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Improving Science Literacy Using Photographic Documentation of Laboratory Activities

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by

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DEDICATION

To my parents, who always made education a priority. To my mother, Margaret Hesse, who encouraged me to do my best and to learn as much as possible. And to my father, Patrick Hesse, who was my idol for his intelligence and wit, his love of life, and his skill at photography.

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I am grateful to my husband, Robin Radus, who has listened with interest to the results of my research, and has encouraged me throughout my graduate studies.

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CHAPTER ONE

Introduction

Introduction

Laboratory experience and hands-on activities are essential to effective science education. Students must make discoveries of their own in order to be successful in science (Neal, 1962). Evidence is essential to the Scientific Method, and laboratory activities provide students with direct evidence to support the material that is taught in the classroom (Williams, 2008). When students connect their own experiences to the material that they have learned in class, they can recall and explain it more clearly. The excitement and satisfaction of completing lab activities can serve as a catalyst for students to continue to study science.

The significance of the laboratory experience is amplified when students carefully reflect on those experiences and integrate them into their learning. Standard laboratory reports allow students to produce written reflections on lab activities, but students sometimes view these reports as rote or mundane (Ende, 2012; Fuller, 2017). To encourage my students to derive more meaning from their laboratory activities, I propose that using photographic documentation to support these activities will lead to deeper reflection and integration of knowledge. The purpose of this capstone is to answer the question, *What is the impact of photographic documentation of lab activities on students' literacy in science?*

This chapter explains the significance of this research question. It also describes my personal history as a student and a teacher of science to justify my personal and professional reasons for conducting this investigation. This chapter also addresses the wider implications of the investigation for improving scientific literacy and its potential to promote change in the field of science education.

Context

I have been a high school science teacher for 25 years. The majority of my career has been spent teaching students at the same high school that I attended as a teen. I have taught biology, chemistry, earth science, and astronomy during my career, and of these subjects, I feel my greatest calling is to teach biology. Before I entered high school, I had very little exposure to meaningful science education. My 9th grade biology class in high school was my imprint of how a science class was conducted. The rigor of the course, the quality of the content, and the frequency of lab activities fascinated me and made me want to learn more. My 12th grade advanced placement biology course was much more challenging, and modeled the experience of a college biology class. At that stage of my development, I was planning for a career in science or medicine, and the lab activities made me feel like I was capable of doing the work of a scientist. I felt well prepared to choose biology as my major when I entered college.

Laboratory activities are the most common way for students in science classes to have authentic engagement with the subject material (Hofstein & Lunetta, 1982). When I reflect on my own high school experiences, those moments of authentic engagement are what I remember. Lab activities made science *real* for me. I clearly remember one of the first lab exercises in my 9th grade biology class was viewing my own cells under the microscope. I had never seen my own cells before. I was instantly fascinated and felt a genuine connection to the statement in the Cell Theory, *"All living things are made of cells."*

My career as a teacher is born from my experience performing and leading laboratory activities. During my high school years, I participated in a program called, “Experiences in Scientific Research” at St. Joseph's College in Brooklyn, NY. The program involved performing college-level laboratory experiments, primarily in chemistry and biology. This program helped me to develop skills in observing and recording data, following laboratory safety procedures, and being patient with the process of scientific investigation. These experiences gave me greater confidence in myself as a science student and made me feel capable of studying science on the college level. I also built strong relationships with the program director, Dr. Mary Maier, and her lab assistants, who were students at the college. These relationships motivated me to attend St. Joseph’s College as an undergraduate student in biology. In time, I served as a lab assistant for the “Experiences in Scientific Research” program, assisting the next generation of high school students who shared my inquisitive nature.

The time that I spent as a lab assistant and facilitator working with high school students gave me practical skills that I still use with my students today. Those experiences taught me how to quickly demonstrate procedures, calmly respond to problems. answer numerous questions, and reinforce safety rules, while circulating among fifteen groups of students at a time. I value those experiences and look back to them as my prime motivation for entering the field of education with a specialty in science. Throughout my career, I have emphasized the value of lab experiences, and have worked to integrate hands-on activities as frequently as possible in the classes that I teach. As the field of science education has changed, my approach to laboratory activities has also changed. Whenever possible, I use technology to facilitate the class's laboratory experiences, particularly digital photographs and data sharing.

In the last several years, I have carefully incorporated digital photography into my students' laboratory experiences. During the introductory labs involving the microscope, I informally teach my students how to use their smartphones to take photographs through the microscope. Initially, I did this to improve the students' drawings of their slides. I quickly noticed how excited the students were to have a visual record of what they had seen. They proudly showed off their pictures to their friends, other teachers, and parents. They were able to remember what they had seen and were more prepared to recreate the images on paper. I observed that when students took photos of their laboratory work, they showed a deeper connection to the lab activity because they had retained the knowledge that they had learned.

In my studies at Hamline University, I have learned to use Photovoice as an alternative means of expressing one's knowledge on a topic. A Photovoice project involves organizing photographs in a meaningful way and then using a brief voiceover or text overlay to convey the story of the photos. Photovoice may be used as a teaching tool or a tool for reflection (Cook & Buck, 2010). As I created my first Photovoice project, I began to consider how my students could use the same methods to tell the story of their laboratory experiments. I want my students to build a stronger connection to their lab activities, and I predict that a photo project in the style of Photovoice would support that connection.

Rationale

Laboratory experiments provide students with authentic experiences to connect them to the content that is taught in science classes. Students gain a deeper understanding of scientific concepts when they are able to see them with their own eyes (Bryan, 1948). When students reflect on these experiences and integrate them into their bank of knowledge and understanding, it supports their success in learning the subject. A common method of reflection on lab activities is the written laboratory report (Todd, 2021). These reports detail the purpose of the experiment, the materials used, the procedure followed, a recording of the experimental results, followed by an analysis of the results and a conclusion.

There are many limitations to using the written lab report as the primary means of assessment of student performance in the lab (Fuller, 2017). Students with dyslexia or other reading and writing delays, and English language learners often struggle to complete such written reports. Other students may try to take shortcuts in the written report, or avoid the assignment completely. McDonald and Dominguez (2009) observed that reflection activities, which often include writing, can help students to make connections between theory and practical applications. Students who avoid these activities, or are unable to complete them, may miss the opportunity to think about what they did or saw, and to integrate those things into their deeper knowledge.

Photographic documentation provides students with an additional level of engagement with their work, and a different way to reflect on what they have learned. If students develop a visual record of their laboratory activities, it will support their memory of those activities (Jones, 2010; Waycott et al., 2012). A photo project provides an alternative means of student engagement and assessment which will help students to develop better writing skills for science (Fuller, 2017). The photo project serves as a pre-writing activity which will aid the writing process in a more creative way. Students are able to take greater control of how the visual content is created and displayed. They are able to individualize their work through the creative use of their photographs. These creative elements will make the activity more meaningful to the students.

This new style of photo-supported laboratory report would serve as an intermediate step in producing a written lab report. The photo project provides a scaffolding opportunity, in which the students learn from each other, while the teacher provides support (Kurt, 2020). These interactions are typical in the setting of the biology lab. Applebee and Langer (1983) showed that these interactions in elementary school lab settings promoted thinking and language skills, and helped students to learn new ways to express their knowledge. In this case, each part of the photo project: planning discussions, performing the lab, taking photographs, organizing the photos, and creating the final product, requires the students to collaborate and learn from each other. These activities will prepare each student to write a lab report.

The photo project used in this study requires the same components as the traditional written report, except each part would be depicted visually with a short written description or voiceover. The students would collaborate with their lab partners to produce a final project that would be a video or slide presentation created by the students from their own photographs. This type of activity supports an array of learning styles and skill sets (Gardner, 1983). Visual learners may engage in taking the photographs or producing the final product. Auditory learners may provide verbal descriptions for voiceovers. Kinesthetic learners would have their greatest engagement with performing the experiment or working with equipment, as well as assembling the content (McGlynn & Kozlowski, 2017). Additionally, students who have an aptitude for technology may excel at creating digital content, and artistic students could add personalized creative details to the finished product.

Through this study, I would hope to see improvement in my students' ability to reflect on what they have learned, and to integrate these experiences with their prior knowledge. A quantitative assessment of this change would include measuring the students' aptitude by answering objective questions related to specific lab activities. I would expect that the students would score a greater number of correct responses to questions related to their photo-supported lab report than questions related to other labs they have completed in the traditional fashion. A qualitative assessment would include evaluating the students' literacy in science before and after engaging in the photo-supported lab report. Changes in literacy were measured by comparing correct usage of scientific vocabulary and communication of scientific principles in a written lab report. I expect that because of the deeper engagement involved in using their own photographs, my students will make a more meaningful connection to the subject material. Deeper understanding will improve their ability to communicate, leading to improved literacy in science.

It is hoped that this small-scale investigation will lead to large-scale change in the field of science education, particularly in how teachers support students in acquiring scientific knowledge and concepts, as well as how teachers evaluate the acquisition of these concepts. The COVID-19 pandemic has introduced many changes to how we teach and learn (Callimaci & Fortin, 2022; Teräs et al., 2020). Digital technology needed to be quickly integrated into our pedagogy. As educators reflect on what tactics have worked successfully in our classrooms, this is an appropriate time to consider how we can use technology to improve students' performance in science.

At the height of the COVID-19 pandemic (2020-2021), many teachers, including myself, had to enlist alternative means to engage students from home. My students performed very well when they were asked to produce visual presentations while learning remotely. I found that my students connected well with the subject matter, and were very proud of the creative choices that they made in their presentations. It was clear that the creative process contributed to my students' understanding of what they were learning. If students are given more opportunities to incorporate the creative process by producing lab reports using digital photographs, I believe their competence in science will improve.

On a long-term scale, if this additional level of engagement does improve students' literacy in science, then these young people will be better prepared to understand real-world issues related to science, such as climate change and how diseases spread. It is important that we educate our children to deeply understand science. The long-term effects may not be measurable in this investigation, but they are important to consider.

Science educators around the country may benefit by expanding their definition of "lab report" to include a photo-supported lab report as a formative assessment in their classes. The photo-supported lab report provides a unique opportunity for students to use their creativity and acumen with digital recording technology to improve their learning in science. We are at a unique moment in the history of education because educators are open to trying new ways to implement technology to help students to gain access to knowledge and promote learning. Photographic documentation of lab activities is a logical step forward to improve student learning in science.

Summary and Conclusion

Lab activities are a vital component of science education. When students reflect deeply on these activities, they can improve their knowledge of science in short-term and long-term ways. My experiences as a student and a teacher have motivated me to find ways to guide my students to derive more meaning from their laboratory activities. Teachers around the world have incorporated more digital technology into their classrooms and laboratories. A photo-supported lab report is a logical use of digital technology in high school science labs. This novel way of creating a lab report using digital photography will support students' deeper knowledge of science.

This investigation examines the role of digital photography as an educational tool in 21st century classrooms and laboratories. The goal of this capstone thesis is to evaluate how digital photography can help students to improve their understanding of and literacy in science. If the findings of this investigation are positive, it may encourage science educators to standardize the use of photography during lab activities, and produce more students who are scientifically literate.

Chapter two of this thesis includes related literature to support the research question: *What is the impact of photographic documentation of lab activities on students' literacy in science?* The chapter explains photo–supported learning and its increased role as a form of educational technology. Chapter two also describes high school laboratory practices, and the value of improving scientific literacy.

Chapter three explains the methods that were used for this investigation. This chapter also discusses the mixed methods approach that was used to collect quantitative and qualitative data on this topic.

Chapters four and five include the data that was collected in the investigation, and a detailed analysis of those results.

CHAPTER TWO

Literature Review

Introduction

Authentic engagement and hands-on learning are fundamental to science education (Haury & Rillero, 1994). When students use photographs to document their lab activities, they are capable of developing deeper reflection, to create a stronger sense of engagement with the material. Research has shown that students who use photography as an educational tool show improvement in knowledge acquisition and content literacy (Capello & Lafferty, 2015; Schmerbeck & Lucht, 2017). In the high school laboratory, photography can help students to recall their activities, and integrate the activities with knowledge gained in the classroom. This investigation seeks to answer the question, *What is the impact of photographic documentation of lab activities on students' literacy in science?*

It is important to understand the normal expectations of students in the setting of a high school science laboratory. The lab activities designed for my 9th grade biology students are intended to improve scientific literacy, to foster inquiry skills, and to teach safe laboratory practices. The use of photography must never impede lab work, or run counter to any lab safety rules, but should enhance the student's engagement and ability to recall details. Similarly, photographic documentation is not meant to replace a traditional lab report, but to supplement it. This method of documentation is intended to encourage students to reflect more deeply on what they have learned. This should improve the quality of their written lab reports, which would indicate improvement in their literacy in science.

This chapter examines literature that supports the idea that digital photography may be useful as an educational tool in high school science laboratories. The topics which will be discussed are photo-supported learning, educational technology, high school laboratory practices, and science literacy. It is important to understand how photographs have been and continue to be used as educational tools, particularly in science classes. As access to educational technology improves and becomes more commonplace, teachers and students can take and use photographs easily. The use of one's own photographs may provide more meaning for students than stock photographs do. Photo-supported learning has become more common due to the recent and ongoing changes to educational policy as a result of the COVID-19 pandemic. This is an opportunity to evaluate the possible benefits of photo-supported learning in high school science labs.

Photo-Supported Learning

The use of visual aids enhances learning in the science classroom (Cook, 2012). Diagrams, drawings, and stock photographs are frequently incorporated into science textbooks and lessons. "Photo-supported learning" refers to the use of original or stock photographs to visually reinforce course content. The terms "photo portfolios," "ePortfolios," or "photo reports" describe how photographs may be used by students to document lab activities. This section examines how photography is used as a learning tool and how students respond to photo-sharing assignments in science classes.

This investigation utilizes student-generated photo portfolios, consisting of a set of photographs taken by the students, with written descriptions. Schmerbeck and Lucht (2017) used this method to reinforce foreign language acquisition. Students in an intermediate level German language class created photo portfolios to demonstrate aspects of German cultural activities. Each set of student photographs was accompanied by written descriptions in German. The researchers found that the act of describing and interpreting the photographs led to improvement in foreign language literacy. Like Schmerbeck and Lucht's study, this investigation involves student-generated photographs alongside written or verbal descriptions in a "new" language, the language of science.

The development of digital photography and smartphones has given teachers and students new visual tools to enhance science education. Photographs allow students to maintain a record of their observations during lab activities. The act of taking photographs also allows students to develop their knowledge of science using a creative vehicle.

Photographs are an effective way to engage students in course material (Hollingsworth, 1985). Visual stimuli convey information differently than written words, and consequently, students may interact differently with a photograph than they might with the written word. Rochette (2007) described the change in her teaching when smart boards were first introduced. The ability to show historical paintings and photographs on the smartboard improved her students' understanding of a poetry unit. The addition of visual stimuli helped the students to give context to what they had read in class, which led to deeper understanding. This suggests that photography may provide an alternative method of conveying information.

A photograph may prompt a typically shy student to speak up and describe the photo. Students who struggle to read may gain deeper understanding from viewing a photograph. English language learners may acquire new skills by connecting images to ideas and terms in their native languages (Jones, 2010). Science teachers often employ drawings and diagrams to illustrate new content, such as the parts of a cell or the shape of an enzyme. In the past, common visual aids in a science classroom included textbooks and posters, as well as hand-drawn diagrams (Harbeck, 1970). Today, smartboards with internet access allow teachers to easily incorporate images into every lesson. Typically, these images are the same type of stock photographs that might be found in a textbook. The use of original photographs, by the student or the teacher, is less common.

The widespread use of smartphones has given teachers and students the ability to take and share original photographs for educational purposes. In science classes, a practical application of this technology would be to record the procedure and observations of laboratory experiments. Research shows that biology students who incorporate their own photographs derive greater meaning and understanding from their lab activities (Capello & Lafferty, 2015; Harper et al., 2015; Waycott et al., 2012).

In the study documented by Harper et al. (2015), undergraduate botany students used digital photography to document lab activities. The students readily shared their photos with their peers and reported that the activity helped them to “create their own knowledge in a more meaningful way” (p. 699). The students in this investigation also reported that taking photos helped them to more accurately remember the activity after they had left the lab.

Waycott et al. (2015) conducted a study involving undergraduate students in biology and chemistry, who performed two different types of photo-sharing activities. The biology students were instructed to create a photo gallery of beetles that they observed on campus. The photos were shared with their peers, and the assignment was graded as part of the coursework related to this topic. The chemistry students were instructed to take photos of everyday applications of chemistry. The assignment was not specifically linked to the coursework, but completion was required in order to pass the course.

The results showed a contrast between the students in each discipline, with the biology students reporting a more positive outcome than the chemistry students. The biology students, whose photo-sharing activity directly related to their class material, reported that the activity was useful and helped them to reflect on their work. The activity for the chemistry students was not directly related to their coursework, and several of those students viewed the activity negatively. The researchers emphasized the importance of ensuring that a photo-supported learning activity is relevant to the class material, and encourages deeper learning.

Cappello and Lafferty (2015) observed elementary students in an earth science class who performed a photo project during a unit on minerals. The students created photo booklets to show how minerals were used in the everyday world. The participants showed measurable improvement in the use of scientific vocabulary. The researchers recommended incorporating photo projects in order to provide students with deeper engagement with course materials. Students will improve due to their personal interaction with the content that they are learning. This would also provide teachers with an alternative means of assessing student understanding. Multiple forms of evaluation may help teachers to find and address learning gaps. These principles may be applied across multiple disciplines.

Photo-supported learning is valuable because it allows students to develop multiple skills and talents. Gardner's Multiple Intelligences Theory (1983) describes different "intelligences" or ways that people process information. Students may fall into categories such as visual, auditory, or tactile learners, with many students being a combination of these. The project outlined in this capstone is designed to appeal to students of many different strengths, intelligences, and learning styles. While the activity focuses on utilizing visual skills and literacy, other skill sets will also be developed. Some students may build writing or public speaking skills by drafting and producing voice-overs for the photo project. Musically talented students may work on music or sound effects. Kinesthetic learning will improve as a consequence of the hands-on experiences of both the lab activity and the photo report. Students will develop organizational and interpersonal skills as they collaborate with their lab partners and make choices about their final product.

Researchers who have utilized photo-supported learning to create video lab reports with their own classes have noted the benefits of student collaboration and employment of creative elements to illustrate their inquiry experiences. The integration of science content with technology and team building supports language acquisition, fosters developmental skills, and promotes digital and scientific literacy (Olivas, 2013).

Fuller (2017) utilized ePortfolios in undergraduate biology courses designed for non-science majors. Students in the control group submitted paper lab reports instead of ePortfolios, which supported multimedia sources. The students who used ePortfolios reported that they received their instructor's feedback faster, and found the feedback to be more useful. The ePortfolio students were also more likely to utilize other digital class resources than the students in the control group. The results of this study showed that the students who used ePortfolios were more likely to pass the course, and had higher grade point averages than the control group.

It has been said that a picture is worth a thousand words. Visual aids have always been valuable in science classes. Digital photography allows teachers and students to create their own photographic content for lessons and assignments. The employment of educational technology allows that content to be transmitted and used in classrooms and laboratories. Photo supported learning relies on digital photography as a form of educational technology. Photography can provide greater engagement and recall of activities. It is important to understand how digital photography may be utilized as an education tool, to be able to answer the research question, *What is the impact of photographic documentation of lab activities on students' literacy in science?*

Technology as an Educational Tool

The COVID-19 pandemic catalyzed a sharp increase in the use of educational technology in all subject areas and grade levels. Teachers and students developed new skills in using digital resources inside and outside the classroom. This section explores improvements in educational technology, most notably in response to the move to remote learning. It will also discuss how educators have responded to the rapid adoption of educational technology in their classrooms.

As early as 1970, researchers have been advocating for educational technology in the science classroom (Harbeck, 1970). Early applications of technology in science classrooms included electronic measurement and other laboratory equipment, with a goal of incorporating more sophisticated software as technology became more widely available.

Since 1970, educational technology has progressed from the introduction of electronic lab equipment and simple technology to interactive online lessons, real-time video conferencing, and the prevalence of digital photography. Teachers incorporate technology to help students to improve their understanding of course materials. The value of educational technology became more evident in March, 2020, when schools around the world abruptly switched to remote learning in response to the COVID-19 pandemic.

The rapid adoption of educational technology has led to many changes in the field of education. The digital content used by many teachers during the shift to remote learning that began in March, 2020 consisted of an array of photo and video presentation platforms, such as Google Docs, Google Slides, Powerpoint, Padlet, Nearpod, Flipgrid, and many others. Students used the same platforms to submit assignments. After more than two years of relying on educational technology, teachers are now able to evaluate how to incorporate it strategically. The return to in-person learning has reduced the dependence on technology, allowing teachers to choose which forms of technology will have the greatest benefits for their students (Teräs et al., 2020). Digital photography remains a common tool that is used in multiple educational platforms, even after the return to in-person learning.

Teachers have been using technology to improve the way that they present their lesson materials and evaluate student progress (West, 2011). The rapid transition to remote learning in 2020 was not a smooth one in all cases. Turkmen and Önturk (2021) reported that some teachers noted several disadvantages to remote learning, including a decreased ability to communicate directly with students, as a result of inexperience with the technology and the limits of their wireless connections. However, these teachers did state that multimedia learning "contributes to meaningful learning" (p. 266). Teachers who had already been using student-driven inquiry activities reported an easier transition to remote instruction. Similarly, teachers who were already comfortable using technology reported fewer problems. The teachers who reported the greatest challenges were those who engaged in lecture-based instruction and those who had limited experience with technology.

The move to remote learning in March 2020 demanded that teachers and students around the world quickly learn to use educational technology. After quickly adopting technology out of necessity, we must now ascertain the best ways to deploy it to improve student learning.

The EdWeek Research Center (Bushweller, 2022) reported a sharp increase in the use of 1:1 computing, beginning in 2020. Monthly surveys tracked the use of digital learning tools. The data provided show that 54% of students surveyed reported that their schools provided 1:1 computing by distributing devices to students. The research also showed that the distribution of digital learning devices increased from 67% to 90% among middle and high schools, and from 40% to 84% in elementary schools. The increase in availability of digital learning devices supports the growth of digital technology in classrooms.

Implementation of technology is changing the field of education (Callimaci & Fortin, 2022). In this moment of change, we must evaluate how we use technology in science classrooms and laboratories. Using photography to document lab activities allows students to incorporate technology into their hands-on activities and connect with science content. This is a natural application of educational technology in science education.

High School Science Laboratory Practices

Laboratory activities are a vital part of high school science classes, focused on the idea of "learning by doing" (Bryan, 1948, p. 180). In a typical laboratory activity, students are expected to interact with materials (lab equipment, living specimens, measurement tools, etc) in order to observe a certain phenomenon (Hofstein & Lunetta, 1982). Through these inquiry activities, students learn to follow the scientific method, how to use equipment, how to follow safety protocols, and how to collaborate with lab partners. These activities serve as a model for how professional scientists go about their work. Traditionally, the assessment of student learning involves a written lab report or a practical exam (Robinson, 1969). This section discusses the value of lab activities and traditional written lab reports, and how the format is changing in the 21st century.

Traditionally, many professional science laboratories have required that researchers maintain a daily written log of their activities in a bound notebook, ensuring that no pages may be added or removed, thus providing an honest account of the researcher's work. In a similar way, students in high school science classes are required to produce a record of their laboratory activities in the form of a written lab report. A standard written lab report includes the following sections (Todd, 2021): a statement of the purpose of the investigation, an equipment list, a summary of the procedure, a record of collected data, and an analysis of the results.

Lab reports can serve as important reflection tools. When students rewrite the procedure in their own words, they must draw on their memories of performing the activity (McDonald & Dominguez, 2009). When they analyze their results, they must put their observations into the context of the purpose of the activity. Lab reports help students to organize and make sense of the data they collect (Aulia et al., 2018). Lab reports also allow teachers to assess student understanding of scientific concepts.

Students report that they enjoy *doing* lab activities, but not writing lab reports (Ende, 2012). Students view writing a lab report as a "chore" and frequently question the importance of the written follow-up of a lab activity. Many students do not connect their lab activities to the work they do in class, and they will sometimes leave out key details in their procedures or data. As Ende said, "Relevance is the key that unlocks the door of learning" (p. 45). Whatever the activity may be, it must be relevant to the course material. He also suggested that if teachers incorporate open-ended questions and creative elements to lab reports, students will find the activities more relevant and meaningful.

The transition to 21st century education requires that we reexamine the methods by which students record their observations of laboratory activities. Hofstein and Lunetta (2003) recommended that more emphasis be placed on inquiry activities and engaging students of different abilities and learning styles. This type of lab setting encourages students to collaborate and construct their knowledge through problem solving. The researchers assert that the high school science lab must continue to serve as a model of the college or professional lab setting.

In preparation for the turn of the 21st century, the National Association of Biology Teachers made similar recommendations for changes in biology education that would move toward a holistic approach which would utilize technology and focus on "science as a process, rather than a product" as cited in The National Association of Biology

Teachers (Wright & Govindarajan, 1992, p. 270). This approach would place emphasis on laboratory investigations, with students collaborating to collect and interpret data. The integration of technology into traditional laboratory practices would engage students' psychomotor skills and encourage students to think critically about the connections between their lab activities and problems in the natural world.

Photographic documentation would serve as an illustrative tool to enhance a traditional lab report, as suggested by Kowles (1965). For example, a photograph of necessary lab equipment would be used to develop a written equipment list. Sequential photos of the steps of the activity would help students to include more detail when summarizing the procedure. Photographs of data, including color changes and microscopic views, would help students to record their data with more accuracy. The attentiveness and safety of the student participants are chief priorities. The act of taking photographs should never interfere with the lab activity but should serve to document what the students did and observed during the activity.

High school laboratories are the training ground for our future scientists. It is important to train our students to follow proper laboratory procedures, including writing lab reports (Tobin, 1990). Photographic documentation will allow students to improve their recall and understanding of lab activities after they have left the lab. This improvement in understanding will lead to better lab reports, ultimately improving their literacy in science. In this way, photographic documentation of lab activities will benefit science students.

Science Literacy

Science literacy can be described as an individual's ability to engage with scientific-related issues and ideas as a reflective citizen (PISA, 2018). Literacy in science is necessary to produce a citizenry that is capable of making well-informed decisions about scientific concepts. A long–term goal of this investigation is to improve science literacy among high school students. This section addresses the importance of literacy in science, and educational strategies designed to improve science literacy.

In broad terms, literacy refers to the ability to read and write, to understand and communicate. PISA for Development (2018) defined *scientific* literacy as "the ability to engage with science-related issues and with the ideas of science, as a reflective citizen" (para. 1). Howell and Brossard (2021) described three categories of science literacy: *civil science literacy, digital media science literacy,* and *cognitive science literacy*. *Civil science literacy* involves understanding how science relates to society. *Digital media science literacy* involves understanding how science information moves through media systems. *Cognitive science literacy* involves understanding how people interpret science information when they encounter it. This investigation seeks to address all of these aspects of science literacy. In order for students to become scientifically literate, they must gain a deep understanding of processes and interrelationships. For this reason, researchers such as Adams and Pegg (2012) suggested that content literacy in science can only be evaluated in the context of engaging in an authentic activity. In a science class, the most common type of authentic, hands-on activity is a lab experiment.

The written lab report is a common method for evaluating student literacy in science (Hofstein & Lunetta, 1982). In this type of report, teachers assess the appropriate use of vocabulary, accurate descriptions of procedures, and clear analysis of data. Proficiency in these areas would be one way to evaluate literacy. When teachers take time to model how to write a lab report and reinforce the importance of those skills for science literacy, their students do show improvement in vocabulary usage (Whitehead & Murphy, 2014).

The most effective strategy to improve literacy in science is for students to do hands-on activities and write about them. A study conducted by Aulia et al. (2018) examined changes in literacy as a result of guided inquiry activities. In this study, 11th grade chemistry students performed a guided inquiry lab activity involving solubility rates. The activity included specific questions related to recent coursework and step-by-step instructions. The students' literacy on the topic was tested before and after performing the guided inquiry activity. Their literacy was shown to improve as a result of the activity, and students reported that they had a greater connection to chemistry concepts in everyday life. Most high school science labs, including those designed for my 9th grade biology classes, are guided inquiry activities. Adams and Pegg (2012) have suggested that when teachers give students an active role in constructing knowledge, their literacy will improve.

When students use photographs to document their lab activities, I predict that they will be more likely to write accurately, include detail, and correctly use scientific vocabulary in a lab report. Since a lab report may be used to evaluate science literacy, the use of photographs should improve science literacy. Research on the relationship between photography and literacy suggests that photography is a useful tool to improve literacy across multiple disciplines. Schmerbeck and Lucht (2017) showed that photography improved literacy in foreign languages when students tried to explain the photographs in the new language. Capello and Lafferty (2015) documented literacy improvements among elementary earth science students. When students created photo booklets of mineral samples, there was an increase in the students' use of scientific vocabulary. It is logical to expect that similar methods of incorporating photography will produce similar results for the students in my 9th grade biology classes. These ideas support the validity of the research question, *What is the impact of photographic documentation of lab activities on students' literacy in science?*

Rationale of Research

This investigation is relevant to the field of education because of the recent increase in the use of educational technology, and the greater facility that students and teachers have developed in using technology. Digital photography is a logical tool to incorporate into student lab reports. In order to modernize the field of education, we must modernize the way we evaluate student performance in science labs. I predict that students who use photography to document their lab experiences will show short-term and long-term improvement in their science classes.

Previous researchers have investigated the use of photography as an educational tool in other subject areas, such as foreign language (Schmerbeck & Lucht, 2017) and chemistry (Aulia et al., 2018). Other research has been conducted in colleges (Fuller, 2017; Waycott et al., 2012) or elementary schools (Capello & Lafferty, 2015), but there is scant research examining the use of photography in high school biology labs. While the application of photography has increased as a result of the COVID-19 pandemic, there is little research on its continued use as an educational tool. This investigation will examine the use of photography as an educational tool, with a focus on high school biology classes. Most research on the use of photography in the classroom has dealt with visual aids, rather than student generated photographs. The recent increase in use of photography as a form of educational technology will help the students to view the investigation as a normal learning practice, hopefully providing unbiased results.

Summary and Conclusion

Photographic documentation adds an additional opportunity for students to reflect on a lab activity. When students reflect on lab activities and integrate them into their deeper knowledge, they grow in understanding and can improve their literacy in science. In order to examine these benefits, it is important to understand photo-supported learning as an educational tool, and its place in the context of educational technology. It is also important to note standard high school laboratory practices, and the importance of lab reports as a means of demonstrating literacy.

Chapter three describes the methodology used to conduct an investigation on this research topic. In this investigation, high school students conducted photo-supported lab activities. They were tested for their short-term recall of the activity, as well as more long-term understanding. They also participated in surveys and reflections before, during, and after the activity. A mixed methods approach was used to collect and analyze data to examine the question, *What is the impact of photographic documentation of lab activities on students' literacy in science?*

CHAPTER THREE

Methodology

Introduction

Historically, scientific inquiry has been an essential part of science education (Bryan, 1948). Inquiry activities provide students with a model of the scientific method, training them to perform the tasks of a scientist. The work that is done in a laboratory setting also reinforces the content that students learn in the classroom. In order to integrate the lab activities with the course content, it is important for students to retain accurate memories of the activities and their results. Digital photography may provide students with a more vivid memory of these activities (Jones, 2010), thereby improving their ability to answer questions about the activity, and write about what they have learned.

This capstone investigates the question, *What is the impact of photographic documentation of lab activities on students' literacy in science?* In this investigation, students utilized photography as a form of educational technology. They used this technology to document the steps of a lab activity, as well as the observations that comprised their data. The goal of using photographs was to improve the quality of their written lab reports, and improve their scores on objective questions related to the activity.

This chapter explains the choice of research paradigm and methodology of this investigation. It includes a description of the setting and participants, and it explains how they were treated ethically as participants in the investigation. This chapter also includes the research tools that were utilized, and how the data was collected and analyzed.

Research Paradigm

This investigation utilized a convergent mixed methods approach to research, incorporating both quantitative and qualitative data, collected simultaneously, and merged for interpretation (Creswell & Creswell, 2018). The quantitative data included survey responses, such as Likert scales. Surveys were used as a pre-assessment and a post-assessment (see Appendix A). A comparison of these survey results before and after the investigation was used to show changes in the participants' attitudes and ability to define scientific vocabulary terms.. Additional quantitative data was collected from scores on student lab reports (see Appendix B) and responses to objective questions related to the lab activity (see Appendix C). Qualitative data was collected via reflection questions (see Appendix A) that were administered following each part of the investigation.

The convergent mixed methods design was the best approach for this investigation. It was important to examine both quantitative and qualitative data at all points during this research: before, during, and after students conducted the experiment. The convergent mixed methods design requires researchers to evaluate quantitative and qualitative data side by side, providing the researcher with a more complete view of the problem being investigated and may uncover causal relationships among the data. The choice of a convergent mixed methods design was the most appropriate for the particular setting and participants, as detailed in the next section.

Setting and Participants

The primary location for this investigation was intended to be the new STEM lab that was scheduled to open in my school building in September, 2022. Due to delays in the opening of the lab, the setting was changed to the Biology lab, where each class had previously performed lab activities. The change in setting did not affect the outcome of the investigation, although it did delay the start of the investigation.

The school is a private, Catholic college preparatory high school, overseen by a Board of Trustees, and located in a middle-class neighborhood in Queens, New York. The student body consists of students ages 13-18 in grades 9-12. The students live in diverse parts of New York City, including other boroughs such as Brooklyn, The Bronx, and Manhattan. Many families are recent immigrants to the United States, and many students are bilingual. Admission is based on a standardized test, the *Test for Admission into Catholic High Schools (TACHS)*, as well as the student's previous school records. On average, the school accepts 200 new 9th grade students each year. The population is predominantly Catholic/Christian, but the school accepts students from all religious backgrounds.

The participants in this study were my 9th grade Biology students. Some of the students may have taken a pre-course in Living Environment during 8th grade, and may already have performed the state-required lab activities that were used in this investigation. Prior knowledge of the outcome of the lab activity did not prevent any students from participating.

The participants were students from four classes: two classes of Honors Biology and two classes of General Biology. The average size of the Honors Biology classes is 18 students; the average size of the General Biology classes is 25 students. The participants will complete a Survey of Multiple Intelligences (Colannino et al., 2004), which will be used to assign the students to well-balanced lab groups of three or four students. These groups will work together on each part of the lab activity.

As a researcher, it was important for me to be mindful that my educational and cultural background differs from the backgrounds of my students/research subjects. Such considerations include modifications to accommodate English language learners and students who have reading or language delays. It was also necessary to provide additional support for students who view science negatively, or students who have previously struggled to understand science.

Prior to conducting the lab activities that were used in this investigation, the students in each class were trained in laboratory safety procedures, equipment, measurement, the microscope, and the scientific method. The students have also had experience in writing a lab report based on a lab activity.

Understanding the backgrounds of the participants reveals the importance of conducting this investigation in an ethical manner. I intend for this study to help my students to improve their performance in my class. The following section discusses the role of the Institutional Review Board (IRB) in ensuring that this research was conducted ethically.

IRB Process

Based on IRB guidelines, I sought an Exempt Review, due to the fact that this investigation fell within the category of Normal Educational Research. The investigation took place as part of the participants' standard educational setting. It did not interfere with usual classroom procedures or impede students from learning the required course content. Because the participants were minors, their parents/guardians were asked to consent to their participation. The participants and their parents were advised of the nature of the investigation, foreseeable risks, and possible benefits of participating. They were also assured of their confidentiality as participants, and were given instructions on how to opt out of participating in the study. None of the participants chose to opt out.

Ethics, peer review, and oversight are important to establish the validity of an investigation (Freedman, 1987). It is important to control the parameters of the investigation, and ensure that the rights and well-being of the participants are protected. The following section explains the methods and procedures of this investigation, to ensure transparency and ethical treatment of all involved.

Methods and Procedure

The purpose of this capstone was to investigate the question, *What is the impact of photographic documentation of lab activities on students' literacy in science?* My hypothesis was that students will achieve higher scores on objective questions, and produce higher quality written lab reports if they use photography to document their lab activities than they will on lab activities that do not use photographic documentation.

Before the investigation began, all participants were trained in lab safety, proper use of lab equipment, and the scientific method. They understood how to formulate hypotheses, record observations and data, and draw conclusions from their data. The students in each class were assigned to well-balanced lab groups, and had experience working with their partners. They had experience in working with lab equipment, such as the microscope and measurement tools. They understood the correct format of a written lab report, and had experience in writing lab reports. The students have also had experience using their personal electronic devices (smartphones, tablets, laptops) to create content and submit assignments. The students shared their photographs and information through Google Classroom and their student email accounts.

A pre-assessment was performed using a survey (see Appendix A). One part of the survey consisted of Likert Scale statements, such as, *It is easy for me to remember what I did after I complete a lab,* and *It is easy for me to correctly answer follow-up questions on a lab activity.* In the second part of the pre-assessment, participants were asked to write informal definitions of scientific terms, such as *diffusion*, *permeable*, and *osmosis*. The data collected in these pre-assessments was compared to similar survey questions that were administered following the lab activities.

The participants were students from four classes, a total of 85 participants. The Honors Biology classes were labeled *Class #1* and *Class #2.* The General Biology classes were labeled *Class #3* and *Class #4.* The lab activity was *Diffusion Through A Membrane*, a required part of the NYS Regents Curriculum for The Living Environment (Biology). The activity can be performed as two separate labs, Part 1: "Diffusion Through a Membrane: Model Cell" and Part 2: "Diffusion of Water Across a Membrane (Osmosis). "

In this investigation, *Class #1 and Class #4* produced photo projects to support their learning in Part 1, but not in Part 2. *Class #2 and Class #3* produced photo projects to support their learning in Part 2, but not in Part 1. In this way, each class served as a control group for the other class of the same academic level. At the completion of both parts, students submitted written lab reports, and answered objective questions (collected from past administrations of state exams) about both parts of the activity.

In each group, the independent variable was the production of a photo project to support their learning of the given activity. The dependent variable was the students' scores on the objective questions, and the quality of their written lab reports. All classes had the same amount of background preparation, and were given the same resources and length of time to complete the lab, photo project, lab reports, and objective questions. They were assessed according to the same rubrics (Appendix B).

The photo project served as a scaffolding assignment, and was used to record the same information that was necessary to produce a written lab report. For the given part of the experiment, each small group of students photographed the materials and equipment that were used, each step of the procedure in chronological order, and the results that they observed or data that they recorded. Taking photographs was not intended to interfere with the proper conducting of the experiment. It is always wise to remind students of lab safety rules.

Following the lab activity, each small group collaborated to create a photo project on a digital platform such as Google Slides to explain the purpose, materials, procedure, and results of the experiment. The photo project was used as a formative assessment (see Appendix B for the assessment rubric). Each student utilized their group's photo project to produce a written lab report. The students used the photo project, along with teacher feedback, to help them include details in the lab report. The lab report and photo project received separate grades.

It was important that the photo project was evaluated separately from the written lab report or the objective questions. Waycott et al., (2012) observed that students felt less motivated to contribute to photography-based projects if those projects were not connected to the student's grade. Also, the photo project was a collaborative assessment, whereas the lab reports and objective questions were individual assessments.

Each group performed the other part of the experiment without using photographs to document their work. At the end of both parts of the experiment, the students wrote lab reports on each part. These reports were evaluated for use of scientific terminology, inclusion of key details, depth of understanding, and mastery of content. Objective questions from past state exams also gauged student understanding and recall of each part of the lab activity.

At the completion of the entire lab activity, the participants completed a survey as a post-assessment. Likert Scale statements from the pre-assessment were repeated, to measure any difference in attitude. Additional statements were added, such as, *Taking pictures helped me to remember what I did in the lab.* Students were also asked to provide informal definitions of the scientific terms related to the lab, to evaluate the depth and quality of the explanation, and to compare each one to the earlier definition in the pre-assessment.

Based on the research of Fuller (2017) and McDonald and Dominguez (2009), who advocated for including reflection questions in science lab activities, the participants completed short reflection questions at the end of each stage of the project. Questions for this study included, *What part of the activity was the most valuable to you?* and *How did you feel about working with your partners?* The effort to reflect on each part of the activity may have helped students to integrate it into their deeper knowledge.

Triangulation of data collection allows a researcher to draw conclusions based on multiple sources of data (Mills, 2018). The following section will discuss the multiple methods of data collection and research tools that will be used in this investigation.

Research Tools

A number of research tools were used in this investigation. Surveys, in the style of Likert Scales (Mills, 2018), were conducted before and after the students completed the lab activity, photo project, and lab report. Surveys, objective questions, and project rubrics provided quantitative data. Qualitative data was collected in the form of responses to reflection questions.

Pre-assessment Tools (Quantitative)

Before the investigation began, a Multiple Intelligence Survey was used to create equitable small groups for lab work (see Appendix A). This survey helped students to identify their strengths, and allowed the teacher to assign the students to well balanced lab groups.

A pre-assessment survey included vocabulary assessments and Likert Scales (Mills, 2018). Likert Scales allow a researcher to quantify participant attitudes by assigning numbers to responses, such as, *Strongly Agree* = 4; *Agree* = 3; *Disagree* = 2; *Strongly Disagree* = 1. The pre-assessment survey gave the researcher the ability to measure changes in attitude and usage of scientific vocabulary by the participants as a result of the investigation.

Reflection Questions (Qualitative)

The activity in this study took place in three parts: taking photos while performing the lab, creating the photo project, and completing the written lab report and objective questions. On completion of each part of the activity, the students answered short reflection questions about what they did, what they learned, and how they felt at each stage of the investigation (see Appendix A). Responses to these reflection questions provided qualitative feedback on how the participants responded to each part of the study.

Post-assessment Tools (Quantitative)

Following the activity, the participants completed a post-assessment survey (see Appendix A) which included many of the same questions as the pre-assessment survey, in order to establish any differences in attitude. The post-assessment survey also asked students to define the same scientific vocabulary terms that they defined in the pre-assessment survey, to measure improvement in vocabulary usage.

Additional quantitative data included student responses to objective questions related to the two parts of the lab activity (see Appendix C). These questions were taken from previous state-administered exams, and will reflect New York State's learning standards. Students were tested on equal numbers of questions on each part of the activity, with equal level of difficulty.

Post-assessment Tools (Qualitative)

Qualitative data was used to indicate possible improvements in science literacy. In the pre-assessment and post-assessment, students were asked to provide informal definitions of terms related to the lab activity (see Appendix A). It was expected that students would demonstrate a deeper understanding of terms as a result of completing the photo project, and include more detailed definitions of the terms.

Written lab reports also served as a form of qualitative data. All students were evaluated according to the same rubric for both lab reports (see Appendix B). The proper use of scientific vocabulary, communication of scientific principles, and analysis of recorded data were used to evaluate each student's science literacy.

This investigation used a convergent mixed methods design to collect and analyze data (Creswell, 1994). The following section will explain how the data will be analyzed according to this model.

Data Analysis and Methods

According to the convergent mixed methods design, after the quantitative and qualitative data have been collected, the data must be merged. A side by side comparison provides the most relevant information in this investigation. If the hypothesis is correct, then the quantitative and qualitative data will reinforce each other, and demonstrate that student performance improves when they use photography to document their lab activities.

The survey questions in the pre-assessment were repeated in the post-assessment, to quantify changes in attitude among the participants. The objective assessment questions provided a quantitative analysis of student understanding and recall of each part of the lab activity, and a way to contrast aptitude in each part. These data were placed in context with qualitative data in the form of written lab reports, to demonstrate deeper integration of the lab activities and improvement of science literacy.

Summary and Conclusion

In order to answer the research question, *What is the impact of photographic documentation of lab activities on students' literacy in science?* a convergent mixed methods approach was undertaken. Two classes of General Biology and two classes of Honors Biology performed two parts of a lab activity; one part was documented using the students' photographs, and the other was not. The students' ability to define key scientific terms was measured before and after working on the photo project. The scores on written lab reports and objective questions were compared to those that were not related to the photo project.

In this investigation, quantitative data was collected in the form of survey responses, vocabulary assessments, and scores on lab reports and objective questions. Qualitative data was collected in the form of student responses to reflection questions. Together, these data were used to assess improvements in student literacy in science.

The following chapter includes the results of the investigation, and an analysis of the observed results in relation to the research question, *What is the impact of photographic documentation of lab activities on students' literacy in science?*

CHAPTER FOUR

Results

Introduction

The purpose of this capstone thesis is to answer the research question, *What is the impact of photographic documentation of lab activities on students' literacy in science?* My hypothesis in this investigation was that if students took photographs while performing lab activities, they would have a clearer memory and understanding of the activities than if they had not taken photographs. This deeper understanding would make students more prepared to read and understand questions related to those activities, and would support their ability to write meaningfully about science.

In the investigation, four classes of 9th grade biology students performed a lab experiment in two parts. Each class took photos of the equipment, procedure, and results for one part of the lab, but not for the other part. The students worked in groups to create a photo project. Afterwards, each student wrote a lab report on each part of the lab activity, and answered objective questions about each part. After each stage of the investigation, the students answered reflection questions about each part of the process.

The investigation utilized a convergent mixed methods approach to data collection. Quantitative data was collected in the form of Likert scales, vocabulary assessments, and student scores on objective questions and written lab reports. Simultaneously, qualitative data was collected in the form of reflection questions related to each part of the activity. These data were merged in order to observe possible patterns of growth among the participants.

This chapter discusses the data that was gathered using these research instruments. In order to look for improvements in science literacy, it was important to examine changes in usage of scientific vocabulary, along with the ability to understand and respond to objective questions. It was also important to understand the attitudes and responses of the participants as they engaged in each part of a multi-faceted activity. These qualitative elements helped to provide context for the quantitative data. This chapter examines and interprets the data that was collected in this investigation.

Research Instruments

Pre-Activity Survey

The first part of the Pre-Activity Survey (see Appendix A) was designed to provide a baseline to examine the participants' attitudes toward lab activities and the relevance of such activities to learning science. Student responses to the statements in the Likert scale were generally positive. The statements, *Lab activities are important to learning science,* and *Doing lab activities helps me to understand what I am learning in science,* received the greatest number of positive responses in all classes. Ninety five percent of the participants agreed or strongly agreed with the statement that lab activities are important to learning science. Ninety eight percent of the participants agreed or strongly agreed that lab activities help them to understand what they are learning in science. Across all classes, 91% of the participants agreed or strongly agreed that *I would remember something more clearly if I took a picture of it.*

The responses from the Honors Biology classes differed from those of the General Biology classes on certain statements. In the General Biology classes, 31% of students disagreed or strongly disagreed with the statement, *It is easy for me to remember details* *of the lab activity the day after lab,* while only 3% of students in Honors Biology felt this way. Similarly, 28% of General Biology students disagreed or strongly disagreed with the statement. *It is easy for me to remember the data that I collected in the lab,* while 8% of the Honors Biology students disagreed or strongly disagreed with this statement. This difference in response seems to indicate that the Honors Biology students were more confident in their recall abilities.

For the statement, *It is easy for me to answer follow-up questions after the lab,* 92% of the students in Honors Biology agreed or strongly agreed, while only 72% of the students in General Biology felt this way. In response to the statement, *It is easy for me to write a lab report based on a lab activity.* 81% of Honors Biology students agreed or strongly agreed, while 74% of General Biology students felt this way.

The second part of the Pre-Activity Survey measured a baseline level of correct usage and knowledge of a set of scientific vocabulary terms. The set of terms had been previously discussed in class, and were important to understanding the lab activity. The students' definitions were rated for the inclusion of certain keywords, use of less specific wording, incomplete definitions, incorrect responses, or responding, "I don't know." Tables 1 and 2 show the vocabulary results for Class #1 and #2 (Honors Biology). Tables 3 and 4 show the vocabulary results for Class #3 and #4 (General Biology).

Table 1

***Class #1 Vocabulary Results, Pre-Activity Survey* (Honors Biology, 19 participants)**

Vocabulary Term	Used Key Words (%)	Used Less Specific Wording (%)	Incomplete Definition (%)	Incorrect (%)	"I Don't Know" (%)
Permeability	74	11	0	0	16
Osmosis	58	16	11	16	0
Diffusion	63	16	21	0	0
Indicator	32	26	16	26	0
Cell Membrane	84	5	0	11	0

Table 2

***Class #2 Vocabulary Results, Pre-Activity Survey* (Honors Biology, 17 participants)**

Vocabulary Term	Used Key Words (%)	Used Less Specific Wording (%)	Incomplete Definition (%)	Incorrect (%)	"I Don't Know" (%)
Permeability	65	12	12	12	0
Osmosis	53	6	41	0	0
Diffusion	65	29	0	6	0
Indicator	18	17	12	12	12
Cell Membrane	65	12	6	18	0

The vocabulary results were consistent between these two classes. In general, more than half of the students were able to demonstrate their understanding of each vocabulary term by correctly using keywords in their definitions. A substantial number of students who did not utilize the key words were able to provide definitions which included less specific wording or were otherwise incomplete. In each class, very few students stated that they did not know the definition, or provided incorrect definitions.

In both classes, the term *Indicator* (a chemical which changes color to show the presence of a specific substance) had the fewest correct responses, and a substantial number of incomplete or incorrect responses. This term had not been widely discussed in class, but it was a term that the students had learned while performing a previous lab activity.

Table 3

Class #3 Vocabulary Results, Pre-Activity Survey **(General Biology, 24 participants)**

Vocabulary Term	Used Key Words (%)	Used Less Specific Wording (%)	Incomplete Definition (%)	Incorrect (%)	"I Don't Know" (%)
Permeability	25	29	4	8	33
Osmosis	29	17	13	17	25
Diffusion	38	25	8	13	17
Indicator	8	8	4	33	46
Cell Membrane	63	17	0	17	4

Table 4

***Class #4 Vocabulary Results, Pre-Activity Survey* (General Biology, 25 participants)**

Vocabulary Term	Used Key Words (%)	Used Less Specific Wording (%)	Incomplete Definition (%)	Incorrect (%)	"I Don't Know" (%)
Permeability	24	12	4	12	48
Osmosis	36	0	24	16	24
Diffusion	36	40	8	12	4
Indicator	12	4	8	24	52
Cell Membrane	84	0	0	12	4

The results for these two classes are more consistent with each other than with the results of the previous two classes. In both classes, fewer than 50% of the students were able to provide definitions that correctly used keywords. A notable exception was the term *Cell Membrane*, which had been the main focus of the lessons leading up to the lab activity. All four groups of students showed a greater familiarity with that term than the others in the Pre-Activity Survey.

The number of students who used less specific wording in their definitions suggested that these students might be able to provide more detailed definitions after performing the lab activity. In these classes, a substantial number of students wrote, "I don't know," (as instructed, rather than to leave any definition blank). This also suggested that after performing the lab activity, those students would be better prepared to offer correct or partial definitions for those terms.

Reflection Questions: After the Lab Activity

Each class spent three class periods performing the activities in the "Diffusion Through a Membrane" lab. Following completion of the lab activity, students were asked to reflect on the act of taking photographs during the activity, and how they felt photography might affect their memory of the activity (see Appendix A). Overall, the responses from the students were positive.

In response to the question, *How did you feel while you took photographs during the lab activity?,* nearly 100% of the students offered positive comments. The most common responses were that it "felt good" or "was fun." Several students in each class responded that they believed that photography would help them to remember the activity. Individual students remarked, "I felt confident," "I felt engaged," and "I was fascinated." The small number of negative responses were mainly technical issues, such as frustration with the technique of using a smartphone to take pictures through the microscope.

When asked, *How well do you think you will remember this lab activity two weeks from today? Why?,* the responses were mixed. In the Honors Biology classes, many students stated that it would be easy to remember the activity, and cited the use of photography as a reason. In the General Biology classes, fewer students offered positive responses. Between 20% and 30% of the General Biology students responded that they would probably not remember the activity well.

Responses to the question, *What parts of the activity will you remember most clearly? Why?,* were specific to the part of the lab that each class photographed. In the classes that took photos of Part 1 of the lab, most students responded that they would remember details such as color changes and how the model cell looked before and after the activity. Some students reported that they would remember actions such as pouring solutions into test tubes. In the classes that photographed Part 2 of the lab, most students stated that they would remember seeing cells change in size while viewing them under the microscope. In each class, approximately 10% of respondents reported that they would have a better memory of the part of the lab that they did not photograph.

The responses to this set of reflection questions showed that the students felt that the use of photography had improved their experience of performing the lab activity. Many students predicted that they would remember the lab activity more clearly as a result of taking pictures. However, it is interesting to note that not all students felt this way. Some students did not believe that photography would improve their memory of details, and others predicted that they would have clearer memories of the part of the activity that they did not photograph.

Reflection Questions: After the Photo Project

The students spent four class periods working with their lab groups to create the photo project for their assigned part of the lab activity. Following the completion of the photo project, each student answered reflection questions about the project. They were asked to reflect on how they felt working with other students, as well as the greatest challenge to completing the project, and which aspect of the project was the most valuable to them.

The general response to the project was positive. In three of the classes, more students reported positive feelings than negative about the project. In one class, several students expressed frustration related to working in assigned groups rather than groups of their own choice. Overall, in each class, most of the negative responses were related to the group work, and not to any other aspect of the project.

In response to the question, *How did you feel working with your group members to build the photo project?*, the responses in three classes were consistent, with an average of 66% of students reporting that it was a fun, productive, or enjoyable experience. Some students stated that their group members were helpful and easy to work with. A few mentioned that they were glad to get out of their comfort zone and work with people they did not know well. In the fourth class, the responses were very different. Only 38% of the students offered positive comments about working with their group. Many of the other students reported that members of their groups had been absent, or had not produced enough work for the project.

When the students were asked, *What was your greatest challenge in completing the photo project?* there were four major themes to the responses: technology, writing, organization, and communication. In each class, some students reported difficulty with the user interface for Google Slides on a smartphone. Others struggled to edit and format their photos, or to set their slides to autoplay. In terms of writing, some students were challenged by condensing their procedure into three to five major steps, while others found it difficult to accurately define terms or provide a written analysis of data. The challenges of organization included assigning tasks to each group member, and ensuring that each member completed those tasks. The organizational challenges were related to challenges in communication. Some students found it difficult to divide the work among their group members. Some students reported that they were frustrated when members of their group were absent from class, and it became necessary to reallocate certain tasks.

Other students found it challenging to work with students whom they did not know very well, and stated that they would have preferred to work with their friends.

In response to the question, *What was the most valuable part of creating the photo project?* the major themes were: the pictures, the writing, and the group. Most students responded that taking and using the photographs was the most valuable part because they believed that the photographs would help them to remember the activity more clearly.. Students who cited writing as the most valuable aspect commented on the importance of being clear and detailed about the procedure, and making sure that their information was correct. One student commented that they struggled with writing, and that was why completing the written portion of the project was valuable to them. Another student referred to the Scientific Method, and that the written procedure was important so that others could replicate their procedure and obtain the same results.

The responses to these reflection questions revealed many of the participants shared a common discomfort with working in groups. Many of the challenges expressed were related to communicating with people who were not part of their friend group. However, other students reported that working with their group was the most valuable part of the project. Students cited “working together,” “sharing ideas” and “meeting new people” as valuable aspects of group work. It is interesting to observe this wide range of responses to collaborative work because high school science lab activities are designed to be collaborative. Students must work in groups to complete these activities. This finding highlights the need for teachers to pay attention to group dynamics when students perform lab activities.

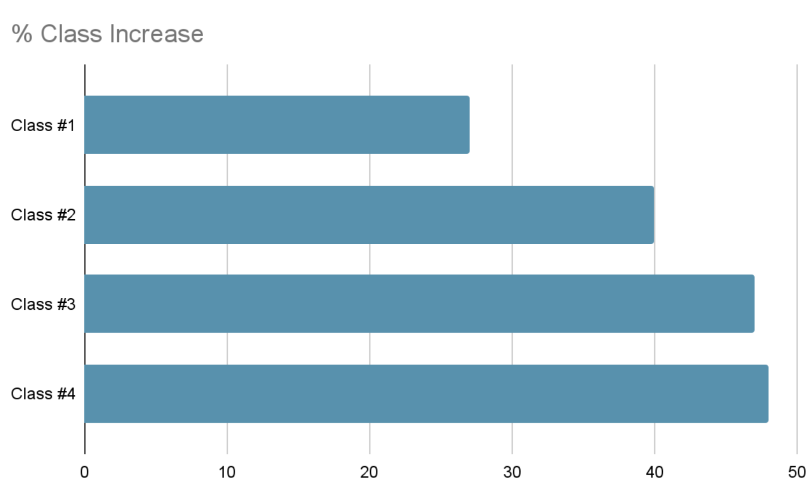
Laboratory Reports

Following the completion of the photo project, each student was assigned to write a laboratory report on each part of the "Diffusion Through a Membrane" lab. Each lab report followed a standard format: *Purpose, Materials, Procedure, Observations/Data, Analysis,* and *Conclusion* (see Appendix B). The students were given approximately one week following the photo project to submit two lab reports: one for the part of the lab that they photographed, and one for the part that they did not photograph. The students were instructed to use their group's photo project to support their writing on the lab report on the part of the lab that they photographed.

The lab reports were graded according to a standard rubric (see Appendix B). The results showed a clear difference between the lab reports that were based on the photo projects and the lab reports that were not. In each class, the scores on the laboratory reports were higher when students had used photographs to document the lab activity. Figure 1 shows the measured improvement in the scores on each lab report, by class.

Figure 1

Percentage of Students With Higher Scores on Photo-Supported Lab Report



In Class #1 (Honors Biology), 27% of students had higher scores on the lab report that was based on the photo project. In Class #2 (Honors Biology), 40% of students scored higher on the photo supported lab report. In Class #3 and Class #4 (General Biology), 47% and 48% of students had higher scores on the lab reports that were based on their photographs.

Table 5 shows the breakdown of the parts of the lab reports. An "X" indicates that students in that class showed improved scores in this part of the lab report..

Table 5

Areas of Improved Scores in Photo-Supported Laboratory Reports

Class	Purpose	Materials	Procedure	Data	Analysis
#1			X	X	
#2			X	X	X
#3	X		X	X	
#4			X	X	

The differences in the students' scores were based on inclusion of details such as specific pieces of equipment, steps of the procedure, observations, and analysis of data. For all classes studied, the lab reports that were based on the photo projects included more detailed steps of the procedure, with no missed steps or steps out of order. There were more accurate descriptions of how procedures were carried out, and which pieces of equipment were used. The data in these lab reports was presented and explained more clearly when the students used photographs as references.

The students' improvement in their ability to write about science is noteworthy. The students exhibited improved level of detail, improved use of vocabulary, and improved understanding of cause and effect relationships in the lab reports that were supported by photographs. PISA for Development (2018) described science literacy as “the ability to engage with science related issues, and with the ideas of science, as a reflective citizen” (para. 1). The improvements that have been observed in the students’ ability to write and communicate about scientific ideas and issues are aligned with PISA’s definition.

Objective Questions

Two weeks after the completion of the photo projects, the students answered objective questions related to both parts of the lab activity (see Appendix C). The questions were collected from past administrations of New York State exams in the subject area of The Living Environment/Biology. The questions were divided into Part 1 and Part 2, as the parts of the lab activity had also been divided. The students were not allowed any preparation. This instrument was designed to measure what they remembered two weeks after the photo project.

Curiously, among all groups, students scored higher on the questions in Part 2 than in Part 1, regardless of which part of the lab activity they had photographed. Some students remarked that they believed that Part 2 of the lab was easier than Part 1, or that the questions were more straightforward. In general, the students earned low scores on both sets of objective questions. The average scores on each set of questions was between 2/10 and 3/10 in all classes. There was little difference between the scores on Part 1 and the scores on Part 2.

The objective questions required students to remember specific details from the lab activities and to make further connections beyond what they observed in the lab. The discrepancy between short-term understanding and long-term recall is worth further investigation. The questions were administered without any previous preparation, in order to more objectively observe the students' recall of the activities. Perhaps those scores would have been different if the students had been given the opportunity to study before answering the questions.

Reflection Questions: After The Lab Reports and Objective Questions

Following the completion of the lab reports and the objective questions, the students were asked to reflect on those experiences (see Appendix A). They were asked to reflect on using photographs to support their writing of the lab report, the details that they remembered most clearly, and which set of objective questions they found easier to answer.

In response to the question, *How did you feel using your group's photo project to help you write your lab report?* there were two common threads in the responses. In all classes, students wrote about how it was easier to remember certain details of the lab because they could refer to the pictures they had taken. They also reported that it was easier to write about what they had done because they could look at the photographs to guide them through the writing process. These responses support my hypothesis that photographic documentation will improve students' ability to write about lab activities.

When asked, *Which specific details of the lab were you able to remember because of the photos you took?* the common responses across all classes were: Equipment, Procedure/Steps, and Data/Results. This correlates to what was observed in the differences between the scores on the lab reports for each part. Among all students, the higher scores on the photo-supported lab report were due to greater detail in the categories of Procedure and Data (see Table 5).

When asked, *Which set of objective questions (Part 1 or Part 2) did you find easier to answer?* many students reported that it was easier to answer the questions about the part of the lab that they had photographed. The responses to this question differed between the Honors Biology and the General Biology students. In the Honors Biology classes over 70% of the students reported that it was easier to answer questions on the part of the lab that they had photographed. Among the General Biology students, fewer than 50% of the students felt this way.

In response to the question, *How did photographs help you to write your lab report?* there were a number of common responses. Many students reported that the photographs helped them to remember the steps of the procedure, and the data that they observed. Students in each class reported that using the photographs helped them to write in more detail. Some students in each class described how the photographs served as evidence to support the data they had reported.

The qualitative data collected from this set of reflection questions supports the data that was collected via the students' lab reports and objective questions. The students' self assessment of using the photographs to support their written lab reports aligned with the parts of the lab reports that showed improvement. The low scores on the objective questions correlates with the students' uncertainty when asked to reflect on which set of questions was easier to answer.

Post-Activity Survey

A Post-Activity Survey was administered after all other assessments were completed. The purpose of this survey was to measure any change in attitude among the participants as a result of taking part in this investigation and to measure the changes in the students' ability to define certain key vocabulary terms, as a result of performing the lab activity. The survey was designed to mirror the Pre-Activity Survey which had been administered at the beginning of the investigation. The survey consisted of Likert Scales and vocabulary terms.

The Likert Scales did not reveal much difference in attitude among the participants. The responses to the Likert Scales in the Pre-Activity Survey had been generally positive, and the responses in the Post-Activity remained positive. In each class, a few more students responded, "Agree" or "Strongly Agree" to the statements, but this did not translate to a large shift in the students' responses.

In the Honors Biology classes, most of the responses were consistent with those of the Pre-Activity Survey, with one notable exception. In response to the statement, *It is easy for me to write a lab report based on a lab activity*, 91% of the students agreed or strongly agreed. In response to the same statement in the Pre-Activity Survey, only 81% of the students responded this way.

In the General Biology classes, there were three statements with which more students agreed or strongly agreed. For the statement, *It is easy for me to remember details of a lab activity the day after lab,* 68% of the students agreed or strongly agreed in the Pre-Activity Survey, compared to 81% in the Post-Activity Survey. For the statement, *It is easy for me to answer follow-up questions after a lab activity*, the number of students who agreed or strongly agreed increased from 72% to 83%. As in the Honors Biology classes, the number of students who agreed or strongly agrees with the statement, *It is easy for me to write a lab report based on a lab activity,* increased in the General Biology classes as well. In the Pre-Activity Survey, 74% of the students agreed or strongly agreed, while 81% of students responded as such in the Post-Activity Survey.

The second part of the Post-Activity Survey consisted of the same vocabulary terms that the students had defined in the Pre-Activity Survey. The same criteria were used to assess the students' definitions. Table 6 and Table 7 show the vocabulary results for the Honors Biology classes, Class #1 and Class #2. Table 8 and Table 9 show the vocabulary results for the General Biology classes, Class #3 and Class #4.

Table 6

***Class #1, Vocabulary Results, Post-Activity Survey* (Honors Biology, 19 participants)**

Vocabulary Term	Used Key Words (%)	Used Less Specific Wording (%)	Incomplete Definition (%)	Incorrect (%)	"I Don't Know" (%)
Permeability	84	11	5	0	0
Osmosis	63	0	5	26	0
Diffusion	74	16	5	5	0
Indicator	53	26	5	11	5
Cell Membrane	42	32	5	21	0

Table 7

***Class #2, Vocabulary Results, Post-Activity Survey* (Honors Biology, 16 participants)**

Vocabulary Term	Used Key Words (%)	Used Less Specific Wording (%)	Incomplete Definition (%)	Incorrect (%)	"I Don't Know" (%)
Permeability	81	13	6	0	0
Osmosis	81	13	6	0	0
Diffusion	75	6	6	13	0
Indicator	69	19	6	6	0
Cell Membrane	88	13	0	0	0

In each class, the percentage of students who correctly used keywords in their definitions increased, and the percentage who used less specific wording or provided incomplete definitions decreased. This indicates an improvement of the precision of the students' definitions. The percentage of students who wrote incomplete definitions or responded "I don't know" decreased. In Class #2, no students responded "I don't know" to any vocabulary term in the Post-Activity Survey.

Table 8

***Class #3, Vocabulary Results, Post-Activity Survey* (General Biology, 23 participants)**

Vocabulary Term	Used Key Words (%)	Used Less Specific Wording (%)	Incomplete Definition (%)	Incorrect (%)	"I Don't Know" (%)
Permeability	57	17	4	13	9
Osmosis	39	9	39	9	4
Diffusion	39	30	13	13	4
Indicator	43	26	0	30	0
Cell Membrane	52	13	13	13	0

Table 9

***Class #4, Vocabulary Results, Post-Activity Survey* (General Biology, 22 participants)**

Vocabulary Term	Used Key Words (%)	Used Less Specific Wording (%)	Incomplete Definition (%)	Incorrect (%)	"I Don't Know" (%)
Permeability	36	32	5	23	5
Osmosis	50	0	27	18	5
Diffusion	41	41	5	14	5
Indicator	18	18	9	55	0
Cell Membrane	41	23	5	32	0

The students in these classes also showed an increase in the ability to use keywords in their definitions. In Class #3, the percentage of students who wrote incomplete definitions increased, and in Class #4, the percentage of students who write incorrect definitions increased, while the percentage of students in both classes who responded “I Don’t Know” decreased substantially. This indicates that in both classes, students were more willing to attempt to define these terms following the project.

A notable exception in this data is the term *Cell Membrane*. When the Pre-Activity Survey was administered, this term had been the focus of the lessons leading up to the activity. More students in each class correctly defined that term in the Pre-Activity Survey than any of the other terms. However, in the Post-Activity Survey, the percentage of students who correctly defined “Cell Membrane” had decreased in every class except Class #2. One possible explanation is that the focus on the integration of new vocabulary terms had allowed students to become complacent about their ability to define previously mastered terms. This could have led to gaps in their definitions of *Cell Membrane* even though many students had previously defined the term correctly.

The data from all participants shows that, in each class, a greater percentage of students correctly defined each term after completing the photo project and lab reports, and fewer students offered incorrect or incomplete responses. The shift toward more complete definitions indicates a deeper understanding of the scientific concepts presented in the lab activity.

Summary and Conclusion

The quantitative data in this investigation consisted of the comparative assessment of usage of scientific vocabulary in the Pre-Activity and Post-Activity Surveys, scores on student lab reports and scores on objective questions. While the scores on the objective questions did not indicate that the use of photography had affected the students’ ability to recall details two weeks after completing the photo project, the other quantitative data supports the hypothesis that photography improves students' ability to write about scientific concepts.

The increase in the correct usage of scientific vocabulary was supported by the improvement in the quality of writing observed in the students' lab reports. Qualitative data in the form of reflection responses indicated that the students viewed the integration of photography into their lab activities as a positive development. Many students reported that the act of taking photographs helped them to feel more engaged in the activity, and gave them artifacts that supported their writing. The photographs served as useful tools to help the students to produce more detailed descriptions of the procedures and observations of this lab activity. These observed changes align with an improvement in science literacy among the participants.

Chapter Five will examine and interpret these results in order to draw conclusions. The major findings of the investigation will be discussed, and this investigation will be placed in context with the previous research cited in Chapter Two. In addition, Chapter Five will discuss possible future avenues of investigation, and how the findings of this research may affect science education.

CHAPTER FIVE

Conclusion

Introduction

Laboratory activities are an essential part of science education. When students perform hands-on activities, they support and reinforce the material that is taught in the classroom (Williams, 2008). It is vital that students remember the details of lab activities in order to be able to produce accurate laboratory reports. A student's correct usage of scientific vocabulary terms and inclusion of precise details in lab reports can indicate a deep understanding of science content.

This capstone is designed to answer the question, *What is the impact of photographic documentation of lab activities on students' literacy in science?* The investigation utilized high school students' affinity for digital photography to document the equipment, procedure, and observations of a lab activity. The students worked in groups to create a photo project about the lab, which then served as a basis for each student to write a lab report, and to answer objective questions. The scores on the lab report and questions were compared to scores on the same assignments related to another part of the lab activity that they did not photograph.

This investigation was prompted by the rapid integration of technology as an educational tool at the height of the COVID-19 pandemic. As schools have returned to in-person learning, teachers have had to decide which forms of educational technology they will continue to use in their classes. Digital photography has many applications, particularly in high school science labs.

The rationale behind this capstone thesis is that the action of taking photographs would give students an additional level of engagement with the material that they are learning. The photo project was designed to give students the opportunity to collaborate on a visual model that they would use to write a lab report. In each group, the students agreed on the information that would be included in the photo project. The expectation was that the work on the photo project would improve the students' ability to write about scientific concepts in their lab reports.

This chapter discusses the major findings of this investigation, and places these findings in context with the previous research that was cited in Chapter Two. The limitations of this investigation will also be discussed, along with possible avenues for further investigation.

Major Findings

Quantitative and qualitative data were collected to answer the research question, *What is the impact of photographic documentation of lab activities on students' literacy in science?* These data show that students improved their use of scientific vocabulary as a result of taking photographs of lab experiments. The students also exhibited improvement in the ability to accurately describe the steps and observations of a lab activity when they had photographed the activity. The students did not show improvement in their ability to answer objective questions about the lab activity. These findings are drawn from the quantitative data that was collected. The major finding from the qualitative data, taken from reflections questions, was the students' reticence to work in assigned groups.

Improvements in Vocabulary Usage

One way of measuring understanding of scientific concepts is through the correct use of scientific vocabulary. In this investigation, students were asked to write their own definitions of important vocabulary terms which were related to the lab activity. In the Honors Biology classes, there were few students who were unable to define the terms at the beginning of the investigation. In the General Biology classes, there were a select number of “I Don’t Know” responses to each vocabulary term. When the same terms were defined following the activity, many fewer students responded “I Don’t Know.”

Across all classes, the number of students who provided definitions that were correct or close to correct increased. The shift from being unable to provide a definition to providing scientifically correct definitions was greatest among the General Biology classes, but this trend was also observed in the Honors Biology classes. These data indicate that performing and photographing the lab activity had helped the students to better articulate their understanding of these terms.

Improvements in Writing Lab Reports

The data obtained from the students’ written lab reports was enlightening. In each class, the students earned higher scores on the lab reports that were written based on their group’s photo project. The specific areas of improvement were in summarizing the steps of the procedure, and describing the data that they collected (see Table 5). In the lab reports that were based on the students’ photo projects, the students included more specific details in each step, including descriptions of how the materials were set up and used. More students included the names of pieces of equipment in the procedure when they were able to use their photographs as a reference. When recording observations and data, the students wrote more accurate descriptions of data in the lab reports that were based on their photo projects. When the students reflected on the experience of using photographs to document their lab activities, several students remarked that the photographs served as evidence to support their written descriptions of the data.

The accuracy of the written descriptions was achieved because the photographs enabled the students to include more specific details than they would have without the support of the photographs. In the lab reports that were written only from the students' notes and memories of the activity, this level of detail was not seen. The data collected from the students' lab reports show that using photographs of the lab activity improved the students' ability to write meaningfully about the lab activity, including a better understanding of the cause and effect relationships demonstrated by the activity.

No Measured Improvement in Objective Questions

The results of the objective questions did not align with the hypothesis that photography would improve students' recall of the activity, but this finding is worth discussion, and may provide an opportunity for further investigation. The objective questions were administered two weeks after the students completed the photo project, or approximately three weeks after they had taken the photographs in the lab. The goal was to observe how the action of taking photographs would affect the students' ability to recall information, so the questions were administered without allowing the students to review the photos before answering.

In this investigation, the action of taking photographs did not help the students to recall the details of the activity after a period of time had passed. A future investigation could involve using photography as a study tool to prepare to answer objective questions.

It is possible that if the students had been instructed to study their photographs, they might have scored higher on the objective questions related to that part of the lab.

Student Responses to Group Work

There was an unexpected finding in the students' responses to the reflection questions, which revealed a mixture of feelings and attitudes toward collaborating in groups to complete the photo project. In each class, students reported reluctance, frustration, and even annoyance related to working with students outside of their friend group. The student groups were selected based on each student's responses to the Multiple Intelligences Survey (see Appendix A) to create groups that included students who would bring different skills to the project. The groups were also designed to encourage the students to get to know other students in their class, and to avoid the potential for distraction that can occur when students work with their friends. Even though these intentions were clearly explained prior to placing the students into groups, some students focused on the group dynamic as a negative aspect of the project. Conversely, there were a number of students in each class who stated that they found the group dynamic to be the most valuable part of the project. Some students reported that they felt more confident after they had gotten to know other students in the class, or that they learned how helpful their classmates were.

The variety of responses indicates that students would benefit from more frequent and varied group activities, to become more accustomed to working with classmates outside of their friend group. It is also important for teachers to be attentive to group dynamics in any collaborative activity.

Summary

The hypothesis in this investigation was that if students took photographs during laboratory activities, it would improve their understanding and ability to write meaningfully about the activity. The major findings of improved vocabulary usage and higher scores on lab reports support this hypothesis. The finding that photography does not improve long term memory in the ability to answer objective questions should be studied further. The group dynamic in adolescent lab settings is also worthy of further study.

Revisiting The Literature

Previous research suggested that photography could be used to improve knowledge acquisition and content literacy. Capello and Lafferty (2015) documented the improvement in students' usage of scientific vocabulary following a photo project in a middle school earth science class. The students created a photo project about common uses of minerals, using scientific vocabulary. When the students were later tested, they showed a measurable improvement in their vocabulary usage. The results obtained in this capstone thesis support Capello and Lafferty's findings by showing that high school biology students also improved their usage of scientific vocabulary as a result of photographing lab activities.

Schmerbeck and Lucht (2017) had performed a study to examine how photography affected the development of vocabulary in foreign language students. They found that writing descriptions of photos in a different language helped the students to improve their use of new vocabulary in that language. In this investigation, when the students wrote descriptions of their data using photographs, they were more likely to correctly incorporate new scientific vocabulary, similar to improving fluency in a new language.

The research of Waycott et al. (2012) examined the use of photography in undergraduate science classes. The major finding of this study was that students felt more invested in completing a photo project when the project was directly related to their classwork, and would be graded as part of that classwork. When my students were asked to reflect on completing the photo project, some students in each class mentioned the hope of earning a good grade, or fear that their grade would be affected by the absence of a group member. Although Waycott et al. were studying college students, the same motivation for a good grade is present in high school students as well. In addition, the connection to the curriculum is vital to student motivation. Waycott et al. reported that students responded negatively to photo projects that were not explicitly tied to the curriculum, but responded favorably to photo projects that were related to class materials. Ende (2012) also emphasized the importance of ensuring that activities and projects are relevant to course materials.

In this investigation, the lab activity was performed after the students had already learned about the structure and functions of the cell membrane. The lab activity was designed to reinforce what the students had learned in class. The direct connection to the class materials made students more invested in the outcome of the project, as Waycott and Ende suggested.

Ende also recommended that when students have the opportunity to incorporate creative elements into their work, they will derive more meaning from it. In this investigation, the photo project served as an opportunity for students to make creative decisions about the outcome of the project. Each group selected its own student-generated photographs, designed the layout and color scheme of the slides, and included additional creative choices to personalize their group's project. Some students cited the ability to add creative touches as the most valuable part of the project. These creative touches may have made the project more meaningful to them.

Research performed by Aulia et al. (2018) showed that guided inquiry activities can help students to improve their science literacy. Olivas (2013) suggested that the combination of science content, technology, and team building would also promote science literacy. The lab activities used for this capstone thesis were guided inquiry activities, as are most other high school science lab activities. The inclusion of digital photography as a form of educational technology did help students to improve their literacy skills in science. Despite the negative responses to group work from some students, other students did benefit from the team building that occurred during the group activities. The intersection of collaboration and technology in these guided inquiry activities promoted the acquisition of new vocabulary terms, and helped the students to improve their ability to understand and write about scientific concepts.

Implications

During the COVID-19 pandemic, teachers around the world met the challenge of quickly integrating technology into their teaching methods. Following the return to in-person learning, teachers have continued to use some forms of technology in the classroom, but not others. Digital photography has consistently been used as an educational tool before, during, and after the pandemic. This investigation showed that using photography to document lab activities is a practical way to continue to use this form of technology in science classrooms and labs.

In my own classroom, I will continue to encourage my students to use photography to help them to accurately describe what they have done and what they have seen in their lab activities. I will share the results of this investigation with the other science educators in my school building, and encourage them to try to incorporate photography into their students' lab experiences. The wide availability of smartphones and other digital cameras makes it easier for teachers to integrate photography into most high school lab activities.

I would recommend that photographic documentation be implemented in other high school science classes, as long as it does not interfere with lab safety. For example, The New York State Regents Exam in *The Physical Setting: Earth Science* requires a laboratory performance test as part of the state exam. The results of this investigation, combined with those of Capello and Lafferty (2015) suggest that photography improves students' understanding of scientific vocabulary. Photographic documentation of lab activities throughout the Earth Science course may help to improve student scores on the performance test.

The creation of the photo project served as an important prewriting activity. The greatest level of writing improvement was seen when students used their photographs as evidence to help them to write. Since the format of the photo project modeled the format of the lab report, the students were able to construct their lab report directly from the photo project. This suggests that teachers of other subjects may also find success in assigning photo projects as pre-writing activities.

Limitations

There were few limitations to this investigation. Laboratory access was one limitation. The school had built a new STEM lab in the summer of 2022, which was intended to be the site that the students would use to perform the lab activity and create the photo project. Delays in the completion of the new lab pushed back the start of the investigation. Ultimately, the lab activity was performed in the older biology lab, and the photo projects were created in my classroom. The original timeline would have given the students time during a weeklong break from school to write their lab reports after completing the photo project. Due to the delays and relocation of the activities, the students wrote their lab reports during a typical school week.

Another limitation to this investigation was the class schedule. Each class period, including lab periods, is forty-two minutes in length. The lab activity took three class periods to complete, and the photo project lasted four class periods. A longer class period would have allowed the students to complete the lab and photo project in fewer days, which may have mitigated some of the negative feelings about the group work.

Student attendance was another limitation. In each class, there were students who were absent during some part of the lab activity or photo project. Students who were absent during the lab activity missed the opportunity to take their own photographs, but were able to use the photos of their group members, which were kept in a shared folder. Those students who were absent for the lab were less certain about the steps of the procedure, and needed help from their group to work on the photo project. Students who were absent for the group work on the photo project meant that some tasks were reallocated to other group members, which led some students to become frustrated.

A final limitation to this investigation was a lack of standardization of the technology used to create the photo projects. Each student needed to use their own devices, usually smartphones, to complete the project. Several students reported that they had difficulty adding content to Google Slides using the interface of a smartphone. Some students who owned laptops brought them to class for the project, but those students took on much of the responsibility of creating layouts, adding content, and formatting the slides. Although the school has access to a small number of Chromebooks, there were not enough available to use during this project, which meant that students had to bring their own devices to class for the project. Equal access to technology may have improved the results of this investigation.

Future Research

The results of this investigation raised additional questions that may be answered by future researchers. The scores on the objective questions were not seen to improve as a result of taking photos of the lab activity, but these questions were presented without allowing the students to study their photos. A worthwhile avenue of investigation would be to allow the students to use their photographs as study tools prior to answering the objective questions. Reviewing the photographs may help students to remember more details, which may lead to higher scores.

Another opportunity for future research would be to investigate the group dynamics in a high school laboratory setting. Most high school lab activities are designed to be performed collaboratively. In my experience, groups have been assigned (pairs or groups of three or four students) based on student preference, the availability of equipment, and the nature of the activity. Simple activities can be performed in pairs, while more complex activities require larger groups. Due to the complex nature of activity, students were assigned to groups of four or five students. The goal was to create groups of students with different strengths, to facilitate the work. The frustration seen among the students revealed that student choice plays an important role in the dynamic of the lab group. These group dynamics merit further investigation.

Previous research had involved the use of photo projects in elementary earth science classes, and undergraduate biology and chemistry classes. An additional research possibility would be to study how photo projects can be used as pre-writing assignments in other high school science classes, such as physics, chemistry, anatomy, environmental science, and forensic science.

Communicating Results

The results of this investigation will be shared on the Digital Commons at Hamline University's Bush Memorial Library, where it will be available to future researchers. On the local level, I will also share these results with the administration in my school building, and the other teachers in my department. I will encourage my colleagues in other subject areas to also consider incorporating photography as an educational tool to help students to improve their writing and usage of specialized vocabulary terms.

Conclusion

Hands-on activities are important to effective science education. These activities give students the opportunity to learn by doing, to work like a scientist in a laboratory setting, and to gain a deeper understanding of scientific concepts. The ability to write about lab activities in the form of a lab report shows that students have integrated these activities into their bank of knowledge.

Previous research in other subject areas and other grade levels had suggested that photography would foster language acquisition and writing skills. The type of guided inquiry activity used in this investigation was also designed to encourage collaborative work that would help students to improve their use of scientific vocabulary. The results showed that photography did improve students' science literacy related to a particular lab activity.

This investigation sought to answer the research question, *What is the impact of photographic documentation of lab activities on students' literacy in science?* The direct impacts involved improving the students' ability to define scientific vocabulary terms, and improving their ability to write meaningfully about the activity in their laboratory reports. The students' responses to reflection questions indicated that they found the use of photography to be a useful and enjoyable addition to the laboratory experience.

The results of this investigation support the hypothesis that photographic documentation of lab activities would improve science literacy in high school students. The limitations that were discussed do not appear to have had a negative impact on the outcome of the experiment. This investigation may also lead to future research in the areas of educational technology and group dynamics in lab settings.

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Appendix A
Surveys and Reflection Questions

Pre-Activity Survey:

Instructions: Read each statement, and circle the number that best represents your feeling about the statement.

1 = Strongly Disagree; **2** = Disagree; **3** Agree; **4** = Strongly Agree

1. Lab activities are important to learning science.
   1 2 3 4
2. It is easy for me to remember details of a lab activity the day after the lab.
   1 2 3 4
3. It is easy for me to remember the data that I collected in the lab.
   1 2 3 4
4. Doing lab activities helps me to understand what I am learning in my science class.
   1 2 3 4
5. It is easy for me to answer follow up questions after a lab activity.
   1 2 3 4
6. It is easy for me to write a lab report based on a lab activity.
   1 2 3 4
7. I would remember something more readily if I took a picture of it.
   1 2 3 4

Instructions: Based on your prior knowledge, define each term below:

1. Permeability:
2. Osmosis:
3. Diffusion:
4. Indicator:
5. Cell Membrane:

Post-Activity Survey:

Instructions: Read each statement, and circle the number that best represents your feeling about the statement.

1 = Strongly Disagree; **2** = Disagree; **3** = Agree; **4** = Strongly Agree

1. Lab activities are important to learning science.
   1 2 3 4

2. It is easy for me to remember details of a lab activity the day after the lab.
   1 2 3 4

3. It is easy for me to remember the data that I collected in the lab.
   1 2 3 4

4. Doing lab activities helps me to understand what I am learning in my science class.
   1 2 3 4

5. It is easy for me to answer follow up questions after a lab activity.
   1 2 3 4
6. It is easy for me to write a lab report based on a lab activity.
   1 2 3 4

7. I would remember something more readily if I took a picture of it.
   1 2 3 4

8. Taking pictures helped me to remember what I did in the lab.
   1 2 3 4

Instructions: Based on your prior knowledge, define each term below:

6. Permeability:
7. Osmosis:
8. Diffusion:
9. Indicator:
10. Cell Membrane:

Reflection Questions

Following the lab activity:

1. How did you feel taking photographs during the lab activity?
2. How well do you think that you will remember this activity two weeks from now?
3. What parts of the activity will you remember the most clearly? Why?

Following the creating of the photo project:

1. How did you feel working with your group to create your photo project?
2. What was your biggest challenge in creating the photo project?
3. What was the most valuable part of creating the photo project?

Following the written lab report:

1. How did you feel using your photo project to help you to write your lab report?
2. How did using photographs help you to remember the details of the lab?
3. How did using photographs help you to write about what you did in the lab?

<u>Multiple Intelligences Survey</u> (Adapted from Colannino, et al, 2004)

<u>Instructions:</u> Next to each statement, fill in the number that corresponds to your agreement with the statement, according to the following scale:
5 = Very High; **4** = Above Average; **3** = Average; **2** = Below Average; **1** = Very Low

Naturalistic Intelligence

"I like to spend as much time as possible outdoors. "	
"I am curious about what happens to the natural world. "	
"I like to be around plants and flowers. "	
"I am very concerned about environmental issues. "	
"I am interested in learning about living things. "	
TOTAL	

Logical-Mathematical Intelligence

"I enjoy playing strategy games like chess or XCOM2. "	
"I solve simple math problems in my head. "	
"I like math courses more than literature courses. "	
"I try to find logical explanations for what occurs. "	
"I tackle problems in a step-by-step manner. "	
TOTAL	

Body-Kinesthetic Intelligence

"I like hands-on activities. "	
"I exercise or play sports on a regular basis. "	
"My best ideas come when I am moving around (walking, running, etc). "	
"In conversation, I often talk with my hands. "	
"I am well coordinated. "	
TOTAL	

Linguistic Intelligence

"I love to read. "	
"I enjoy word games like Scrabble or Wordle. "	
'I get compliments on the way I write. "	
"I like literature classes better than math classes. "	
"Listening to a lecture, I try to write everything down. "	
TOTAL	

Interpersonal Intelligence

"I am complimented for having 'a way with people'. "	
"People like to talk about their problems with me. "	
"When working with a group, I am sensitive to who is or is not participating. "	
"I like sharing or explaining information to other people. "	
"I learn more from live interaction with people than from reading on my own. "	
TOTAL	

Give yourself 5 extra points in any category in which you feel you are highly talented.

Scores of 23 or higher mean a highly developed intelligence in that area.

Scores of 12 or below mean an underutilized intelligence in this area.

Appendix B

Rubrics

Photo-Project

Category	5-Exceeds Expectations	3-Approaches Expectations	2-Does Not Meet Expectations
Introduction: (Title, Overview, Objectives)	Title of lab is clearly shown/stated; Overview and Objectives match those in the lab handout.	Title of lab is clearly shown/stated; Overview and objectives are missing details	Title of lab is not clearly shown/stated; Overview and objectives do not match those in the lab handout.
Equipment/ Materials	All materials and equipment are shown and identified.	Some, but not all, materials and equipment are shown and identified.	Equipment and materials are not shown or identified.
Procedure	The procedure is broken down into 3-5 major steps; steps are explained chronologically	A step is missing OR steps are not in chronological order.	Multiple steps are missing from the procedure.
Observations & Data	All required observations and data are shown and thoroughly explained.	Required observations and data are shown, but not thoroughly explained; OR data is incomplete	Required observations and data are missing; OR data are not explained.
Analysis & Conclusion	Data are analyzed in the context of the objectives of the experiment.	Analysis does not refer to the objectives of the experiment; OR analysis is incomplete.	Data is not analyzed.
Photographs	All photos are student-generated, and formatted into a visual	A mix of student-generated and stock photos are used; OR	Photos are not student-generated; OR photos are not well organized

	presentation. All photos relate to the experiment.	photos are not formatted into a visual presentation; OR photos do not relate to the experiment.	
Collaboration	Each group member documents their contribution to the project; work is evenly split among group members; group members work together to produce the photo project.	Group members do not document their contribution; OR work is not split evenly among group members; OR group members do not work together to produce the photo project.	Group members do not document their contribution AND work is not split evenly among group members.
Vocabulary	All necessary vocabulary terms are included and used correctly.	Some vocabulary terms are missing OR used incorrectly.	Vocabulary terms are not included AND/OR used incorrectly.

Lab Report

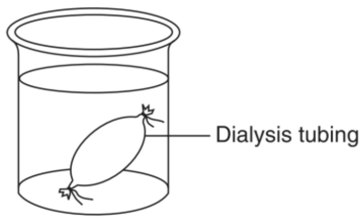
Category	5-Exceeds Expectations	3-Approaches Expectations	2-Does Not Meet Expectations
Introduction: (Title, Purpose, Objectives)	Title, Overview, and Purpose are restated from the lab handout.	Title of lab is clearly shown/stated; Purpose and objectives are missing details	Title of lab is not clearly shown/stated; Purpose and objectives do not match those in the lab handout.
Equipment/ Materials	All equipment and materials are included.	Some equipment and materials are missing or incomplete	Equipment and materials are missing.
Procedure	Steps of the procedure are summarized in 1-2 paragraphs, including all relevant details.	Steps of the procedure are listed by steps; OR Steps of the procedure are incomplete.	Steps of the procedure are incorrect or not included.
Observations & Data	Diagrams, drawings, and written descriptions are used to record data.	Diagrams and drawings are included, without written descriptions;	Diagrams and drawings are missing; descriptions are incorrect.
Analysis & Conclusion	Analysis is summarized in one paragraph; Analysis relates directly to the Objectives.	Analysis does not relate directly to Objectives.	Analysis is missing or incorrect.
Vocabulary	All necessary vocabulary terms are included and used correctly.	Some vocabulary terms are missing OR used incorrectly.	Vocabulary terms are not included AND/OR used incorrectly.

Appendix C

Objective Questions

Part 1

1. An experimental setup using a model cell is shown in the diagram below.



State what cell structure the dialysis tubing represents.

2. Molecules *A* and *B* come in contact with the cell membrane of the same cell. Molecule *A* passes through the membrane readily, but molecule *B* does not. Which statement could describe molecules *A* and *B*?

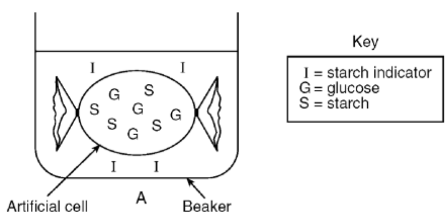
(1) Molecule *A* is a protein, and molecule *B* is a fat.

(2) Molecule *A* is a starch, and molecule *B* is a simple sugar.

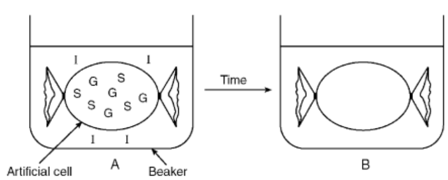
(3) Molecule *A* is an amino acid, and molecule *B* is a simple sugar.

(4) Molecule *A* is a simple sugar, and molecule *B* is a starch.

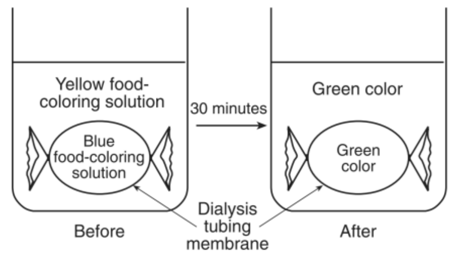
3. Base your answer(s) to the following question(s) on the information and diagram below and on your knowledge of biology. The diagram illustrates an investigation carried out in a laboratory activity on diffusion. The beaker and the artificial cell also contain water.



Predict what would happen over time by showing the location of molecules *I*, *G*, and *S* in diagram *B* below.



4. Base your answer(s) to the following question(s) on the diagram below and on your knowledge of biology. The diagram shows the changes that occurred in a beaker after 30 minutes. The beaker contained water, food coloring, and a bag made from dialysis tubing membrane.



When the colors yellow and blue are combined, they produce a green color. Which statement most likely describes the relative sizes of the yellow and blue food-coloring molecules in the diagram?

(1) The yellow food-coloring molecules are small, while the blue food-coloring molecules are large.

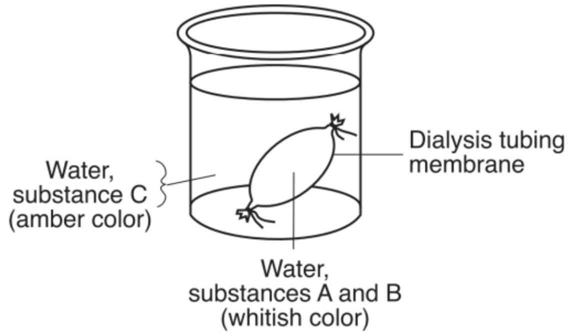
(2) The yellow food-coloring molecules are large, while the blue food-coloring molecules are small.

(3) Both the yellow food-coloring molecules and the blue food-coloring molecules are large.

(4) Both the yellow food-coloring molecules and the blue food-coloring molecules are small.

5. Base your answers to the following questions on the information and table below and on your knowledge of biology.

A model of a cell is prepared and placed in a beaker of fluid as shown in the diagram below. The letters *A*, *B*, and *C* represent substances in the initial experimental setup.



The table below summarizes the content and appearance of the cell model and beaker after 20 minutes.

Results after 20 minutes

	Outside of cell model	Inside of cell model
Substances	water, A, C	water, A, B, C
Color	amber	blue black

Complete the table below to summarize a change in location of substance *C* in the experimental setup.

Name of Substance C	Direction of Movement of Substance C	Reason for the Movement of Substance C

6. Base your answer to the following question on the information below and on your knowledge of biology.

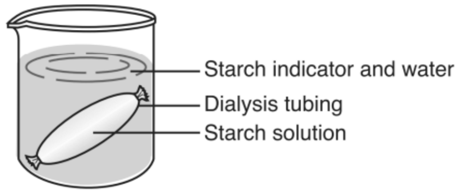
A student added glucose indicator to a beaker of an unknown liquid. Starch indicator was added to a different beaker containing an equal amount of the same unknown liquid. The color of the indicator solutions before they were added to the beakers and the color of the contents of the beakers after adding the indicator solutions are recorded in the chart below.

Beaker	Solution	Color of Indicator Solution Before Adding to Beaker	Color of Contents of Beaker After Adding Indicator Solution
1	unknown liquid + glucose indicator	blue	blue (after heating)
2	unknown liquid + starch indicator	amber	blue-black

State *one* conclusion the student would make about the unknown liquid based on the results. Support your answer with information from the data table.

7. Base your answers to the following questions on the information and diagram below and on your knowledge of biology.

Starch turns blue black in the presence of a starch indicator. Dialysis tubing tied at both ends and containing starch solution is placed in a beaker of water. Yellowish brown starch indicator is then added to the



What will the solutions in the beaker and the tubing look like after 20 minutes?

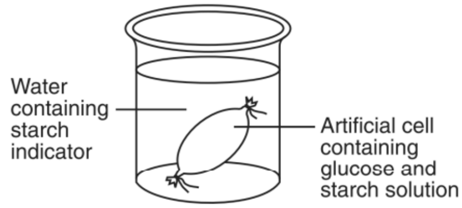
(1) The indicator solution in the beaker will be blue black and the starch solution in the tubing will not change color.

(2) The starch solution in the tubing will be blue black and the indicator solution in the beaker will not change color.

(3) Neither the indicator solution nor the starch solution will be blue black.

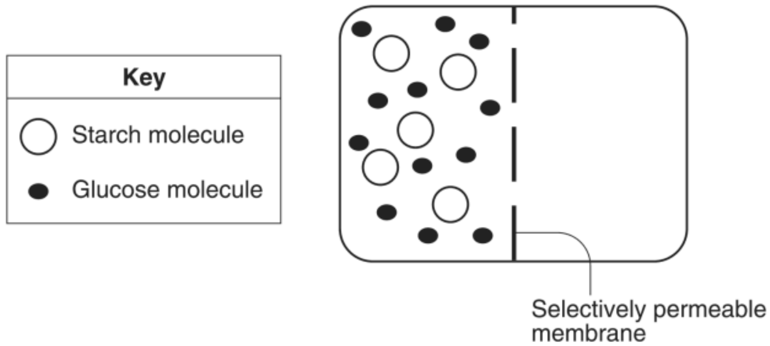
(4) Both the indicator solution and the starch solution will be blue black.

8. Base your answers to the following questions on the laboratory setup illustrated below and on your knowledge of biology.

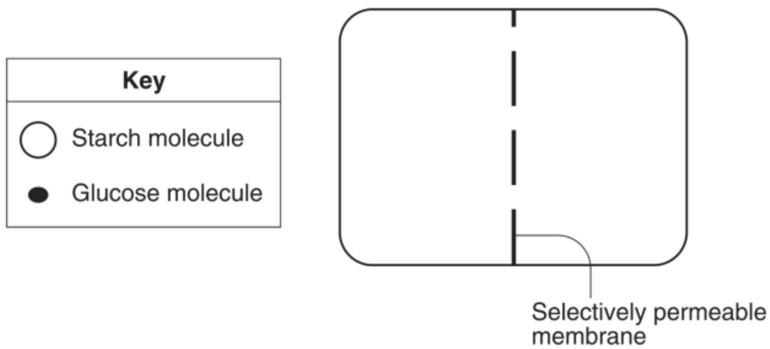


Identify the color of the contents of the artificial cell after two hours.

9. The diagram below represents a laboratory setup used to demonstrate the movement of molecules across a selectively permeable membrane.



In the diagram below, draw the 5 starch and the 12 glucose molecules to show where they would most likely be located after 15 minutes.



10. Base your answer to the following question on the information below and on your knowledge of biology.

Some students tested two samples of a mixture of starch and water with two different indicators. The results of these tests are shown in Table 1 below.

Table 1: Results of Testing a Starch-Water Solution with Indicators.

Indicator Used	Color of Indicator Alone	Sample Being Tested	Color of Sample After Indicator Was Added
starch indicator	amber	starch and water	black
glucose indicator + heat	blue	starch and water	blue

Next, a specific protein was added to two new samples of the starch and water mixture. After waiting 30 minutes, the students tested these samples with the same two indicator solutions. The results are shown in Table 2 below.

Table 2: Results of Testing a Starch-Water Solution with Indicators 30 Minutes After Adding a Certain Protein

Indicator Used	Color of Indicator Alone	Sample Being Tested	Color of Sample After Indicator Was Added
starch indicator	amber	starch and water	amber
glucose indicator + heat	blue	starch and water	brick red

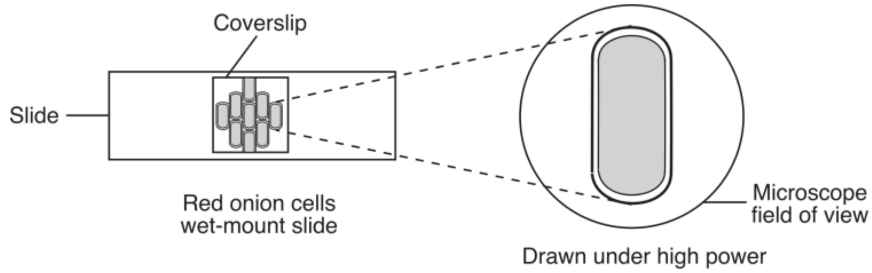
Based on these results, it can be concluded that the specific protein that was added to the samples was

(1) a salt solution
(2) a new indicator
(3) a pancreatic hormone
(4) a biological catalyst

Part 2

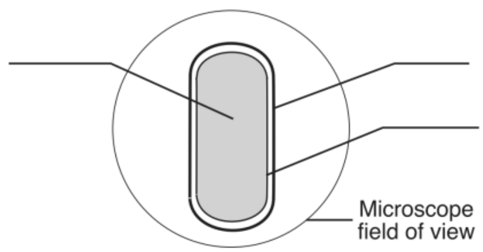
1. Base your answers to the following questions on the information below and on your knowledge of biology.

A wet-mount slide of red onion cells is studied using a compound light microscope. A drawing of one of the cells as seen under high power is shown below.

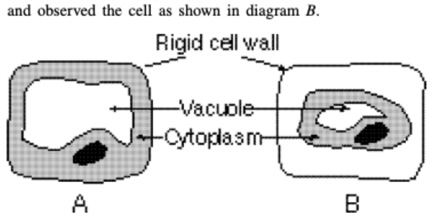


On the diagram below, label the location of each of the cell structures listed.

cell wall
cytoplasm
cell membrane



2. A biologist observed a plant cell in a drop of water as shown in diagram *A*. The biologist added a 10% salt solution to the slide and observed the cell as shown in diagram *B*.



The change in appearance of the cell resulted from

(1) more salt moving out of the cell than into the cell

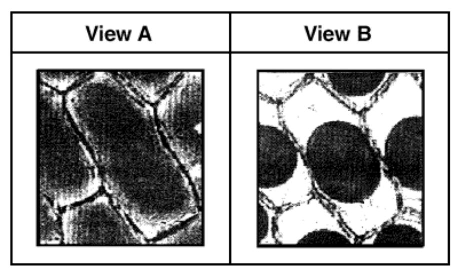
(2) more salt moving into the cell than out of the cell

(3) more water moving into the cell than out of the cell

(4) more water moving out of the cell than into the cell

3. Base your answer(s) to the following question(s) on the information and diagram below.

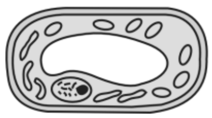
A student prepared a wet-mount slide of red onion skin and observed it under high power of a compound light microscope (view *A*). After adding a substance to the slide and waiting one minute, the student observed that there were changes in the cells (view *B*).



Identify *one* substance that could have been added to the cells on the slide in view *A* that would make them resemble the cells observed in view *B*.

4. Identify the specific substance that diffused to cause the change in appearance from view *A* to view *B*.

5. The diagram below represents a plant cell in tap water as seen with a compound light microscope.



Which diagram best represents the appearance of the cell after it has been placed in a 15% salt solution for two minutes?

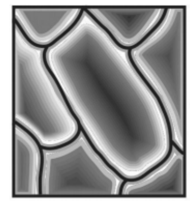
(1)


(2)

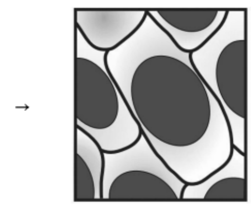

(3)


(4)


6. Red onion cells undergo the change represented in the diagram below.



A



B

This change is most likely caused by the cell being transferred from

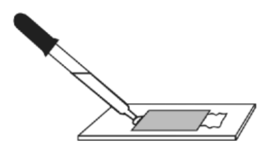
(1) distilled water to starch indicator

(2) distilled water to salt water

(3) salt water to tap water

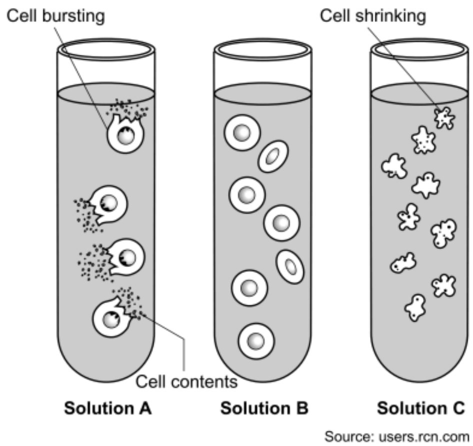
(4) salt water to distilled water

7. The diagram below represents a laboratory technique.



State *one* reason a student would use this technique during a scientific investigation.

8. Base your answers to the questions on the information and diagram below and on your knowledge of biology. The diagram represents red blood cells placed in three test tubes, each containing a different salt solution.



Which statement best describes solution *C*?

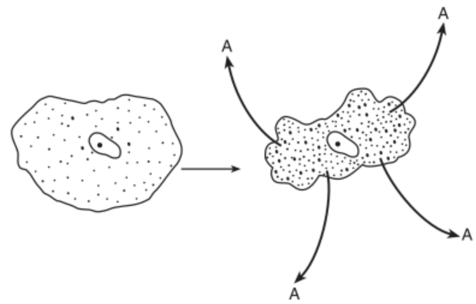
(1) The concentration of dissolved salt in the solution is greater than the concentration in the cells.

(2) The concentration of dissolved salt in the solution is less than the concentration in the cells.

(3) The concentration of water in the solution is greater than the concentration in the cells.

(4) The concentration of water in the solution is equal to the concentration in the cells.

9. Base your answers to the following questions on the diagram below, which represents the shrinking of a cell in response to an increase in the concentration of a substance outside of the cell.



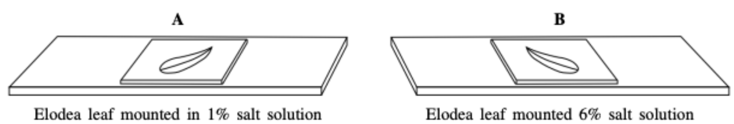
Identify *one* likely substance in the environment of the cell that caused this response.

10. *A* and *B* below represent two different slide preparations of elodea leaves. Elodea is a plant found in streams and ponds in New York State.

The water used on slide *A* contained 1% salt and 99% water.

The salt solution used on slide *B* contained 6% salt and 94% water.

Elodea cells normally contain 1% salt.



Five minutes after the slides were prepared, a student using a compound light microscope to observe the cells in leaves *A* and *B* would most likely see that

(1) water had moved out of the cells of the leaf on slide *A*

(2) salt had moved into the cells of the leaf on slide *A*

(3) water had moved out of the cells of the leaf on slide *B*

(4) salt had moved out of the cells of the leaf on slide *B*