school chemistry lab. The incorporation of a digital video project as part of the laboratory reflection will be compared to a traditional written laboratory report to determine whether a digital video project is able to better engage students in connecting the purpose of the lab, science processes, and chemistry concepts. The study will be conducted in two classes of a general chemistry course over two units of study. The two classes will be completing the same coursework, laboratory experiment, and exam in each unit, over the same period of time. In the first unit, one class will complete a traditional written report, and the other class will complete a digital video project in the form of an iMovie or multimodal Google Slides presentation for their laboratory reflections. In the next unit, the classes will switch modes of laboratory reflection. By comparing the students’ reflective practices in the two classes, the researcher can determine how the use of an iMovie or multimodal Google Slides presentation affects the quality of students’ understanding, application, and reflection of chemistry concepts in an experiment compared to a traditional written report.

For the purpose of triangulation, this investigative study combined both qualitative and quantitative design elements and involved collecting artifacts, as well as observational and inquiry data during two units of study. A pre- and post-student questionnaire, containing both quantitative scales and open-ended questions was implemented to measure students’ perception of their experiences in the chemistry lab with the different methods of reflection. Artifacts, in the
form of a common rubric and written unit exams, were used to score the projects and provide information about students’ conceptual knowledge, scientific process skills, and the overall quality of their understanding of the lab. Observational notes were made and collected throughout the laboratory reflection process to provide insight on students’ successes and difficulties, as well as information about the overall logistics of implementing different formats of laboratory reflection in the classroom.

The population of this study included two classes of chemistry students at a large, public high school in a Midwestern suburb with a total population of approximately 1,800 students. The population at the high school is 63.4% white, non-Hispanic; 13.8% Asian, Pacific Islander; 12.7% Hispanic; 8.5% black; and 1.7% American Indian students (Minnesota Report Card, 2016). Also, 29.3% of students are eligible for free-and-reduced-price lunch (Minnesota Report Card, 2016). The classes consisted of 31 and 29 students, 50 of whom participated in the study over the course of the first semester of the school year. The sample of participating students consisted of 21 females and 29 males: 29 tenth-grade students, 19 eleventh-grade students, and 2 twelfth-grade students. Table 1 shows the distribution of grades and genders in each class period. The study was implemented in a required on-level course for graduation and therefore is a representative sample of the high school population.

Table 1

<table>
<thead>
<tr>
<th>Class Period</th>
<th>10th Graders</th>
<th>11th Graders</th>
<th>12th Graders</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th Hour</td>
<td>13</td>
<td>10</td>
<td>1</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>5th Hour</td>
<td>16</td>
<td>9</td>
<td>1</td>
<td>12</td>
<td>13</td>
</tr>
</tbody>
</table>
Pre- and post-surveys were administered in the form of an online questionnaire. The surveys were designed to gather information about students’ experiences and perceptions of the scientific processes involved in the chemistry laboratory as well as their previous experiences with laboratory reflection.

A common rubric was developed to analyze students’ digital video projects and written reports. The rubric was designed to analyze students’ projects regarding their portrayal of the purpose of the lab, conceptual understanding, summary and reflection, diagrams and media, and the overall quality of the project. Total rubric scores, as well as specific subsection scores, were measured and compared across the two different modes of laboratory reflection.

At the conclusion of each unit, a written exam was given to measure students’ understanding of the chemistry concepts within the unit. Students’ scores from the exams provided information about whether students gained a better understanding of the purpose of the lab, chemistry concepts, and scientific practices through the digital video projects or written reports.

A daily observation and reflection log was kept during each laboratory reflection process. The observation log tracked the types of questions asked by students and categorized them into questions regarding technology, general project requirements, and chemistry concepts. Further qualitative notes were recorded about the class dynamics and project logistics, as well as student and teacher successes and struggles throughout the implementation of the new forms of laboratory reflection.

The first class (5th hour) was introduced to the digital video project, and students were asked to individually complete the pre-survey in the format of an online Google Form during class time. After the completion of the laboratory experiment, students were given four, 45-
minute class periods to complete the video project with their assigned groups of four. Students were asked to provide a preference for their group role and were then assigned to either the role of director, technology specialist, researcher, or presenter. Students were tasked with developing a cohesive iMovie that combined video, narrations, animations, diagrams, and photos, to showcase their results as well as their understanding of the Calorimetry Lab. Each day, groups were provided with a specific task to complete as students made progress working towards the final product. Throughout these work days, a daily observation and reflection log was kept. After the completion of the project, students completed an online post-survey that contained identical questions to the pre-survey as well as additional questions about their experience completing the digital video project. The videos were scored using the common rubric and students completed the written exam. The researcher reviewed the student pre- and post-surveys, determined any commonalities among the rubric scores and unit exams, and compared the data to students in the second class (4th hour) who completed the written laboratory reflection.

In the next unit of study, the 4th hour class was introduced to the digital video project, and students were asked to complete the same pre-survey during class time. After the completion of the laboratory experiment, students were given four, 45-minute class periods to complete the video project with their assigned group of four. This class of students was tasked to develop a multimodal Google Slides Presentation that contained embedded videos, as well as animations, narrations, and diagrams to showcase their results and understanding of the Formula of an Unknown Compound Lab. After the completion of the project, students completed the same online post-survey about their experience completing the digital video project. Projects were scored using the common rubric and students completed the written exam for the unit. The researcher reviewed the student pre- and post-surveys, determined any commonalities among the
rubric scores and unit exams, and compared the data to students in the other class (5th hour) who completed the written laboratory reflection.

Through the analysis and comparison between class periods, one can determine the effectiveness of an iMovie or multimodal Google Slides Presentation as a method of laboratory reflection regarding students understanding and application of chemistry concepts compared to a traditional written laboratory report.

**Analysis of Data**

The quantitative data for student rubric scores was analyzed by both the sub-section score and overall score for each student to determine how the use of an iMovie or multimodal Google Slides presentation affects the quality of students’ laboratory reflections compared to a traditional laboratory report. An identical rubric was used to analyze all three modes of laboratory reflection in the study (Appendix B). Each student received a score ranging from two to five in the subsections of the question and purpose, conceptual understanding, summary and reflection, diagrams and media, and the quality and organization of the project. This common rubric was used to provide information about students’ conceptual knowledge, scientific process skills, and the overall quality of their understanding of the lab. Average scores of each subsection were compared across the different modes of laboratory reflection.

At the conclusion of each unit of study, each student completed an individual unit exam that was scored out of 100 points. The average and median percentage scores of each class were compared for each unit to determine whether the mode of laboratory reflection had an impact on students’ overall understanding of the chemistry concepts. Further, each student’s scores was compared between the unit in which they completed the digital video project and the unit in which they completed the traditional written laboratory report.
The quality of students’ laboratory reflection and their perceptions of their experiences with the different methods of reflection was also analyzed using the pre- and post-student questionnaires that contained both quantitative and qualitative data. Student responses were compared before and after completing the multimodal video project. The raw post-survey qualitative data regarding the multimodal video project was in the form of simple sentences and short statements written by the students in their own words. After reviewing the survey responses, the researcher grouped the responses as either positive, negative, or neutral. Then, the researcher coded each group of responses to identify major themes in each response.

Teacher observation notes during the laboratory reflection process were recorded and used to identify any areas of improvement with each mode of laboratory reflection. These responses were coded and then categorized into themes. Further, the number of students’ questions around the topics of chemistry, technology, and project logistics asked each class period were recorded and compared across the two forms of digital video projects.

The purpose of this study was to investigate how learner-generated video, in the form of an interactive Google Slides presentation or iMovie, could be used as a form of laboratory reflection in a high school chemistry class. The research design was both qualitative and quantitative, utilizing pre- and post-survey questionnaires, a common rubric to analyze the projects, unit exam scores, and instructor observations to analyze the impact of learner-generated video on student understanding of a chemistry laboratory investigation in comparison to a traditional written laboratory report.

The subjects for this study were high school students enrolled in general or on-level chemistry at public high school in a Midwestern suburb. The study involved two classes and was completed over the course of the second and third units of study in the first semester of the
2017/2018 school year. A total of 50 students participated in all portions of the study (pre-
survey, unit two project and exam, unit three project and exam, and post-survey).

**Understanding of Chemistry Concepts**

The first research question addressed in this study was how the use of an iMovie or
multimodal Google Slides presentation affects student understanding and application of
chemistry concepts in a laboratory experiment compared to the use of a traditional written
laboratory report. To answer this question, the researcher analyzed rubric scores, unit exam
scores, and survey data.

Students’ conceptual chemistry understanding in the laboratory investigation was
assessed using a common rubric. Appendix B shows the requirements for achieving a proficient
rating (5) in conceptual understanding. On both the multimodal presentation and the iMovie,
students scored slightly higher on average in the conceptual understanding category. In 4th hour,
students received an average score of 3.9 in conceptual understanding on the multimodal Google
presentation compared to an average score of 3.5 in conceptual understanding on the written
laboratory report. Further, in 5th hour, students received an average score of 3.7 in conceptual
understanding on the iMovie compared to an average score of 3.2 in conceptual understanding
on the written laboratory report. Both class periods demonstrated a greater understanding of the
chemistry concepts in the digital video laboratory reflection compared to the traditional written
laboratory report.

Students’ understanding of chemistry concepts was also assessed on a unit exam. The
percent difference was calculated by taking each student’s unit exam percent from the unit in
which they completed the digital video mode of laboratory reflection and subtracting the
student’s unit exam percent from the unit in which they completed the traditional written report.
Overall, 52% of the students showed lower unit exam scores and 48% of the students showed a higher unit exam score in the unit in which they completed the digital video mode of laboratory reflection (Figure 1). Also, the median and average scores for each class period were compared during the two units of study (Table 2). Hour 4 showed a decrease in the median and average unit exam scores from the unit where they completed the laboratory report to the unit where they completed the multimodal presentation. However, hour 5 showed a slight increase in the median and average unit exam scores in the unit that utilized iMovie when compared to the unit that utilized a traditional written laboratory report. This leads to inconclusive results regarding whether using digital video as a form of laboratory reflection translates into increased chemistry understanding, as evidenced in the final unit exam scores.

![Graph showing percent difference in unit exam scores]

*Figure 1. The individual student percent difference for the unit exams based on the method of laboratory reflection.*
Table 2

*Average and Median Class Results on the Unit Exams*

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4th Hour</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab Report</td>
<td>86.4%</td>
<td>89.4%</td>
</tr>
<tr>
<td>Multimodal Presentation</td>
<td>83.7%</td>
<td>82.8%</td>
</tr>
<tr>
<td><strong>5th Hour</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab Report</td>
<td>75.9%</td>
<td>83.8%</td>
</tr>
<tr>
<td>iMovie</td>
<td>79.4%</td>
<td>84.4%</td>
</tr>
</tbody>
</table>

As shown in Figure 2 below, 80% of students self-reported a value of 3-5 when asked to rank the extent to which their understanding of lab content improved throughout the video project. Ten percent of students reported that their understanding of the lab content significantly improved.
Figure 2. Student survey responses to the question, “To what extent did your understanding of the lab content improve through the work you did creating the video?”

**Modes of Laboratory Reflection**

The second research question that this study addressed was related to how the use of an iMovie or multimodal Google Slides presentation affects the quality of student laboratory reflections compared to a traditional written laboratory report in a chemistry classroom. To answer this question, the researcher analyzed overall rubric scores and subsections for the iMovie, multimodal Google Slides presentation, and traditional laboratory reports. Further, the researcher coded and analyzed student open-ended responses on a pre- and post-survey for central themes regarding how students qualitatively assessed their learning experience.

Each student’s digital video projects and written laboratory reports were graded using a common rubric (Appendix B). Average scores for each class are shown in Table 3. Students in
4th hour scored higher in the question, conceptual understanding, and diagrams and media categories in the multimodal presentation form of laboratory reflection. Students in 5th hour scored higher in the conceptual understanding, diagrams and media, and quality and organization categories. Students in both classes had higher overall scores on the rubrics in the digital video format of reflection. Table 3 also indicates differences across the two digital video modes of reflection. Students received higher average scores in the question and summary categories with the multimodal Google Slides presentation format. Students who completed the iMovie had higher average scores in the diagrams and organization categories.

Table 3

*Average Scores for each Rubric Subsection Compared across Classes and Modes of Laboratory Reflection*

<table>
<thead>
<tr>
<th></th>
<th>Hour 4</th>
<th></th>
<th>Hour 5</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Lab Report</td>
<td>Presentation</td>
<td>Lab Report</td>
<td>iMovie</td>
</tr>
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<td>Question</td>
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<td>4.8</td>
<td>4.1</td>
<td>3.2</td>
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<tr>
<td>Conceptual Understanding</td>
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<td>3.9</td>
<td>3.2</td>
<td>3.7</td>
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<td>Summary and Reflection</td>
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<td>3.7</td>
<td>3.9</td>
<td>3.5</td>
</tr>
<tr>
<td>Diagrams and Media</td>
<td>3.7</td>
<td>4.6</td>
<td>3.6</td>
<td>5</td>
</tr>
<tr>
<td>Quality and Organization</td>
<td>4.4</td>
<td>4.1</td>
<td>4.3</td>
<td>4.8</td>
</tr>
<tr>
<td><strong>Overall Score</strong></td>
<td><strong>20.3</strong></td>
<td><strong>21.2</strong></td>
<td><strong>19.2</strong></td>
<td><strong>20.3</strong></td>
</tr>
</tbody>
</table>
Table 4 shows student perceptions of the laboratory reflection process in terms of the group work and usefulness of the project in terms of their learning. Seventy-four percent of students thought their group worked well together on the project. The major themes in students’ responses indicated that effective group roles, communication, and collaboration all contributed to a successful group video project. When asked to explain the benefits of working in a group on the laboratory reflection, one student reported that, “Everyone helped each other out if someone was confused about something.” Another student noted that, “We worked well because we all did the work that was assigned to us in our individual roles.” However, 9% of the students reported a negative experience in working with a group and 17% of students reported an overall neutral experience working in a group. Students who had a negative experience indicated that this was due to either lack of contributions from all group members, ineffective group dynamics, or lack of time management and focus during class. For example, one student explained, “our group was able to split the project out evenly we just had an issue with how much time we had to work on it with everything that we needed to finish.”

Table 4

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>Positive</th>
<th>Negative</th>
<th>Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do you think your group worked well OR did not work well together on the digital video project?</td>
<td>74%</td>
<td>9%</td>
<td>17%</td>
</tr>
<tr>
<td>Give an example of how your understanding of the lab improved with the video project work OR explain why you think the video project didn't help you with your understanding.</td>
<td>63%</td>
<td>22%</td>
<td>15%</td>
</tr>
</tbody>
</table>
Sixty-three percent of students believed that the digital video project improved their overall understanding of the lab. The themes in students’ responses indicated that working in groups, the hands-on nature of the project, and the ability to really explain and apply concepts in creative ways all contributed to an improved understanding on the lab. Listed below are several students responses related to why they felt the digital video project improved their understanding:

- “It helped [me see] the procedure from a different standpoint.”
- “It helped me understand why a lot of it happened in a deeper way.”
- “Seeing the same thing a lot got it stuck in my head.”
- “You had to apply yourself into making the video.”
- “It helped me, because there were images, text and audio. Different ways to understand.”
- “You are participating in the project in multiple ways so you have more ways to learn it.”
- “It helped me understand it because I had to explain the topics learned in the experiment in my own words.”
- “The video helped express what could not be written on paper.”

On the other hand, 22% of students believed that the digital video project did not help their understanding. The major theme in students’ negative responses was that there was too much of a focus on the video portion of the project, which took the focus away from understanding the experiment. For example, one student stated that, “Since it was a video project I felt like working on the project itself was more important than the lab we did.” Further, another student stated that, “I just think the video project was more work and harder to understand on how to put this together.” Other students reported no change in overall understanding because they believed the amount of learning in the laboratory report and video project were equivalent. For instance, a
student suggested, “The only thing that is different is that the words are being said and not typed so there wasn't a big change in understanding.” Overall, the majority of students reported a positive experience working on the digital video project regarding the group work nature of the reflection process and indicated an improvement in their understanding.

Another post-survey question prompted students to choose whether they would want to do a laboratory report or digital video project in the future (Table 5). When compared across both classes students were fairly split in their responses: 50% of all students would choose a digital video project over a laboratory report. When the data is broken down further by class, the majority of students (64%) who completed the multimodal Google Slides presentation would choose a video project over a lab report in the future. However, only 39% of students who completed the iMovie would prefer to complete another video project in the future.

Table 5

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>Presentation</th>
<th>Lab Report</th>
<th>No Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Next unit if you had the choice between a digital video project and a lab report which option would you choose and why?</td>
<td>64%</td>
<td>23%</td>
<td>13%</td>
</tr>
<tr>
<td><strong>Hour 5</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>iMovie</td>
<td>39%</td>
<td>57%</td>
<td>4%</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital Video</td>
<td>50%</td>
<td>42%</td>
<td>8%</td>
</tr>
</tbody>
</table>
Students who indicated their preference as a digital video project stated that they preferred the interactive group work and creative nature of the project compared to the laboratory report. For example, students stated that, “It makes learning more fun and in depth, [it] gives me [a] chance to express myself, you have people to help you easily, and it is more comprehensive.” Students who preferred the laboratory report stated that they thought the laboratory report was easier or that they preferred to work alone on projects. They viewed the laboratory report as a simpler, easier, and less time-consuming option of reflection. Several students noted that it was hard to record their thoughts and put it into pictures and videos. Between both classes, 8% of students indicated no preference, stating that they would be content with either mode of laboratory reflection.

In the pre- and post-surveys, students were asked to choose their preferred method of reflection to complete two tasks, explaining a chemistry concept and the results of a laboratory experiment (Table 6). After the completion of the video project, a greater percent of students would choose to complete an audio recording, create a video, or write a paper to explain a chemistry concept. However, the percent of students who would choose to draw a diagram to explain a chemistry concept decreased. Further, in the pre-survey, 41.8% of students indicated that they would choose writing a paper to explain the results of a laboratory experiment. This percent decreased to 21.2% in the post-survey. The percent of students who would choose to draw a diagram, complete an audio recording, or create a video to explain the results of an experiment all increased. Overall, students showed a variety of preferences in their preferred mode of communication for explaining a concept or experiment.
Table 6

*Pre-survey and post-survey comparison of students’ laboratory reflection preferences*

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>Writing a paper</th>
<th>Drawing a diagram</th>
<th>Audio recording</th>
<th>Creating a video</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which method would you choose to best explain a chemistry concept?</td>
<td>Pre 20%, Post 25%</td>
<td>Pre 52.7%, Post 36.5%</td>
<td>Pre 12.7%, Post 21.2%</td>
<td>Pre 14.5%, Post 17.3%</td>
</tr>
<tr>
<td>Which method would you choose to best explain the results of a laboratory experiment?</td>
<td>Pre 41.8%, Post 21.2%</td>
<td>Pre 34.5%, Post 38.5%</td>
<td>Pre 7.3%, Post 23.1%</td>
<td>Pre 16.4%, Post 17.3%</td>
</tr>
</tbody>
</table>

Finally, the number of questions asked by students during each class period were recorded, tallied, and averaged over the course of each period of laboratory reflection (Figure 3). Overall, students had less questions in all areas when completing the multimodal Google Slides presentation compared to the iMovie project. Further, the teacher observed more moments of stress and confusion during the iMovie work time compared to the presentation. For example, on the third day of work time the teacher noted:

“Some groups seemed to be very frustrated and overwhelmed by the project and how to put the final pieces together. The main struggle today was students being absent...in another group the tech person was absent who had all the video footage. There were lots of questions about what they were supposed to be doing and a lot of frustration was being voiced.”

Students still had questions and problems when working on the multimodal Google Slides presentation, including technology issues and absent group members, but the teacher noted that it
was a “calm work environment, and whenever groups [were asked if they] had questions they mostly said that they were good.”

![Graph showing average questions asked by groups per class period around the topics of chemistry, technology, and project logistics.]

*Figure 3.* Average questions asked by groups per class period around the topics of chemistry, technology, and project logistics.

In summary, the data shows both positive and negative aspects of each mode of the digital video projects in terms of chemistry understanding and overall laboratory reflection.

**Action Plan**

The purpose of this action research study was to examine the implementation of a digital video project to determine its effect on students’ reflection skills and chemistry understanding in a high school chemistry lab, compared to a traditional written laboratory report. High school chemistry students often have a difficult time connecting chemistry concepts to scientific practices in laboratory investigations. As part of their science education, students should have
authentic opportunities to critically think and question, construct explanations, and obtain, evaluate, and communicate information using a variety of digital tools — all of which are skills needed to become scientifically literate. Therefore, the goal of this study was to investigate whether the combination of narration, video, animations, and diagrams into a digital, learner-generated laboratory reflection would help students to go beyond the surface knowledge often gained from an experiment. This research was conducted in the hopes of finding a method to help increase student understanding, reflection, and the construction of knowledge from laboratory investigations, as well as to help students develop skills to create and analyze different types of communication.

The first question of this study addressed how the use of a learner-generated digital video project affected students’ understanding of chemistry concepts compared to a traditional laboratory report. As outlined above, students who completed the digital video projects scored higher on average in the conceptual understanding category on the common rubric when assessed on their final projects. The digital video project provided students with opportunities to incorporate animations to showcase their particle level understanding, voice-overs of the experimental procedure to explain what was happening chemically, and to summarize the results of the experiment in a visual and hands-on way. Therefore, students were able to demonstrate a deeper understanding of the chemistry concepts in the digital video project than by completing a monomodal written report. When teachers implement learner-generated multimodal digital media, “teachers can tap the power of visual and verbal forms of expression in the service of promoting student understanding” (Mayer, 2003, p. 127).

The evidence in the study did not support a correlation between chemistry understanding in the laboratory reflection and success on a unit exam. The quantitative data found in the study
did not see any significant increase in chemistry understanding on the unit exams as a result of completing a learner-generated digital mode of laboratory reflection. Therefore, the conceptual understanding gained in the laboratory through the digital video project did not translate into understanding demonstrated on a unit exam. This could be due to students spending significant portions of their time filming, editing, and processing the videos — time that they did not spend focusing on understanding and applying the concepts. Schuck and Kearny (2006) noted that “sometimes the technology seemed to be impeding conceptual understanding outcomes” (p. 17). Several students mentioned that the emphasis on the video and technology portion of the project took the focus away from understanding the experiment. This could have resulted in lower unit exam scores for some students. Therefore, the results were inconclusive on whether using digital video as a form of laboratory reflection translates into increased chemistry understanding, as evidenced by unit exam scores.

The second research question addressed how the use of a learner-generated digital video project affects the quality of students’ laboratory reflections compared to a traditional written laboratory report. As outlined above, students showed a variety of preferences in their preferred mode of communication for explaining a concept or experiment. Therefore, multimodal learning is an ideal approach for incorporating a variety of ways to interact and connect with the material. After the completion of the video project, the percent of students who would choose to draw a diagram, complete an audio recording, or create a video to explain the results of an experiment all increased. Further, as evidenced by students’ comments from the post-survey, the digital video projects provided an effective way for students to process, analyze, and communicate information learned in the lab in a digital format. The hands-on, collaborative, and in-depth nature of the projects allowed students to process the experiment in multiple ways. This was also
evidenced by the fact that students received higher overall rubric scores on the digital video projects than the traditional written laboratory reports. The multimodal nature of the digital video project provided students with an opportunity to meaningfully reflect on the laboratory experiment and synthesize the information into a final product. Loh et al. (2001) state that “if students are to learn scientific process, they must have the means to reflect on and learn from their own investigative process” (p. 282-283).

Both the iMovie and Google Slides presentation provided students with opportunities to create video communication and collaborate using a variety of digital tools. In the final products, students used animation software, voice-over technology, captions, music, narration, photos, and videos to tell the story of the laboratory experiment. In the 21st century, “the ability to design such texts using multimodal resources to represent knowledge and communicate it for a purpose is now required for civic, personal, and workplace lives” (Miller & McVee, 2012, p. 3, emphasis in original). Therefore, iMovie and multimodal Google Slides presentations allow students to learn how to effectively communicate and collaborate on various technology platforms, an important skill for students to learn moving forward in their education and careers.

As evidenced by the teacher’s observation notes and the post-survey results of 5th hour, the implementation of an iMovie as a form of laboratory reflection presented many challenges. While it provided an opportunity for students to combine animations, narration, photos, and videos into a cohesive project, it also came with many technology and group work stressors. Trying to incorporate all of the different parts of a video was very difficult to accomplish in only a couple 45-minute class periods. Due to the nature of iMovie technology, only the technology specialist was able to fully control and manipulate the aspects of the video. One student stated that “only one person could work on it because it was on their MacBook and that was very
stressful not to be able to see what they were doing or make sure that they were even doing it right.” Further, as outlined above, students had more questions during the completion of the iMovie project, especially in the areas of technology and project logistics. Other studies have also found the over-emphasis on technology to be a source of student frustration when implementing a digital video project (Miller & McVee, 2012; Green et al., 2014; Jarvinen et al., 2012). This stress was alleviated by switching the nature of the project from a cohesive iMovie to a Google Slides presentation. The hope was that the presentation format would be easier to complete, allow for more collaboration, and alleviate some of the editing focus. The two classes did not see any noticeable differences in the unit exam scores. However, the class who completed the Google Slides presentation had a higher percentage of students who indicated that they would choose a digital video project in the future. Hoban, Nielsen, and Shepherd (2013) explain that each form of digital media has particular affordances, features, and qualities that are unique to that form. While a video is the most comprehensive, it requires the more editing and technical knowledge than creating a digital story or presentation. By implementing two forms of multimodal digital video reflections, I will be able to assist students in the future related to making decisions about what form of media to use to best understand, explain, and communicate their ideas.

Based on the findings and conclusions of this study, the following actions will be taken:

- Smaller learner-generated multimodal projects will be implemented throughout the course to increase students’ skills, knowledge, and familiarity with using different digital tools for communication.
• The type of multimodal representation (podcast, animation, presentation, videos, etc.) will continue to be explored to determine the optimal mode of laboratory reflection.

• Students will be provided with options and more choice on the format of their laboratory reflections. No longer will each laboratory experiment be followed by a traditional written laboratory report; instead, students will have options to express their ideas and knowledge in creative ways.

• The researcher will continue to investigate ways to promote the connection between scientific practices and the chemistry concepts learned in class.

This method of laboratory reflection will continue to prove to be more successful as teachers have more opportunities to scaffold, instruct, and guide multimodal learning, and students have more opportunities to practice creating a learner-generated digital video. A lot of time during the reflection process was spent learning how to use QuickTime Player, iMovie, the animation applications, YouTube, and the Google Slides app, resulting in some of the focus was taken off the chemistry concepts and laboratory experiment. Therefore, in the future, the researcher will incorporate smaller assignments to gradually teach students how to use these tools throughout the year. The pre-teaching of skills would alleviate a lot of the stress and frustration associated with the projects. Further, ways to promote students’ connection to chemistry concepts will need to continue to be researched and reviewed. How can teachers keep students focused on understanding the chemistry concepts during the project work time? Further, how can this understanding be extended and translated to improvements on students’ unit exam scores? The iMovie and Google Slides presentations provided students with the opportunity to collaboratively work in groups, reflect on the laboratory concepts in a meaningful way, and
communicate their learning using digital tools. This research is important to teachers because it opens additional avenues for meeting students’ learning needs in a laboratory setting while providing them with firsthand practice in using 21st-century tools to communicate scientific understanding.
References


Appendix A

Pre- and Post-Survey on Students’ Experiences in the Chemistry Lab

Students Experiences in the Chemistry Lab Pre-Survey

What is your student ID number? ______

This section of the questionnaire investigates your confidence you have in undertaking different tasks in the chemistry lab. Please rate how confident you feel about completing each of the following tasks from not confident (1) to totally confident (5).

1. Not confident: I don't think I could do this and wouldn't know where to start. I would need to ask my peers and teacher a lot of questions.
2. A little confident: I would need to ask for help from my peers or teacher before I began but then I could complete most of the task.
3. Relatively confident: I feel okay but might need to ask a couple questions.
4. Mostly confident: I feel pretty good about this but I might need to ask a question.
5. Totally confident: I got this! I could even help someone else with this.

1. Reading the procedure for an experiment and conducting the experiment without assistance.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not confident</td>
<td></td>
<td></td>
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</tbody>
</table>

2. Making sure that data collected from an experiment is accurate.

<table>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not confident</td>
<td></td>
<td></td>
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</tbody>
</table>
3. Proposing a meaningful question that can be answered in an experiment.

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<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not confident</td>
<td></td>
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</table>

4. Drawing or diagramming what is happening at a particulate (molecular) level in an experiment.

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<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not confident</td>
<td></td>
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</tbody>
</table>

5. Relating the observations in an experiment to what is happening at a particle (molecular) level.

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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not confident</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

6. Identifying the reasons for possible errors in an experiment.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not confident</td>
<td></td>
<td></td>
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</tbody>
</table>

7. Applying concepts learned in class to a laboratory experiment.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not confident</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8. Explaining something that you learned in this chemistry course to another person.

9. Which one would be easier for you to explain to another person?
   a. Explaining the how/why of a procedure. (For example, why is it important to measure the temperature before and after?)
   b. Explaining the meaning of the results of an experiment (For example, why did the temperature change?)

10. Why did you choose that answer to question #9 above? (Why is explaining the procedure or results easier for you?)

11. Choose the answer that best fits your ideas about real-world applications of chemistry.
   a. The subject of chemistry has little relation to what I experience in the real world.
   b. I don't usually see the real world application of the chemistry labs we do in class.
   c. I can typically name one real world application of the information from a lab.
   d. I can explain several ways in which each of our chemistry experiments applies to the real world.

12. If you had to explain a chemistry concept, which method would you choose to best explain your thoughts?
   a. Writing a paragraph or paper
   b. Drawing an image or diagram
   c. Creating a voice/audio recording
   d. Creating a video with images, video, and words
13. If you had to explain the results of a laboratory experiment, which method would you choose to best explain your thoughts?
   a. Writing a paragraph or paper
   b. Drawing an image or diagram
   c. Creating a voice/audio recording
   d. Creating a video with images, video, and words

14. In your own words, why do chemists do labs?

15. Which of the following is MOST true?
   a. When I do a lab, if I don't get the right answers, I didn't do the lab correctly.
   b. When I do a lab, if I follow the procedures, I will always get the right answers.
   c. In a lab doing an experiment, the goal is to apply theories and principles and see what happens. There is not a right answer.
   d. Doing a lab is a practice of modeling concepts so that we can "see" them in action. It is important to do it right and get the right answers.
Students Experiences in the Chemistry Lab Post-Survey

What is your student ID number? ______

This section of the questionnaire investigates your confidence you have in undertaking different tasks in the chemistry lab. Please rate how confident you feel about completing each of the following tasks from not confident (1) to totally confident (5).

(1) Not confident: I don't think I could do this and wouldn't know where to start. I would need to ask my peers and teacher a lot of questions.

(2) A little confident: I would need to ask for help from my peers or teacher before I began but then I could complete most of the task.

(3) Relatively confident: I feel okay but might need to ask a couple questions.

(4) Mostly confident: I feel pretty good about this but I might need to ask a question.

(5) Totally confident: I got this! I could even help someone else with this.

1. Reading the procedure for an experiment and conducting the experiment without assistance.

   ![Confidence Scale]

2. Making sure that data collected from an experiment is accurate.

   ![Confidence Scale]

3. Proposing a meaningful question that can be answered in an experiment.
4. Drawing or diagramming what is happening at a particulate (molecular) level in an experiment.

5. Relating the observations in an experiment to what is happening at a particle (molecular) level.

6. Identifying the reasons for possible errors in an experiment.

7. Applying concepts learned in class to a laboratory experiment.

8. Explaining something that you learned in this chemistry course to another person.
9. Which one would be easier for you to explain to another person?
   a. Explaining the how/why of a procedure. (For example, why is it important to measure the temperature before and after?)
   b. Explaining the meaning of the results of an experiment (For example, why did the temperature change?)

10. Why did you choose that answer to question #9 above? (Why is explaining the procedure or results easier for you?)

11. Choose the answer that best fits your ideas about real-world applications of chemistry.
   a. The subject of chemistry has little relation to what I experience in the real world.
   b. I don't usually see the real world application of the chemistry labs we do in class.
   c. I can typically name one real world application of the information from a lab.
   d. I can explain several ways in which each of our chemistry experiments applies to the real world.

12. If you had to explain a chemistry concept, which method would you choose to best explain your thoughts?
   a. Writing a paragraph or paper
   b. Drawing an image or diagram
   c. Creating a voice/audio recording
   d. Creating a video with images, video, and words
13. If you had to explain the results of a laboratory experiment, which method would you choose to best explain your thoughts?
   
a. Writing a paragraph or paper
   b. Drawing an image or diagram
   c. Creating a voice/audio recording
   d. Creating a video with images, video, and words

14. In your own words, why do chemists do labs?

15. Which of the following is MOST true?
   
a. When I do a lab, if I don't get the right answers, I didn't do the lab correctly.
   b. When I do a lab, if I follow the procedures, I will always get the right answers.
   c. In a lab doing an experiment, the goal is to apply theories and principles and see what happens. There is not a right answer.
   d. Doing a lab is a practice of modeling concepts so that we can "see" them in action. It is important to do it right and get the right answers.

16. To what extent did your understanding of the lab content improve through the work you did creating the video?

   ![Likert Scale]

   Not at all  ○ ○ ○ ○ ○ Significantly

17. Give an example of how your understanding of the lab improved with the video project work OR explain why you think the video project didn't help you with your understanding.

18. Do you believe that a "hands-on" project like this is beneficial for you? Why or why not?
19. What were the negatives or problems with the assignment to create the video as part of this lab?

20. What would have helped you during the digital video project?

21. How could this video project be improved in the future?

22. How do you think your group worked well OR did not work well together or the digital video project?

23. Next unit if you had the choice between a digital video project and a lab report which option would you choose and why?

24. Do you have any other comments or suggestions about the digital video project?
Appendix B

Common Rubric Used to Grade the Digital Video Projects and Laboratory Reports.

<table>
<thead>
<tr>
<th>Student ID</th>
<th>Format: Lab Report or Video Project</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Question/Purpose</td>
</tr>
<tr>
<td>5</td>
<td>Daring and dynamic presentation of the lab’s purpose and question. Compelling, informed, and accurate portrayal that connects all aspects of the project.</td>
</tr>
<tr>
<td></td>
<td>The purpose of the lab or the question to be answered during the lab is partially identified, and is stated in a somewhat unclear manner.</td>
</tr>
<tr>
<td>4</td>
<td>Includes diagrams and descriptions of what is occurring at the particle level in the experiment. The particle level explanation is connected to the data/observations in the lab.</td>
</tr>
<tr>
<td></td>
<td>Attempts to include information about particles but the information contains errors or does not connect to the experiment.</td>
</tr>
<tr>
<td>3</td>
<td>The results of the experiment are thoroughly and accurately explained using the concepts involved in the lab. Reasoning is justified using data and analysis of data. Summary describes the skills learned, the concepts learned, and an application to a real life situation.</td>
</tr>
<tr>
<td></td>
<td>The results of the experiment are somewhat explained using the concepts involved in the lab. Reasoning is justified using data and analysis of data. Summary describes the concepts learned.</td>
</tr>
<tr>
<td>2</td>
<td>Clear, accurate diagrams are included and make the experiment easier to understand. Diagrams are labeled neatly and accurately. Makes good use of font, color, graphics, effects, etc. to enhance the project (when appropriate).</td>
</tr>
<tr>
<td></td>
<td>Diagrams are included and are labeled. Makes use of font, color, graphics, effects, etc. but occasionally these detract from the content. Needed diagrams are missing OR are missing important labels. Use of font, color, graphics, effects etc. but these often distract from the presentation content.</td>
</tr>
<tr>
<td>Organization and Quality</td>
<td>Includes all important sections: introduction, procedure, data, and conclusion. Sections are complete, clearly described, and flow smoothly together.</td>
</tr>
<tr>
<td></td>
<td>Missing one important section: introduction, procedure, data, and conclusion. Sections do not seem well connected to each other.</td>
</tr>
<tr>
<td></td>
<td>Missing two or more section: introduction, procedure, data, and conclusion. Sections are not well connected to each other.</td>
</tr>
</tbody>
</table>
Appendix C

Unit 2 Written Exam: Particles and Energy

**Objective:** Determine the specific heat capacity of an unknown metal based on the information below.

**Procedure:**
1. Measure 100 mL of 20.0 °C water using a graduated cylinder and pour it into the calorimeter. Record the initial temperature of the water in the data table on the next page.
2. Cool a 50g sample of an unknown metal to 0.0 °C and quickly transfer it into the calorimeter. Record the initial temperature and mass of the metal in the data table.
3. Once the system stabilizes, record the final temperature of the system in the data table.

<table>
<thead>
<tr>
<th>Initial</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal</td>
<td>Metal + Water</td>
</tr>
<tr>
<td>Water</td>
<td></td>
</tr>
</tbody>
</table>

Examine the procedure and diagrams to answer the following questions:

1. Why will the final temperature of the water and the material be the same?

2. Explain why it is important in this lab to find the mass of the metal AFTER you find the temperature change in the calorimeter.
3. Complete the following data table based on the information in the pictures above.

<table>
<thead>
<tr>
<th>Substance</th>
<th>metal</th>
<th>water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific Heat Capacity (Cₚ)</td>
<td></td>
<td>4.184 J/g°C</td>
</tr>
<tr>
<td>Change in Temperature (ΔT)</td>
<td>Final - initial = change</td>
<td>Final - initial = change</td>
</tr>
<tr>
<td>Energy lost or gained?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Calculate the specific heat capacity of the metal. What is most likely the identity of the metal? Show all work and label your answer with the correct unit.

Specific Heat Capacity Reference Chart:

<table>
<thead>
<tr>
<th>Metal</th>
<th>Gold</th>
<th>Tin</th>
<th>Silver</th>
<th>Nickel</th>
<th>Calcium</th>
<th>Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Heat (J/g°C)</td>
<td>0.13</td>
<td>0.21</td>
<td>0.24</td>
<td>0.44</td>
<td>0.65</td>
<td>0.90</td>
</tr>
</tbody>
</table>
5. Use the following heat curve to answer the questions below.

![Heat Curve for Water](image)

a. Label the phases of water on the graph (solid, liquid, gas).
b. Label the phase changes for water on the graph (melting, boiling).
c. Draw a diagram to show how the particles are organized at Point A on the graph and Point B on the graph. Include and make sure to clearly show the following information:
   - Show the particle attractions
   - Use arrows to show the movement/energy
   - Spacing between particles

![Diagram](image)

Point A  |
---|
Point B

d. Use your particle diagram from part c, to explain why the temperature does not change between Point A and Point B.

e. How much energy is required to heat the water from 20.0 °C to 120 °C?
Use the following information to answer questions 6-8.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Gold</th>
<th>Tin</th>
<th>Silver</th>
<th>Nickel</th>
<th>Calcium</th>
<th>Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Heat (J/g°C)</td>
<td>0.13</td>
<td>0.21</td>
<td>0.24</td>
<td>0.44</td>
<td>0.65</td>
<td>0.90</td>
</tr>
</tbody>
</table>

6. How much energy is required to heat 10 grams of nickel from 20 °C to 60 °C?

7. If the metals listed above were the same mass (10g), which metal would require the most energy (q) to change its temperature (ΔT)? Explain using a calculation or a definition of specific heat capacity.

8. A calorimeter contains 150 g of water at an initial temperature of 20 °C. A sample of silver with an unknown mass is heated to an initial temperature of 100 °C and then placed into the calorimeter. When the temperature stabilized, the system had a final temperature of 24 °C. What is the mass of the silver?
Appendix D

Unit 3 Written Exam: Counting Particles

Background
Rocks contain a mixture of particles including compounds and pure elements. In certain parts of the world, rocks also contain compounds called iron ore, from which the element iron can be extracted. Rocks that contain iron ore are not pure, rather they are mixtures of the compound that contains iron and other compounds present in the rock. The two most common iron ores mined are: hematite which has a formula of Fe₂O₃ and magnetite which has a formula of Fe₃O₄.

<table>
<thead>
<tr>
<th>Type of Ore</th>
<th>Hematite</th>
<th>Magnetite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula of Iron Ore</td>
<td>Fe₂O₃</td>
<td>Fe₃O₄</td>
</tr>
<tr>
<td>Location Mined</td>
<td>South America</td>
<td>United States</td>
</tr>
<tr>
<td>Composition of Rock</td>
<td>60% Iron Ore, Fe₂O₃</td>
<td>30% Iron Ore, Fe₃O₄</td>
</tr>
<tr>
<td></td>
<td>40% Other compounds</td>
<td>70% Other compounds</td>
</tr>
</tbody>
</table>

1. What is an example of an element, compound, and mixture from the data table and background paragraph given above?
   
   Element: ______________________
   
   Compound: ____________________
   
   Mixture: ____________________

2. Draw a particle diagram for a rock containing hematite and a rock containing magnetite. Include a key or labels for all types of particles in your diagram.

Key: Hematite:_________ Magnetite:_________ Other Compounds:_________
3. Calculate the molar mass of hematite, Fe$_2$O$_3$

4. How many grams is in a sample of 1.5 moles of hematite, Fe$_2$O$_3$?

5. Calculate the molar mass of magnetite, Fe$_3$O$_4$

6. A 10.0 gram sample of magnetite, Fe$_3$O$_4$ was collected in Minnesota. How many moles is this?

7. Classify the following statement as True or False. Explain your answer in calculations and/or words.

   One mole of magnetite has the same number of particles as one mole of hematite.
8. Calculate the percent composition of the element iron in each ore.

\[ \text{% iron in the ore hematite} \]
\[ \text{% iron in the ore magnetite} \]

<table>
<thead>
<tr>
<th>Type of Ore</th>
<th>Hematite</th>
<th>Magnetite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula of Iron Ore</td>
<td>Fe$_2$O$_3$</td>
<td>Fe$_3$O$_4$</td>
</tr>
<tr>
<td>Location Mined</td>
<td>South America</td>
<td>United States</td>
</tr>
</tbody>
</table>
| Composition of Rock  | 60% Iron Ore, Fe$_2$O$_3$  
40% Other compounds | 30% Iron Ore, Fe$_3$O$_4$  
70% Other compounds |

9. Based on all of the information given in the background (shown above) and your calculations. Which location (South America or the United States) would have the greatest total percent of iron in the rock and therefore would be best for mining? Include in your answer:
- Identify the best location to mine
- Discuss the percent of pure iron in each type of ore
- Discuss the percent iron ore in each rock mixture
- Explanation that includes actual data/numbers
## Appendix E

### Teacher Reflection and Observation Log

<table>
<thead>
<tr>
<th>Date:</th>
<th>Class Period:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Checklist - Tally number of occurrences each class period

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group asking for technology help:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Group asking for chemistry help:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Group asking for general project help:</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Self-reflection of class period

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
</table>